RDT&E BUDGET ITEM JUSTIFICATION SHEET (R-2 Exhibit)

DATE
February 1998

BUDGET ACTIVITY
2 - Applied Research

PE NUMBER AND TITLE
0602601F Phillips Laboratory Exploratory Development

	COST (*$ In Thousands*)	FY 1997 Actual	FY 1998 Estimate	FY 1999 Estimate	FY 2000 Estimate	FY 2001 Estimate	FY 2002 Estimate	FY 2003 Estimate	Cost to Complete	Total Cost
	Total Program Element (PE) Cost	138,483	118,266	116,139	131,078	138,457	141,412	143,492	Continuing	Continuing
1010	Geophysics and Weather Technology	25,322	20,321	15,457	16,349	16,736	16,134	16,609	Continuing	Continuing
1011	Rocket Propulsion Technology	32,651	29,407	35,542	37,121	38,456	37,733	37,575	Continuing	Continuing
3326	Lasers and Imaging Technology	16,771	18,485	19,376	20,096	19,924	20,525	20,815	Continuing	Continuing
5797	Advanced Weapons and Survivability Technology	14,072	14,468	14,645	15,834	16,159	16,779	17,188	Continuing	Continuing
8809	Space and Missile Technology	49,667	35,585	31,119	41,678	47,182	50,241	51,305	Continuing	Continuing
	Quantity of RDT&E Articles	0	0	0	0	0	0	0	0	0

(U) A. <u>Mission Description and Budget Item Justification</u>: This is the Applied Research program for space technology, rocket propulsion, and directed energy for the Air Force Research Laboratory. In geophysics, this PE develops technologies to understand, mitigate, and exploit effects of weather and geophysics environments on the design and operation of Air Force systems. This includes defining, modeling, and developing techniques to predict the phenomena of solar and space environments. In rocket propulsion, this PE develops technologies for boost and orbit transfer, satellite maneuvering, and tactical/ballistic missile rocket propulsion. In lasers, this PE examines the technical feasibility of moderate to high power lasers, associated optical components, and long-range optical imaging concepts required for Air Force missions. Technologies researched include high power laser devices, mid-infrared semiconductor laser devices, semiconductor diode laser arrays, optical components, advanced beam control and atmospheric compensation technologies, techniques for laser target vulnerability assessments, and nonlinear optics processes and techniques. Advanced weapons examines high power microwave and other unconventional weapon concepts using innovative technologies such as compact toroids. This also provides for vulnerability assessments of representative U.S. strategic and tactical systems to directed energy weapons, directed energy weapon technology assessment for specific Air Force missions, and directed energy weapon lethality assessments against foreign targets. In space and missiles, this PE develops the following technologies: spacecraft platform (e.g., structures, controls, power, and thermal management); space-based payload (e.g., sensors, satellite communications, and survivable electronics); satellite control (e.g., spacecraft software); ballistic missile/launch vehicle-specific (e.g., astrodynamics and guidance, navigation, and control avionics); and integrated experiments of advanced technologies for transition to planned systems (e.g., payload/platform/launch vehicle merging). Note: Congress added $20.75 million in FY 1997 (Project 1010, $5.0 million for High Frequency Active Auroral Research Program (HAARP); Project 1011, $4.75 million for Integrated High Payoff Rocket Propulsion Technology (IHPRPT); and Project 8809, $6.0 million for Phase III terabit fiber optic technology and $5.0 million for MightySat) which explains the perceived decrease in FYs 1998 and 1999. Also, the emphasis on Geophysics and Weather Technology has been decreased, while additional emphasis has been placed on space and associated technologies.

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(U) B. <u>Program Change Summary ($ in Thousands)</u>:

	FY 1997	FY 1998	FY 1999	Total Cost
(U) Previous President's Budget (FY 1998 PB)	147,712	111,136	123,514	Cont
(U) Appropriated Value	153,507	127,259		
(U) Adjustments to Appropriated Value				
a. Congressional/General Reductions	-3,417	-7,390		
b. SBIR	-1,916	-1,603		
c. Omnibus/Other Above Threshold Reprogrammings	-8,228			
d. Below Threshold Reprogrammings	-1,179			
e. Rescissions	-284			
(U) Adjustments to Budget Year Since FY 1998 PB			-7,375	
(U) Current Budget Submit/FY 1999 PB	138,483	118,266	116,139	Cont

(U) Change Summary Explanation:

Funding: Changes to this PE since the previous President's Budget are due to higher priorities within the Science and Technology (S&T) Program.

Schedule: Not Applicable.

Technical: Not Applicable.

(U) C. <u>Other Program Funding Summary</u>: Not Applicable.

(U) D. <u>Schedule Profile</u>: Not Applicable.

RDT&E BUDGET ITEM JUSTIFICATION SHEET (R-2 Exhibit)

DATE
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BUDGET ACTIVITY
2 - Applied Research

PE NUMBER AND TITLE
0602601F Phillips Laboratory Exploratory Development

PROJECT
1010

COST (*$ In Thousands*)	FY 1997 Actual	FY 1998 Estimate	FY 1999 Estimate	FY 2000 Estimate	FY 2001 Estimate	FY 2002 Estimate	FY 2003 Estimate	Cost to Complete	Total Cost
1010 Geophysics and Weather Technology	25,322	20,321	15,457	16,349	16,736	16,134	16,609	Continuing	Continuing

(U) A. <u>Mission Description and Budget Item Justification</u>: This project develops the technologies to understand, mitigate, and exploit the effects of the weather and geophysics environments on the design and operation of Air Force systems. This includes defining, modeling, and developing techniques to predict the phenomena of solar and space environments. Models are developed to specify and predict optical and infrared backgrounds and signatures of spacecraft and missiles, as well as techniques to predict when and where ionospheric disturbances will occur. New techniques for measuring, modeling, simulating, and predicting those environmental effects that impact the Air Force mission are investigated.

(U) <u>FY 1997 ($ in Thousands)</u>:

- (U) $4,290 Developed techniques to specify and predict the space environment for space system design and operations.
  - (U) Designed sensors for detecting/characterizing space particle populations that degrade and destroy satellite electronic components/subsystems, thereby, reducing mission lifetimes and raising system costs.
  - (U) Designed optical tracking experiment for solar coronal ejections to provide first-warning of space disturbances that cause spacetrack errors and false launch indicators in infrared (IR) and radar warning sensors.
  - (U) Developed/validated a solar flare forecast theory to improve warning notices to spacecraft operators.
  - (U) Developed/transitioned solar shock-front transit model to 55th Space Weather Squadron (SWS), improving warning capability to one hour.
- (U) $3,151 Developed atmospheric optical background clutter prediction techniques to support Space Based Infrared System/Defense Surveillance Program (SBIRS/DSP).
  - (U) Completed code for use in SBIRS systems engineering phase that specifies the high-altitude atmospheric background clutter environment encountered during endo-atmospheric target intercepts.
- (U) $2,013 Developed active/passive remote sensing techniques for identifying aircraft and missile target signatures and specifying atmospheric wind profiles needed to improve ordnance delivery.
  - (U) Expanded/validated spectral in-band radiance images of aircraft/missile targets and scenes using Flying Infrared Signatures Technology Aircraft (FISTA) aircraft data.

RDT&E BUDGET ITEM JUSTIFICATION SHEET (R-2 Exhibit)		DATE February 1998
BUDGET ACTIVITY **2 - Applied Research**	PE NUMBER AND TITLE **0602601F Phillips Laboratory Exploratory Development**	PROJECT **1010**

- (U) $4,152 Developed ionospheric specification and forecast techniques for communications, surveillance, navigation, and space system applications.
  - (U) Incorporated a wideband scintillation statistical model into Scintillation Network Decision Aid (SCINDA) to improve the reliability of satellite communication and warnings of Global Positioning System (GPS) disruptions.
  - (U) Delivered coupled ionospheric/thermosphere specification model to Air Weather Service to support the 55th Space Weather Squadron (SWS).
  - (U) Added plasmaspheric populations of hydrogen and helium ions to the Paramaterized Real-Time Ionospheric Specification Model (PRISM) needed to expand its operational utility to higher altitude orbital planes (from 6000 km to geosynchronous earth orbit).
  - (U) Demonstrated Scintillation Network Decision Aid (SCINDA) technique that exploits real-time ionospheric scintillation data to specify ionospheric disturbances that disrupt Ultra High Frequency (UHF) satellite communication and GPS.
- (U) $7,500 Evaluated the interaction between high power, high-frequency, ground transmitted radio waves and the ionosphere.
  - (U) Augmented, from 360 kilowatt (kW) towards 960 kW, the power of the High Frequency Active Auroral Research Program's (HAARP) transmitter in Alaska, enabling an expanded class of experiments for demonstrating advanced DoD system concepts.
  - (U) Conducted initial research on generating in the ionosphere Extremely Low Frequency/Very Low Frequency (EHF/VLF) radio waves for potential communications and underground structure/bunker imaging applications.
- (U) $4,216 Developed global and theater weather analysis, simulation, and prediction techniques for combat weather system applications.
  - (U) Delivered theater-scale analysis procedures for combat weather displays and theater weather forecast model initialization to Air Weather Service.
- (U) $25,322 Total

(U) <u>FY 1998 ($ in Thousands)</u>:

- (U) $4,016 Develop space radiation specification and solar hazard prediction techniques for space system design and operations.
  - (U) Transition increased accuracy radiation belt models to U.S. Air Force system program offices and industry for more survivable satellite designs, orbit selection, trade offs, and reduced outage operations.
  - (U) Complete initial assessment on the threat of using space particles for both defensive and offensive counterspace activities.
  - (U) Fabricate space experiment to optically track coronal mass ejections from the sun to near earth space where they can trigger geomagnetic disturbances that cause false launch indicators, satellite tracking errors, and communications disruptions.
  - (U) Develop magnetic diffusion model for the evolution of active regions on the solar surface, required to forecast the occurrence of solar flares that can disrupt space systems and operations.
  - (U) Transition data driven solar wind model to 55th Space Weather Squadron for operational use in providing one hour warnings of interplanetary shocks that can trigger geomagnetic disturbances, disrupting space systems and operations.

RDT&E PROGRAM ELEMENT/PROJECT COST BREAKDOWN (R-3)		DATE February 1998
BUDGET ACTIVITY **2 - Applied Research**	PE NUMBER AND TITLE **0602601F Phillips Laboratory Exploratory Development**	PROJECT **1010**

– (U) $2,943 Develop background clutter mitigation techniques for space system design and operations.
- (U) Incorporate Mid-course Space Experiment (MSX) and Miniature Sensor Technology Integration (MSTI-3) satellite data into atmospheric background clutter codes MSX space system clutter processing.
- (U) Develop hyperspectral background clutter suppression and target identification methods for space surveillance with tactical applications.

– (U) $1,385 Develop active and passive remote sensing techniques for atmospheric parameter measurements.
- (U) Use advanced modeling and simulation technologies to provide real-time target and background scene generation capability for training and hardware-in-the-loop simulations
- (U) Terminate development of compact solid state wind sensing lidar for ballistic wind applications (e.g., cargo drops and B-52 bomb drops).
- (U) Terminate evolution of lidar designs for remote sensing of atmospheric optical and wind turbulence for aircraft safety and surveillance systems.

– (U) $3,458 Develop global ionospheric models for applications to communications and navigation systems.
- (U) Transition Global Ionospheric Forecast models to 55 Space Weather Squadron for operational support to Command, Control, Communications, and Intelligence (C3I) systems, the SPACETRACK-space/object tracking system, and ground-based surveillance radars.
- (U) Demonstrate a ground-based scintillation network decision aid (SCINDA) to provide theater specifications of ionospheric disturbances that cause ultra-high frequency (UHF) satellite communication outages, Global Positioning System (GPS) navigation degradations.
- (U) Explore and demonstrate space-based techniques to provide a global forecast of ionospheric disturbances that cause milsatcom outages and GPS degradation.

– (U) $5,000 Characterize the ionospheric Extremely Low Frequency/Very Low Frequency (ELF/VLF) signal generation process.
- (U) Expand the scope of research by fielding an array of ELF/VLF receivers and adding off-site diagnostics to determine source properties, and provide real-time communication, processing, display and Internet distribution of data.
- (U) Improve the research infrastructure by completing the operations center in the power plant building, for centralized transmitter control and diagnostic instrument data display.

RDT&E BUDGET ITEM JUSTIFICATION SHEET (R-2 Exhibit)		DATE February 1998
BUDGET ACTIVITY 2 - Applied Research	PE NUMBER AND TITLE 0602601F Phillips Laboratory Exploratory Development	PROJECT 1010

– (U) $3,519 Develop global and theater weather analysis, simulation, and prediction techniques for combat weather system applications including Airborne Laser (ABL).
- (U) Complete validation of satellite data, unified retrieval method to support theater weather forecast models.
- (U) Incorporate satellite-based cloud module into simulation procedures for system design and testing.
- (U) Terminate development of a method to incorporate satellite weather data into combat weather support forecast modules.

– (U) $20,321 Total

(U) FY 1999 ($ in Thousands):

– (U) $3,944 Develop techniques to specify and predict the space environment for space system design and operations.
- (U) Develop model to forecast coronal mass ejections (CME) and fabricate space experiment to optically track CMEs from sun to earth providing three-to-seven day warning of geomagnetic disturbances.
- (U) Add alert capability to three-dimensional space environment models used to warn operators, launch crews and users of space systems of conditions detrimental to their mission performance.
- (U) Validate space storm model for predicting spacecraft charging that creates satellite outages and system failures.
- (U) Develop physics-based solar wind model to provide a one to three day warning of interplanetary shocks that trigger geomagnetic disturbances causing false missile launch indicators, satellite tracking errors, and communication disruptions.
- (U) Complete magnetic diffusion model of the evolution of active regions on the solar surface, required to predict the occurrence of solar flares that disrupt space systems and operations with emphasis on preparing for Solar Max (periods of maximum relative solar activity).

– (U) $3,369 Develop background clutter mitigation techniques for adaptive hyperspectral space system design.
- (U) Develop optical background clutter models for detecting and tracking dim targets, including missiles.
- (U) Develop real-time background clutter codes for target tracking satellite operations.

– (U) $1,599 Develop active and passive remote sensing techniques for atmospheric parameter measurements and simulation of battlefield environments.
- (U) Demonstrate and validate design concepts for real-time target and background scene generation capability.
- (U) Test and evaluate solid-state wind sensing lidars for B-52 applications.
- (U) Develop compact, solid-state ultraviolet differential absorption lidar for trace gas and chemical detection for use on aircraft.

RDT&E PROGRAM ELEMENT/PROJECT COST BREAKDOWN (R-3)		DATE February 1998
BUDGET ACTIVITY **2 - Applied Research**	PE NUMBER AND TITLE **0602601F Phillips Laboratory Exploratory Development**	PROJECT **1010**

– (U) $5,545 Develop ionospheric specification and forecast techniques for communications, surveillance, navigation, and space system applications.
- (U) Develop coupled Ionosphere-Thermosphere-Electrodynamic forecast model (CITEFM) for transition to 55th Space Weather Squadron for operational support of communications, surveillance, navigation, and space-object tracking users.
- (U) Deliver validated real-time, data driven, Scintillation Network Decision Aid (SCINDA) techniques to 55th Space Weather Squadron to provide specification and advance warning of ionospheric disturbed conditions (scintillation) that cause Ultra-High Frequency (UHF)/L-Band satellite communication outages and Global Positioning System (GPS) navigation disruption.
- (U) Explore and demonstrate space-based techniques to provide global forecasts of ionospheric disturbances that cause UHF satellite communication outages and GPS navigation degradations.

– (U) $1,000 Develop global and theater weather analysis, simulation and prediction techniques for combat weather systems applications.
- (U) Tailor numerical weather prediction models to forecast contrails for stealth aircraft operations.
- (U) Develop radiative cloud module for weather scene simulation techniques for training and wargaming applications.

– (U) $15,457 Total

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BUDGET ACTIVITY **2 - Applied Research**	PE NUMBER AND TITLE **0602601F Phillips Laboratory Exploratory Development**	PROJECT **1010**

(U) B. Program Change Summary ($ in Thousands):

	FY 1997	FY 1998	FY 1999	Total Cost
(U) Previous President's Budget (FY 1998 PB)	25,744	16,507	19,076	Cont
(U) Current Budget Submit/FY 1999 PB	25,322	20,321	15,457	Cont

(U) Change Summary Explanation:

Funding: Changes to this project since the previous President's Budget are due to higher priorities within the Science and Technology (S&T) Program.

Schedule: Not Applicable.

Technical: Not Applicable.

(U) C. Other Program Funding Summary:

(U) Related Activities:

- (U) PE 0305160F, Defense Meteorological Satellite Program.
- (U) PE 0601102F, Defense Research Sciences.
- (U) PE 0602204F, Aerospace Avionics.
- (U) PE 0603410F, Space Systems Environmental Interactions Technology.
- (U) PE 0603707F, Weather Systems Advanced Development.
- (U) This project has been coordinated through the Reliance process to harmonize efforts and eliminate duplication.

(U) D. Schedule Profile: Not Applicable.

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BUDGET ACTIVITY	PE NUMBER AND TITLE	PROJECT
2 - Applied Research	**0602601F Phillips Laboratory Exploratory Development**	**1011**

COST ($ In Thousands)	FY 1997 Actual	FY 1998 Estimate	FY 1999 Estimate	FY 2000 Estimate	FY 2001 Estimate	FY 2002 Estimate	FY 2003 Estimate	Cost to Complete	Total Cost
1011 Rocket Propulsion Technology	32,651	29,407	35,542	37,121	38,456	37,733	37,575	Continuing	Continuing

(U) A. Mission Description and Budget Item Justification: The technologies developed in this project are boost and orbit transfer, satellite maneuvering, and tactical and ballistic missile rocket propulsion. This project develops technologies and provides technology options for rocket propulsion advanced demonstrations, components, or subsystems. Technologies of interest are those which will improve reliability, operability, survivability, affordability, environmental compatibility, and performance of future space and missile launch sub-systems while reducing material, manufacturing, and support costs. Technology will be developed to reduce the weight and cost of components using new materials, improved designs, and improved manufacturing techniques. All efforts in this project are part of the Integrated High Payoff Rocket Propulsion Technology (IHPRPT) initiative; a joint Department of Defense, NASA, and industry effort to focus rocket propulsion technology on national needs.

(U) FY 1997 ($ in Thousands):

- (U) $2,253 Developed high-energy-density materials.
  - (U) Completed analysis of solid hydrogen and metallic clusters, metal atom doped cryogenic solids, and solids with impurities. Transitioned the best high-energy-density materials into the cryogenic solid properties and combustion programs. Began testing and evaluation of downselected propellants to transition into future high-performance boost and orbit transfer propulsion systems.
  - (U) Finished exploring cryogenic solid, high-pressure solid, and extended solid properties. Determined candidates for cryogenic solid combustion programs that will show revolutionary performance increases by replacing current liquid or solid propulsion systems with cryogenic solid or hybrid-fuel rockets in future space launch missions.
  - (U) Developed techniques to accurately measure high-energy-density additive concentrations in cryogenic solids to maximize future propulsion system performance.
  - (U) Tested fire cryogenic hybrid-fuel rocket using oxygen and a cryogenic hydrocarbon to demonstrate performance increases over current liquid propulsion systems.
  - (U) Performed large-scale engine tests/demonstrations with new additives (quadricyclane). Prepared for launch-size demonstrations and began transitioning additives into system-ready applications.
  - (U) Completed strained-ring hydrocarbon high-energy compound development. Identified the best candidates for a scale-up program to replace current liquid fuels.
  - (U) Selected solid, non-ozone depleting oxidizers and other synthesized, new, high-energy-density materials for development. Began small-scale demonstrations of environmentally-safe solid rocket motor fuel processing using these new ingredients.

– (U) $3,134 Developed propulsion technologies for tactical missile system applications.

- (U) Tested fabrication techniques to manufacture lightweight solid rocket engine liners.
- (U) Completed testing and demonstration of environmentally safe, minimum-smoke propellants to eliminate vulnerability caused by exhaust plume signature tracking.
- (U) Developed the fabrication processes for novel nozzle concepts (supersonic splitline flexseal nozzle) that reduce missile weight while increasing missile agility.
- (U) Evaluated commercial technologies and practices for their possible incorporation into low-cost, high-performance, environmentally-safe tactical missiles.
- (U) Analyzed new propellants and components to develop a lightweight, highly-maneuverable propulsion system that will assure high kill ratios against the next generation of highly maneuverable aircraft.
- (U) Continued development of hybrid propulsion systems for potential use as a tactical missile.

– (U) $14,390 Developed propulsion technology to meet the needs of reliable, safe, and low-cost boost and orbit transfers.

- (U) Demonstrated low-cost, high temperature, non-erosive, lightweight coated carbon-carbon ceramic and hybrid polymer components for use in solid rocket space launch and missile motors.
- (U) Demonstrated the fluid film bearing designs and verified their performance and integrity when used in liquid turbopumps on future boost and orbit transfer systems.
- (U) Designed and tested injectors that enable reduced cost, increased reliability, and increased engine performance in liquid boost and orbit transfer engines.
- (U) Fabricated and tested a high-performance, low-cost cryogenic upper stage combustion chamber for an expander cycle application.
- (U) Fabricated and tested an advanced preburner engine component that uses using liquid cryogenic propellants that meets the high throttling requirements and does not vaporize propellants.
- (U) Continued to characterize new materials and developed processes required to apply the materials to liquid-propellant rocket production with dramatic weight reductions.
- (U) Developed design and processing techniques for high-strength, low-weight engine and motor components (metals and non-metals).

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BUDGET ACTIVITY **2 - Applied Research**	PE NUMBER AND TITLE **0602601F Phillips Laboratory Exploratory Development**	PROJECT **1011**

– (U) $6,499 Developed advanced boost and orbit transfer propellants which are environmentally safe during manufacture, storage, and use.
- (U) Evaluated ignition characteristics, determine combustion efficiencies, and report the results of the synthesized non-toxic, non-cryogenic, high-performance, storable liquid fuels and oxidizers to begin developing a high-performance, environmentally safe, liquid replacement for current space launch systems.
- (U) Fabricated and tested non-toxic, non-cryogenic, high-performance, storable liquid additives for use with these new propellants (capable of withstanding the firing conditions created by the new propellants).
- (U) Determined alternative disposal procedures/technologies to thermolyze or breakdown propellant, explosive, and pyrotechnic wastes into their non-hazardous constituent parts.
- (U) Integrated all of the current solid propellant work being done under the high-energy-density materials program and incorporated the most promising chemicals into state-of-the-art propellants (liquid, solid, and hybrid).
- (U) Evaluated and analyzed radically new methods of solid rocket motor and propellant manufacturing to develop low-cost, environmentally friendly solid rocket motors that exceed the performance of current liquid propellant rockets.
- (U) Scaled-up and demonstrated the most innovative high-energy chemicals that are currently being synthesized within government and contractor laboratories. The most promising chemicals (solid or liquid) will be fed into an innovative propellants project to be used in next generation propellants for space launch systems.

– (U) $2,525 Developed techniques for use in sustainment of strategic systems while at the same time being potentially advantageous to the development of the next generation booster.
- (U) Continued the development of service life assessment techniques of current solid rocket propellant missile systems.

– (U) $3,850 Developed satellite propulsion technology for control and on-orbit transfer.
- (U) Developed and evaluated improved designs to fabricate a pulsed plasma thruster with increased power efficiency.
- (U) Designed solar thrusters and concentrators for satellite propulsion systems with longer life.
- (U) Developed and improved technologies for implementation of the high power Hall thruster.

– (U) $32,651 Total

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BUDGET ACTIVITY **2 - Applied Research**	PE NUMBER AND TITLE **0602601F Phillips Laboratory Exploratory Development**	PROJECT **1011**

(U) FY 1998 ($ in Thousands):

– (U) $3,442 Develop propellants with a high-energy density.

- (U) Continue testing and evaluation of downselected propellants to transition into future high-performance boost and orbit transfer propulsion systems. These potential propellants were selected from the previously conducted analysis of solid hydrogen and other cryogenic solids, doped with high energy impurities such as atoms and dimers of lightweight elements and metals.
- (U) Begin sub-scale testing of potential candidates for cryogenic solid combustion programs that will show revolutionary performance increases by replacing current liquid or solid propulsion systems with cryogenic solid or hybrid-fuel rockets in future space launch missions.
- (U) Build low temperature hazards testing apparatus with capability to test energetic cryosolids as well as propellants at cold temperatures they might experience in field applications.
- (U) Continue testing and comparison of techniques to accurately measure high energy-density additive concentrations in cryogenic solids to maximize future propulsion system performance.
- (U) In collaboration with NASA, scale up selected energetic hydrocarbons for further testing in larger quantities.
- (U) Begin new energetic hybrid rocket fuels development
- (U) Continue selection of solid, non-ozone depleting oxidizers and other synthesized, new, high energy-density materials for development. Continue small-scale demonstrations of environmentally-safe solid rocket motor fuel processing using these new ingredients.

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BUDGET ACTIVITY **2 - Applied Research**	PE NUMBER AND TITLE **0602601F Phillips Laboratory Exploratory Development**	PROJECT **1011**

– (U) $14,998 Develop propulsion technology for reliable, safe, and low-cost boost and orbit transfers.

- (U) Continue to demonstrate low-cost, high temperature, non-erosive, lightweight coated carbon-carbon ceramic and hybrid polymer components for use in solid rocket space launch and missile motors.
- (U) Complete fabrication and testing of an advanced preburner engine component that uses using liquid cryogenic propellants that meets the high throttling requirements and does not vaporize propellants.
- (U) Complete demonstration of the fluid film bearing designs and verify their performance and integrity when used in liquid turbopumps on future boost and orbit transfer systems.
- (U) Complete fabrication and test of a high-performance, low-cost cryogenic upper stage combustion chamber for an expander cycle application.
- (U) Continue to characterize new materials and develop processes required to apply the materials to liquid-propellant rocket production with dramatic weight reductions.
- (U) Continue to develop design and processing techniques for high-strength, low-weight engine and motor components (metals and non-metals).
- (U) Continue development of altitude compensating thrust chamber assembly technology improvements which will provide significant gains in performance for reusable launch vehicles.

– (U) $3,601 Develop advanced boost and orbit transfer propellants which are environmentally safe during manufacture, storage, use, and disposal.

- (U) Complete fabrication of spacecraft thruster and begin using it for evaluation of high energy monopropellant candidates.
- (U) Continue the fabrication and testing of non-toxic, non-cryogenic, high-performance, storable liquid additives for use with the above new propellants (capable of withstanding the firing conditions created by the new propellants).
- (U) Begin research and development of pulsed detonation rocket engine.

-- (U) $6,000 Develop technologies for use in long-term sustainment of strategic systems while at the same time being potentially advantageous to the development of the next generation booster.

- (U) Begin development of compatible case/liner and insulator system for higher combustion temperature propellants to be used in strategic systems.
- (U) Begin development of tools to increase the look-ahead capability in determining the age life of strategic and other solid rocket motors.
- (U) Begin development of improved and replacement propellants and materials for both solid and liquid postboost control systems for application to strategic missiles with the purpose of developing technologies that are more readily available over the life of strategic systems (i.e., 20+ years).

– (U) $1,366 Develop propulsion technology for satellite control and on-orbit transfer.
- (U) Continue the Hall thruster development for possible inclusion into the next generation satellites.
- (U) Continues work in the development and evaluation of improved designs to fabricate pulsed plasma thrusters with increased power efficiency, the next level of improvements.
- (U) Continue the design and test of solar thrusters and concentrators for satellite propulsion systems with longer life.

– (U) $29,407 Total

(U) <u>FY 1999 ($ in Thousands)</u>:

– (U) $3,762 Develop propellants with a high-energy density.
- (U) Continue testing and evaluation of downselected propellants to transition into future high-performance boost and orbit transfer propulsion systems. These potential propellants were selected from the previously conducted analysis of solid hydrogen and other cryogenic solids, doped with high energy impurities such as atoms and dimers of lightweight elements and metals.
- (U) Begin sub-scale testing of potential candidates for cryogenic solid combustion programs that will show revolutionary performance increases by replacing current liquid or solid propulsion systems with cryogenic solid or hybrid-fuel rockets in future space launch missions.
- (U) Continue testing and comparison of techniques to accurately measure high energy-density additive concentrations in cryogenic solids to maximize future propulsion system performance.
- (U) Complete performance of large-scale engine tests/demonstrations with new additives (quadricyclane). Continue preparation for launch-size demonstrations and transitioning additives into system-ready applications.
- (U) Begin evaluation of next generation of hydrocarbon fuel additives to improve the performance of current and future space launch systems.
- (U) Continue selection of solid, non-ozone depleting oxidizers and other synthesized, new, high energy-density materials for development. Continue small-scale demonstrations of environmentally-safe solid rocket motor fuel processing using these new ingredients.

RDT&E BUDGET ITEM JUSTIFICATION SHEET (R-2 Exhibit)		DATE February 1998
BUDGET ACTIVITY **2 - Applied Research**	PE NUMBER AND TITLE **0602601F Phillips Laboratory Exploratory Development**	PROJECT **1011**

– (U) $2,985 Develop propulsion technologies for tactical missiles.
- Continue scale-up of minimum smoke propellant formulations which reduce system vulnerability due to exhaust plume signature. Continued exploration of nozzle and insulation materials that are compatible with the above propellants. Coordination with Navy and Army tactical missile programs is extensive.
- Continue development of hybrid propulsion as part of an international cooperative project to develop this propulsion technology for application to tactical missiles. This is technology can provide very significant increases in range and average velocity and is coordinated extensively with Navy and Army programs.

– (U) $7,616 Develop propulsion technology for reliable, safe, and low-cost boost and orbit transfers.
- (U) Continue to demonstrate low-cost, high temperature, non-erosive, lightweight coated carbon-carbon ceramic and hybrid polymer components for use in solid rocket space launch and missile motors.
- (U) Complete demonstration of the fluid film bearing designs and verify their performance and integrity when used in liquid turbopumps on future boost and orbit transfer systems.
- (U) Complete fabrication and test of a high-performance, low-cost cryogenic upper stage combustion chamber for an expander cycle application.
- (U) Continue to characterize new materials and develop processes required to apply the materials to liquid-propellant rocket production with dramatic weight reductions.
- (U) Continue to develop design and processing techniques for high-strength, low-weight engine and motor components (metals and non-metals).
- (U) Continue development of altitude compensating thrust chamber assembly technology improvements which will provide significant gains in performance for reusable launch vehicles.
- (U) Verify performance and weight improvements of rapid densification nozzle technology using improved strategic propellants for future ballistic missiles.

– (U) $10,093 Develop advanced boost and orbit transfer propellants which are environmentally safe during manufacture, storage, use, and disposal.
- (U) Continue the evaluation of ignition characteristics, determine combustion efficiencies, and report the results of the synthesized non-toxic, non-cryogenic, high-performance, storable liquid fuels and oxidizers to begin developing a high-performance, environmentally safe, liquid replacement for current space launch systems.
- (U) Continue the fabrication and testing of non-toxic, non-cryogenic, high-performance, storable liquid additives for use with the above new propellants (capable of withstanding the firing conditions created by the new propellants).
- (U) Continue research and development of pulsed detonation rocket engine.

RDT&E BUDGET ITEM JUSTIFICATION SHEET (R-2 Exhibit)	DATE February 1998	
BUDGET ACTIVITY **2 - Applied Research**	PE NUMBER AND TITLE **0602601F Phillips Laboratory Exploratory Development**	PROJECT **1011**

– (U) $8,000 Develop technologies for use in long-term sustainment of strategic systems while at the same time being potentially advantageous to the development of the next generation booster.

- (U) Continue development of compatible case/liner and insulator system for higher combustion temperature propellants to be used in strategic systems.
- (U) Continue development of tools to increase the look-ahead capability in determining the age life of strategic and other solid rocket motors.
- (U) Continue development of improved and replacement propellants and materials for both solid and liquid postboost control systems for application to strategic missiles with the purpose of developing technologies that are more readily available over the life of strategic systems (i.e., 20+ years).

– (U) $3,086 Develop propulsion technology for satellite control and on-orbit transfer.

- (U) Continue work in the development and evaluation of improved designs to fabricate pulsed plasma thrusters with increased power efficiency.
- (U) Continue the design and test of solar thrusters and concentrators for satellite propulsion systems with longer life.

– (U) $35,542 Total

RDT&E BUDGET ITEM JUSTIFICATION SHEET (R-2 Exhibit)	DATE February 1998	
BUDGET ACTIVITY **2 - Applied Research**	PE NUMBER AND TITLE **0602601F Phillips Laboratory Exploratory Development**	PROJECT **1011**

(U) B. Program Change Summary ($ in Thousands):

	FY 1997	FY 1998	FY 1999	Total Cost
(U) Previous President's Budget (FY 1998 PB)	33,863	29,505	36,509	Cont
(U) Current Budget Submit/FY 1999 PB	32,651	29,407	35,542	Cont

(U) Change Summary Explanation:

Funding: Changes to this project since the previous President's Budget are due to higher priorities within the Science and Technology (S&T) Program.

Schedule: Not Applicable.

Technical: Not Applicable.

(U) C. Other Program Funding Summary:

(U) Related Activities:

- (U) PE 0602111N, Anti-Air/Anti-Surface Warfare Technology.
- (U) PE 0602303A, Missile Technology.
- (U) PE 0603302F, Space and Missile Launch Technology.
- (U) PE 0603311F, Ballistic Missile Technology.
- (U) PE 0603401F, Advanced Spacecraft Technology.
- (U) This project has been coordinated through the Reliance process to harmonize efforts and eliminate duplication.

(U) D. Schedule Profile: Not Applicable.

RDT&E BUDGET ITEM JUSTIFICATION SHEET (R-2 Exhibit)	DATE February 1998

BUDGET ACTIVITY	PE NUMBER AND TITLE	PROJECT
2 - Applied Research	0602601F Phillips Laboratory Exploratory Development	3326

COST ($ In Thousands)	FY 1997 Actual	FY 1998 Estimate	FY 1999 Estimate	FY 2000 Estimate	FY 2001 Estimate	FY 2002 Estimate	FY 2003 Estimate	Cost to Complete	Total Cost
3326 Lasers and Imaging Technology	16,771	18,485	19,376	20,096	19,924	20,525	20,815	Continuing	Continuing

(U) A. Mission Description and Budget Item Justification: This project examines the technical feasibility of moderate to high power lasers, associated optical components, and long-range optical imaging concepts required for Air Force missions. Technologies researched include advanced, short-wavelength laser devices for application as illuminators and imaging sources as well as advanced optical imagers for target identification and assessment. Laser technologies will be studied for their utility in aimpoint selection, target maintenance, and damage assessment. Additionally, high power laser devices, mid-infrared semiconductor laser devices, semiconductor diode laser arrays, optical components, advanced beam control and atmospheric compensation technologies, techniques for laser target vulnerability assessments, and nonlinear optics processes and techniques are developed.

(U) FY 1997 ($ in Thousands):

- (U) $2,625 Developed generic, high energy laser technologies for applications such as illuminators for use in wavelength-specific military missions.
  - (U) Demonstrated lasing at 5.1 microns for a semiconductor laser.
  - (U) Demonstrated a three-pass stable resonator concept and produced a single mode, five kilowatt continuous wave beam.
  - (U) Demonstrated production of nitrogen chloride and scaling potential of atomic-iodine laser.
  - (U) Developed the magnetic gain switch hardware necessary to demonstrate a ten kilohertz repetitively pulsed chemical oxygen-iodine laser.
  - (U) Demonstrated a continuous-wave, single-frequency portable laser.
  - (U) Completed a laser illuminator study to meet future Air Force requirements.
- (U) $1,013 Developed basic laser source and targeted coupling technology for use in high-payoff applications such as infrared countermeasures and creating laser-induced microwave effects.
  - (U) Completed field test series which demonstrated capabilities of concept over extended ranges.
  - (U) Developed two mid-infrared lasers operating at three and four microns for infrared countermeasures use.
  - (U) Completed experiment and analysis to assess the effectiveness of laser-induced microwave emissions in military applications; results provided a database on a novel effect used for upsetting electronic systems.

RDT&E BUDGET ITEM JUSTIFICATION SHEET (R-2 Exhibit)		DATE February 1998
BUDGET ACTIVITY **2 - Applied Research**	PE NUMBER AND TITLE **0602601F Phillips Laboratory Exploratory Development**	PROJECT **3326**

– (U) $2,320 Developed long-range optical imaging technologies for increased resolution and data fusion to support missions such as space object identification and ground target identification from space.

- (U) Conducted initial development of experiments on active and passive spectral technologies which increase performance and reduced cost of space-based optical sensors used for ground target identification.
- (U) Developed advanced concepts for smart integrated sensor-processors to reduce data bandwidth requirements on space-based sensors.
- (U) Developed advanced concepts for lightweight deployable large optics to permit long dwell optical surveillance from higher orbits.
- (U) Developed the Atlas laser which produces the highest average power brightness ever reported at the 1.06 micron and 532 nanometer wavelengths. This diode-pumped, solid-state laser, with excellent beam quality, was installed at Kirtland’s Starfire Optical Range for active tracking experiments and for use as a Raleigh Beacon.

– (U) $1,935 Investigated and developed nonlinear optics (NLO) technologies to support imaging and other applications.

- (U) Continued to characterize automatic, all-optical techniques for producing pristine images from large, lightweight mirrors.
- (U) Initiated an effort to produce a very efficient, mid-infrared source that uses a standard, near-infrared solid state laser and multiple nonlinear optical processes.
- (U) Began studying NLO techniques for high bandwidth laser communications, automatic aimpoint maintenance, and lightweight optics for space applications. These techniques have the potential to increase communication data rates, reduce system size, weight and complexity, and improve system efficiency.
- (U) Demonstrated an all-optical technique for correcting gross surface deformation errors in inflatable mirrors.
- (U) Extended the operational modulation bandwidth of commercial diode laser by a factor of twenty. Performed a laboratory demonstration of an NLO technique for automatically acquiring and establishing an optical communication crosslink. These techniques have the potential to increase optical communication data rates, reduce system size, weight and complexity, and improve system efficiency.
- (U) Demonstrated two sources of frequency-tunable, mid-infrared radiation based on NLO crystals pumped by standard, fixed-frequency, near-infrared, solid state lasers. Sources represented the most powerful, tunable sources in this spectral regime. The sources were transitioned to field tests.

– (U) $1,980 Investigated and developed advanced, high energy laser optical components.

RDT&E BUDGET ITEM JUSTIFICATION SHEET (R-2 Exhibit)		DATE February 1998
BUDGET ACTIVITY **2 - Applied Research**	PE NUMBER AND TITLE **0602601F Phillips Laboratory Exploratory Development**	PROJECT **3326**

- (U) Completed development of techniques to evaluate optical components installed in operational high energy laser systems for transition to advanced technology development.
- Completed testing and accepted delivery of cooled, transmissive optical element which is environmentally safe, and relieves thermal overload in optical systems.
- (U) Completed development of very low absorption, low-scatter optical, thin-film coatings. Transitioned technology to industry for scaling. This work will result in reduced cooling requirements, less optical distortion, decreased size and weight, and increased efficiency of optical systems used in airborne and space platforms.
- (U) Designed and deposited optical coatings on three large optics (one 22-inch and two 36-inch) for use at the Starfire Optical Range.
- (U) Identified a non-toxic, low-absorption coolant for use in a cooled transmissive optics operating at 1.315 microns. Also developed an optical contacting process for assembly of this type of optic. Active cooling of transmissive elements, such as beamsplitters, will reduce optical distortion due to laser heating.
- (U) Designed, fabricated, and delivered a set of coating samples for incorporation into the Optical Properties Monitor (OPM) Experiment to determine the effect of the space environment on optical properties of coatings and materials. OPM is currently on Russia's Mir space station.

– (U) $3,552 Developed laser radar for space surveillance and remote sensing applications.

- (U) Demonstrated capabilities to collect range, range rate, and doppler images against unaugmented low-earth orbit satellite. The technology provides improved range resolution and system operation without illumination from the sun.

– (U) $3,346 Developed high power semiconductor lasers/arrays at alternate wavelengths for applications and uses such as forward looking infrared (FLIR) systems and infrared (IR) missile warning sensor jamming, chemical agent detection, illuminators, efficient semiconductor laser array pumping modules and infrared countermeasures (IRCM).

- (U) Demonstrated ten watts peak output power at two microns continuous wave operation from a semiconductor diode laser array module at room temperature. This demonstration provides a baseline for high efficiency pump laser arrays used as subcomponent in Band 4 optically-pumped semiconductor lasers, as well as a robust source for Band 1 IRCM.
- (U) Demonstrated 100 milliwatts continuous laser output power at four microns from a single semiconductor diode. The data collected will be used to scale output power to levels required for next generation, high efficiency, compact Band 4 IRCM sources for small tactical aircraft self-protection -- a requirement which cannot be met by bulkier optically-pumped semiconductor lasers.

– (U) $16,771 Total

(U) <u>FY 1998 ($ in Thousands)</u>:

– (U) $872 Develop generic, high energy laser technologies for applications such as illuminators and use in wavelength-specific military missions.

RDT&E BUDGET ITEM JUSTIFICATION SHEET (R-2 Exhibit)	DATE February 1998

BUDGET ACTIVITY	PE NUMBER AND TITLE	PROJECT
2 - Applied Research	**0602601F Phillips Laboratory Exploratory Development**	**3326**

– (U) Apply FY 1997 experimental results to technology demonstration of a high energy, chemical nitrogen chloride iodine transfer laser. This laser has the potential to be significantly lighter weight than a comparable chemical oxygen-iodine laser.

– (U) $2,678 Develop long-range optical imaging technologies for increased resolution and data fusion to support missions such as space object identification.

– (U) Develop initial experiments on active and passive spectral technologies which increase performance and reduce cost of space-based optical sensors used for ground target identification.
– (U) Evaluate on-board image processing concepts to decrease communication bandwidth requirements.
– (U) Establish lab test facility for large deployable optics technology and smart sensors.

– (U) $1,460 Investigate and develop advanced laser radar for space surveillance and remote sensing using transceiver systems, and advanced data collection and processing algorithms for laser radar (LADAR) remote sensing of atmospheric properties, chemical agents, and target effluents, and intelligence preparation of the battlefield.

– (U) Develop wavelength tunable laser heterodyne receiver technologies for advanced detection use.
– (U) Develop models of advanced detection method performance based on heterodyne technologies.
– (U) Investigate data analysis tools for real-time chemometric identification capability.

– (U) $4,659 Develop laser source and target coupling technology for next-generation high-payoff applications such as damage/destroy countermeasures against infrared imaging seekers.

– (U) Begin investigating effects of laser illumination on materials relevant to degrade and damage infrared countermeasures (IRCM) applications.

– (U) $1,652 Investigate and develop nonlinear optics (NLO) technologies to support imaging and other applications.

RDT&E BUDGET ITEM JUSTIFICATION SHEET (R-2 Exhibit)		DATE February 1998
BUDGET ACTIVITY **2 - Applied Research**	PE NUMBER AND TITLE **0602601F Phillips Laboratory Exploratory Development**	PROJECT **3326**

– (U) Transition technology for automatic, all-optical compensation techniques for large lightweight mirrors with poor optical quality to imaging satellite systems development projects. Nonlinear optics are an improvement over currently used technologies by providing a more compact, lighter weight, faster, and less complex system for correcting figure errors.
– (U) Demonstrate a tunable mid-infrared laser converter with better than 50% conversion efficiency from the near-infrared. This converter could potentially improve infrared countermeasures (IRCM) and sensing system efficiencies by a factor of two.
– (U) Begin investigating NLO techniques to decrease system complexity and increase speed of aimpoint imaging and tracking for countermeasure applications.
– (U) Continue to investigate NLO techniques to increase current laser communication bandwidths with automatic crosslink acquisition and tracking and lightweight optics. The use of NLO will provide a more lightweight, efficient communications system capable of handling more information.

– (U) $4,076 Develop high power semiconductor lasers/arrays at alternate wavelengths for applications and uses such as forward looking infrared (FLIR) systems and infrared (IR) missile warning sensor jamming, chemical agent detection, illuminators, efficient semiconductor laser array pumping modules, and disrupt/jam countermeasures against near-term threats.
– (U) Demonstrate an incoherent 20 watt peak output power, continuous wave operation, two micron semiconductor diode laser array module at room temperature. This device will provide a compact, high power, efficient pump laser array used as a subcomponent in Band 4 optically-pumped semiconductor lasers to increase their performance.
– (U) Demonstrate 750 milliwatts continuous laser output power at four microns wavelength from a single semiconductor diode. This demonstration will establish the feasibility of direct electrical-to-optical generation of mid-infrared wavelengths, enabling improved packing efficiency and reliability by a factor of two for small tactical aircraft self-protection.
– (U) Demonstrate two watts coherent peak output power at quasi-continuous wave operation from a single, Band 1 semiconductor diode at room temperature. The collected data will demonstrate the necessary powers needed to jam Band 1 infrared surface-to-air missiles.

– (U) $3,088 Develop coherent laser diode arrays for improved performance/higher power in applications requiring high power levels.
– (U) Demonstrate 100 watts continuous wave power from an array of phased diode lasers to establish the baseline technology for advanced laser defenses such as large aircraft self-protection.
– (U) Demonstrate and evaluate a 200 watt high power system with a one cubic foot laser head. This one cubic foot design will provide the basis for high performance aircraft and space asset self-protection system designs.

– (U) $18,485 Total

(U) FY 1999 ($ in Thousands):

– (U) $1,092 Develop generic, high energy laser technologies for applications such as illuminators and use in wavelength-specific military missions.

- (U) Demonstrate a repetitively-pulsed, high average power, frequency-shifted chemical oxygen-iodine laser for use as a target illuminator.
- (U) Develop scaling methodology for an all-electric, radio frequency-excited wave guide laser for aircraft application.

– (U) $3,837 Develop long-range optical imaging technologies for increased resolution and data fusion to support missions such as space object identification and ground target identification from space.

- (U) Conduct initial experiments on 75 cm inflatable telescope mirror. This technology offers a dramatic reduction in weight for space-based optics.
- (U) Conduct initial field experiments to evaluate the utility of space-based hyperspectral sensors for improved support for military operations.
- (U) Evaluate on-board processing concepts to decrease satellite to earth communications requirements. This technology will deliver information much more quickly to the warfighter.
- Develop remote optical sensing capabilities that demonstrate capabilities to identify and quantify battlefield gases in the atmosphere for both airborne and space applications.

– (U) $1,502 Investigate and develop advanced laser transceiver systems, and advanced data collection and processing algorithms for light detection and ranging (LIDAR) remote sensing of atmospheric properties, chemical agents, and target effluents, and intelligence preparation of the battlefield.

- (U) Develop and characterize wavelength tunable hertodyne receiver. Integrate into breadboard LIDAR system.
- (U) Perform laboratory demonstration of heterodyne LIDAR (short-range field tests).
- (U) Develop advanced detection analysis techniques using heterodyne methodology data.

– (U) $2,977 Develop laser source and target coupling technology for next-generation high-payoff applications such as damage/destroy countermeasures against infrared imaging seekers.

- (U) Begin development of improved surrogate threats for laboratory investigations.
- (U) Begin development of advanced lasers and high accuracy pointer/tracker for potential use in infrared countermeasures (IRCM).
- (U) Identify the laser characteristics required for an optimum damage and destroy device.

– (U) $704 Investigate and develop nonlinear optics (NLO) technologies to support imaging and other applications.

RDT&E BUDGET ITEM JUSTIFICATION SHEET (R-2 Exhibit)		DATE February 1998
BUDGET ACTIVITY **2 - Applied Research**	PE NUMBER AND TITLE **0602601F Phillips Laboratory Exploratory Development**	PROJECT **3326**

– (U) Continue improving performance of NLO devices to new regimes of operations: higher output powers; longer wavelengths; higher efficiencies. NLO techniques represent a powerful paradigm for leveraging off of technology investments in fixed-frequency laser sources for use in frequency conversion applications providing reduction in size, weight, power, and complexity while improving performance and efficiency.

– (U) $4,849 Develop high power semiconductor lasers/arrays at alternate wavelengths for applications and uses such as forward looking infrared (FLIR) systems and infrared (IR) missile warning sensor jamming, chemical agent detection, illuminators, efficient semiconductor laser array pumping modules, and disrupt/jam countermeasures against near-term threats.

– (U) Demonstrate 100 watts incoherent peak output power at quasi-continuous wave operation from a two micron semiconductor diode laser array module at room temperature. This demonstration will provide a baseline for high efficiency pump sources used as a subcomponent in portable, high brightness Band 4 optically-pumped semiconductor lasers for FY 2000 field experiments.

– Demonstrate 0.5 watts average output power at greater than four microns from a semiconductor laser to establish the baseline for all laser-based small tactical aircraft self-protection capabilities.

– (U) $4,415 Develop monolithic, coherent lasers for tactical/unmanned air vehicle and space applications such as designation/illumination and remote sensing which require higher power sources.

– (U) Demonstrate fast electronic beam steering in a greater than100 watt output power continuous wave array of phased diode lasers at 980 nanometers.

– (U) Demonstrate a greater than 100 watt dual core fiber laser/array building blocks for use in multi-kilowatt laser systems.

– (U) $19,376 Total

RDT&E BUDGET ITEM JUSTIFICATION SHEET (R-2 Exhibit)

DATE: February 1998

BUDGET ACTIVITY: **2 - Applied Research**

PE NUMBER AND TITLE: **0602601F Phillips Laboratory Exploratory Development**

PROJECT: **3326**

(U) B. Program Change Summary ($ in Thousands):

	FY 1997	FY 1998	FY 1999	Total Cost
(U) Previous President's Budget (FY 1998 PB)	18,553	21,252	20,716	Cont
(U) Current Budget Submit/FY 1999 PB	16,771	18,485	19,376	Cont

(U) Change Summary Explanation:

Funding: Changes to this project since the previous President's Budget are due to higher priorities within the Science and Technology (S&T) Program.

Schedule: Not Applicable.

Technical: Not Applicable.

(U) C. Other Program Funding Summary:

(U) Related Activities:
- (U) PE 0602101N, Directed Energy Weapons.
- (U) PE 0602307A, Laser Weapon Technology.
- (U) PE 0603314A, High Energy Laser and Directed Energy Components.
- (U) PE 0603319F, Airborne Laser Demonstrator.
- (U) PE 0603605F, Advanced Weapons Technology.
- (U) This project has been coordinated through the Reliance process to harmonize efforts and eliminate duplication.

(U) D. Schedule Profile: Not Applicable.

RDT&E BUDGET ITEM JUSTIFICATION SHEET (R-2 Exhibit)		DATE February 1998
BUDGET ACTIVITY **2 - Applied Research**	PE NUMBER AND TITLE **0602601F Phillips Laboratory Exploratory Development**	PROJECT **5797**

COST ($ In Thousands)	FY 1997 Actual	FY 1998 Estimate	FY 1999 Estimate	FY 2000 Estimate	FY 2001 Estimate	FY 2002 Estimate	FY 2003 Estimate	Cost to Complete	Total Cost
5797 Advanced Weapons and Survivability Technology	14,072	14,468	14,645	15,834	16,159	16,779	17,188	Continuing	Continuing

(U) A. <u>Mission Description and Budget Item Justification</u>: High power microwave (HPM) and other unconventional weapon concepts using innovative technologies are explored in this project. Technologies that support a wide range of Air Force missions such as suppression of enemy air defenses, command and control warfare, and vehicle self-protection are developed. This project provides for vulnerability assessments of representative U.S. strategic and tactical systems to directed energy weapons, directed energy weapon technology assessment for specific Air Force missions, and directed energy weapon lethality assessments against foreign targets. In addition to directed energy weapon threats, this project conducts assessments of specific space environmental (natural and man-made) effects on space systems and develops hardening technologies and methodologies.

(U) <u>FY 1997 ($ in Thousands)</u>:

– (U) $4,536 Developed generic advanced weapon technologies that support many Air Force applications.
  - (U) Continued to develop advanced pulse-power, microwave, and radio-frequency technologies for offensive and defensive weapon systems.
  - (U) Improved high-performance computer codes to support narrowband HPM source and pulsed power research.
  - (U) Began development of first-generation, compact, high-voltage pulsed electrical power generator for microwave and radio frequency sources.
  - (U) Began assessment of the ability of pulsed power and HPM technology to neutralize biological weapons.
  - (U) Continued to develop narrowband and wideband sources and antennas.

RDT&E BUDGET ITEM JUSTIFICATION SHEET (R-2 Exhibit)		DATE February 1998
BUDGET ACTIVITY **2 - Applied Research**	PE NUMBER AND TITLE **0602601F Phillips Laboratory Exploratory Development**	PROJECT **5797**

– (U) $2,414 Assessed effects/lethality of directed energy weapon technologies against representative air and ground military systems.
- (U) Progress made in developing computer modeling codes that model high power microwave (HPM) coupling into cockpit areas of advanced technology aircraft. Small-aircraft simulator was used to make wide variety of direct-injection HPM experiments which yielded data on HPM effects on subsystems.
- (U) Proposed protection technology presented to F-16 system program office (SPO) for their consideration; assessment of aircraft susceptibilities to wide-band HPM continued.
- (U) Numerical analyses and associated experimental measurements were made on a large group of command and control warfare hardware assets.
- (U) Large group of space-related electronics and command and control warfare electronics were investigated for type and threshold of effects caused by different HPM threats.
- (U) Extensive HPM coupling measurements were performed on C-130 aircraft. Criteria for protection for mission-essential electronics were developed.

– (U) $3,265 Developed HPM technologies that will support applications such as suppression of enemy air defenses, command and control warfare, and aircraft self-protection.
- (U) Extensive experimental measurements conducted on key elements of a command and control installation.
- (U) Solid state source technology was selected for aircraft self protection application. Two large experimental efforts provided valuable information on source waveform requirements.
- (U) Refined computer models of weapon effectiveness for all weapon applications.
- (U) The down-selected narrow-band source for suppression of enemy air defenses demonstrated capability to defeat older (harder) technology mobile command and control center.

– (U) $2,182 Developed HPM technologies, including susceptibility and effects experiments and modeling and data base development, to support space control applications.
- (U) Executed susceptibility experiments and analysis of effects on two subsystems and two devices.
- (U) Selected and evaluated technologies that lead to selection of best concepts for basing of HPM technology.
- (U) Developed requirements for source technology development in support of threat demonstration.
- (U) Began to develop experimental methodologies to measure effects of HPM on satellite systems.

RDT&E BUDGET ITEM JUSTIFICATION SHEET (R-2 Exhibit)		DATE February 1998
BUDGET ACTIVITY **2 - Applied Research**	PE NUMBER AND TITLE **0602601F Phillips Laboratory Exploratory Development**	PROJECT **5797**

- (U) $1,675 Assessed the vulnerability of various space assets to threats such as solar radiation and directed energy weapons.
  - (U) Improved directed energy weapon lethality and assessment models for five satellites.
  - (U) Continued satellite survivability/vulnerability/lethality assessments for ground-based laser technology.
  - (U) Transitioned advanced data fusion techniques to the multi-spectral, multi-sensor data analysis workstation.
- (U) $14,072 Total

(U) <u>FY 1998 ($ in Thousands)</u>:

- (U) $5,688 Develop generic advanced weapon technologies that support many Air Force applications.
  - (U) Apply high performance, parallel, plasma physics computer codes to narrowband source and compact pulsed power design.
  - (U) Perform integrated experiments to assess coupling compact, high voltage electrical generators; gigawatt narrowband devices; and efficient antennas.
  - (U) Complete development of high power, first generation wideband source, including antenna.
  - (U) Complete the assessment of the ability of pulsed power and high power microwave (HPM) technology to neutralize biological weapons.
- (U) $1,864 Assess effects/lethality of directed energy weapon technologies against representative air and ground military systems.
  - (U) Continue to identify HPM protection requirements for large aircraft (cargo-transport and bombers) carrying future HPM devices.
  - (U) Continue to develop practical methods to protect existing and advanced technology aircraft from proposed/identified external HPM threats.
  - (U) Continue to develop techniques and technology to evaluate HPM coupling and effects into hardened, command-post like structures with modern electronics.
  - (U) Continue to develop and validate techniques to evaluate HPM effects on families of electronics components found in difficult-to-obtain weapons/threats.
  - (U) Continue to develop and validate advanced computer models which provide predictions for HPM coupling and effects into a wide variety of structures (command posts) and weapons systems of moderate complexity.

RDT&E BUDGET ITEM JUSTIFICATION SHEET (R-2 Exhibit)		DATE February 1998
BUDGET ACTIVITY **2 - Applied Research**	PE NUMBER AND TITLE **0602601F Phillips Laboratory Exploratory Development**	PROJECT **5797**

– (U) $3,154 Develop high power microwave (HPM) technologies that will support applications such as suppression of enemy air defenses, command and control warfare, and aircraft self-protection.
- (U) Use new technology ultra-wideband (UWB) sources to perform effects experiments on structures with command and control electronics systems.
- (U) Prepare and implement diagnostic procedures and instrumentation for a critical experiment to demonstrate UWB capability to defeat infrared seekers.
- (U) Improve transition of computer modeling code and experimental data into operational (flyout) modeling codes to model HPM effects on postulated missile threats.
- (U) Integrate previously down-selected narrow-band source with newly developed pulsed-power generator for suppression of enemy air defenses.

– (U) $1,890 Develop high power microwave (HPM) technologies, including susceptibility and effects experiments and modeling and data base development, to support space control applications.
- (U) Transition effects analysis and experimentation from subsystem to systems, begin to demonstrate and quantify effects on systems.
- (U) Thoroughly evaluate best basing mode for HPM technology demonstration.
- (U) Begin source development to support threat demonstration.

– (U) $1,872 Assess the vulnerability of various space assets to threats such as solar radiation and directed energy weapons.
- (U) Continue to develop directed energy weapon lethality and assessment models for five satellites.
- (U) Continue satellite survivability/vulnerability/lethality assessments for ground-based laser technology.
- (U) Continue to transition advanced data fusion techniques to the multi-spectral, multi-sensor data analysis workstation.

– (U) $14,468 Total

(U) <u>FY 1999 ($ in Thousands)</u>:

– (U) $6,074 Develop generic advanced weapon technologies that support many Air Force applications.
- (U) Develop and test components for next-generation, compact, high voltage, high impedance, pulsed electrical power sources for microwave and radio frequency sources.
- (U) Complete the transition of high performance plasma physics computer simulation codes to designers of microwave and pulsed power devices.
- (U) Develop technology to increase the energy efficiency of multiwatt narrowband sources.
- (U) Develop technologies for next-generation wideband sources and antennas.

RDT&E BUDGET ITEM JUSTIFICATION SHEET (R-2 Exhibit)		DATE February 1998
BUDGET ACTIVITY **2 - Applied Research**	PE NUMBER AND TITLE **0602601F Phillips Laboratory Exploratory Development**	PROJECT **5797**

– (U) $2,046 Assess effects/lethality of directed energy weapon technologies against representative air and ground military systems.
- (U) Finalize development of computer modeling codes that predict high power microwave (HPM) coupling into advanced technology aircraft.
- (U) Begin transitioning specifications and standards and HPM hardness technologies to fighter aircraft.
- (U) Continue directed energy weapon lethality/survivability enhancements and characterization of equipment upset of various foreign and U.S. systems for advanced tactical applications.
- (U) Transfer HPM protection technology for large aircraft, such as cargo-transport, air-refueling, and bomber aircraft.
- (U) Continue effects experiments on networks typical of command and control facilities.

– (U) $3,425 Develop HPM technologies that will support applications such as suppression of enemy air defenses, command and control warfare, and aircraft self-protection.
- (U) Finalize in situ experimentation with installed systems for command and control warfare using HPM.
- (U) Continue in situ demonstrations of selected HPM sources that could be used for aircraft self-protection and other advanced tactical applications.
- (U) Continue to improve and validate computer models of weapon effectiveness for all weapon applications.
- (U) Demonstrate technology applicability for advanced tactical applications with an experiment using a downselected source.

– (U) $1,286 Develop HPM technologies, including susceptibility and effects experiments and modeling and data base development, to support space control applications.
- (U) Continue source technology development to support threat demonstration.
- (U) Continue susceptibility experiments on subsystems to support threat demonstration.

– (U) $1,814 Assess the vulnerability of various space assets to threats such as solar radiation, space debris, and directed energy weapons.
- (U) Select directed energy weapon lethality and assessment models for five satellites.
- (U) Continue survivability/vulnerability/lethality assessments for ground-based laser technology.
- (U) Continue to transition advanced data fusion techniques to the multi-spectral, multi-sensor data analysis workstation.

– (U) $14,645 Total

RDT&E BUDGET ITEM JUSTIFICATION SHEET (R-2 Exhibit)		DATE February 1998
BUDGET ACTIVITY **2 - Applied Research**	PE NUMBER AND TITLE **0602601F Phillips Laboratory Exploratory Development**	PROJECT **5797**

(U) B. Program Change Summary ($ in Thousands):

	FY 1997	FY 1998	FY 1999	Total Cost
(U) Previous President's Budget (FY 1998 PB)	16,039	15,403	15,950	Cont
(U) Current Budget Submit/FY 1999 PB	14,072	14,468	14,645	Cont

(U) Change Summary Explanation:

Funding: Changes to this project since the previous President's Budget are due to higher priorities within the Science and Technology (S&T) Program.

Schedule: Not Applicable.

Technical: Not Applicable.

(U) C. Other Program Funding Summary:

(U) Related Activities:

- (U) PE 0602120A, Electronic Survivability and Fuzing Technology.
- (U) PE 0602111N, Anti-Air/Anti-Surface Warfare Technology.
- (U) PE 0602202F, Human Systems 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. Schedule Profile: Not Applicable.

RDT&E BUDGET ITEM JUSTIFICATION SHEET (R-2 Exhibit)	DATE February 1998	
BUDGET ACTIVITY **2 - Applied Research**	PE NUMBER AND TITLE **0602601F Phillips Laboratory Exploratory Development**	PROJECT **8809**

COST (*$ In Thousands*)	FY 1997 Actual	FY 1998 Estimate	FY 1999 Estimate	FY 2000 Estimate	FY 2001 Estimate	FY 2002 Estimate	FY 2003 Estimate	Cost to Complete	Total Cost
8809 Space and Missile Technology	49,667	35,585	31,119	41,678	47,182	50,241	51,305	Continuing	Continuing

(U) A. Mission Description and Budget Item Justification: This project focuses on five major space and missile technology areas: spacecraft platform technologies (e.g., structures, controls, power, and thermal management); space-based payload technologies (e.g., sensors, satellite communications, and survivable electronics); satellite control technologies (e.g., spacecraft software); ballistic missile/launch vehicle specific technologies (e.g., astrodynamics and guidance, navigation, and control avionics); and integrated experiments of advanced technologies for transition to planned systems (e.g., payload/platform/launch vehicle merging).

(U) FY 1997 ($ in Thousands):

- (U) $5,206 Developed technologies for space platform subsystems such as cryocoolers, space vehicle thermal management, compact solar power cells, lightweight batteries, and innovative power generation concepts.
  - (U) Completed solar cell flexible array technology trade studies.
  - (U) Initiated development program for ultra-high efficiency four-junction photovoltaic and thermal electric cells.
  - (U) Continued development of solid state primary battery for space and missile launch vehicle applications.
  - (U) Began development of lightweight flywheel integrated power and attitude control systems (IPACS); goal is seven-fold decrease in subsystem weight.
  - (U) Initiated cryocooler component reliability characterization study.
  - (U) Designed, fabricated, and flight-qualified capillary pumped loop/looped heat pipe thermal management systems for distributed and load sharing applications.
- (U) $4,916 Developed technologies for space platform structures such as spacecraft structural controls for vibration suppression and lightweight composite satellite and launch vehicle structures.
  - (U) Continued research efforts in adaptive structures technology emphasizing Adaptive Neural Control (ANC).
  - (U) Fabricated, tested, and integrated an advanced isolation system into the Space Test Research Vehicle 2 (STRV2) spacecraft to stabilize an electro-optic camera.
  - (U) Continued joint program to develop advanced mechanisms which will improve the design of solar array subsystems.
  - (U) Fabricated, tested, and flight demonstrated advanced lightweight launch vehicle structures.
  - (U) Continued the development of multifunctional spacecraft structures.
  - (U) Initiated space-based radar structures program.

RDT&E BUDGET ITEM JUSTIFICATION SHEET (R-2 Exhibit)	DATE February 1998	
BUDGET ACTIVITY **2 - Applied Research**	PE NUMBER AND TITLE **0602601F Phillips Laboratory Exploratory Development**	PROJECT **8809**

– (U) $4,556 Developed technologies for space-based payload subsystems such as hardened sensors and satellite communications.
- (U) Continued improvement of long-wavelength mercury cadmium telluride detectors and optimized design for large focal plane arrays.
- (U) Continued development of larger format, quantum well, infrared photodetector focal plane arrays.
- (U) Evaluated and characterized radio frequency communications modem, modem controllers and network components.
- (U) Integrated space-based surveillance antenna component technologies to support system level design concepts.

– (U) $3,411 Developed technologies for space-based payload components such as hardened electronics and memories.
- (U) Evaluated and fabricated advanced packaging technology whose goal is a ten times size/volume/weight reduction.
- (U) Initiated evaluation of a standard space-based surveillance signal processing module.

– (U) $3,263 Developed technologies for satellite control, astrodynamics, modeling and simulation, and autonomous operations.
- (U) Developed satellite control software for applications such as multi-mission advanced ground intelligent control.
- (U) Developed next generation astrodynamics models for orbit determination and collision risk assessment.
- (U) Developed simulation architecture for space-based surveillance models.
- (U) Evaluated software for autonomous space technology product development.

– (U) $16,904 Developed ground and small satellite integration technologies for space and near-space experiments.
- (U) Completed MightySat I spacecraft and experiments assembly. Integrated experiments with spacecraft. Technologies to be evaluated include: increased power solar cells; lightweight composite structures; shape memory release device; microparticle impact detector; and electronics miniaturization techniques. Performed environmental test and checkout. Integrated MightySat I on Shuttle Hitchhiker Ejection System for launch on shuttle flight Shuttle Transportation System 88 (STS-88).
- (U) Assembled and integrated exploratory, hardware-in-the-loop satellite technologies to validate overall sparse optical array concept through the UltraLITE ground demonstration, a large high precision space mirror.
- (U) Designed the baseline MightySat Phase II vehicle. Tailored vehicle basic design to meet requirements of first flight which will demonstrate nine distinct experiments. These include a Fourier transform hyperspectral imager, pulsed plasma thrusters, multi-functional structures, miniaturized electronics, and a solar array concentrator.
- (U) Developed near-space capabilities for experiments requiring high altitudes and guided recovery systems.

RDT&E BUDGET ITEM JUSTIFICATION SHEET (R-2 Exhibit)		DATE February 1998
BUDGET ACTIVITY **2 - Applied Research**	PE NUMBER AND TITLE **0602601F Phillips Laboratory Exploratory Development**	PROJECT **8809**

– (U) $1,908 Developed technologies such as guidance, navigation, and control avionics to support launch vehicles and ballistic missile flights.
- (U) Began fabrication of solid state micro-mechanical guidance instruments for future ballistic missile environments.
- (U) Evaluated a next generation thrust axis accelerometer.
- (U) Continued development of improved techniques to determine accurate gravity field values--major source of error in space inertial navigation systems.

– (U) $9,503 Began development of a Rocket System Launch Program launch capability using excess ballistic missile assets to test low-cost pop-up upperstage systems.

– (U) $49,667 Total

(U) FY 1998 ($ in Thousands):

– (U) $4,723 Develop technologies for space platform subsystems such as cryocoolers, space vehicle thermal management, compact solar power cells, lightweight batteries, and innovative power generation concepts.
- (U) Continue development of ultra-high efficiency four-junction photovoltaic and thermal electric cells.
- (U) Conduct in-house electrical characterization of Manufacturing Technology (ManTech) 24% efficient three-junction solar cell.
- (U) Establish interagency cooperative development of lithium ion battery technology for space vehicle applications.
- (U) Continue development of lightweight flywheel integrated power and attitude control systems (IPACS); goal is seven-fold decrease in subsystem weight.
- (U) Continue cryocooler reliability improvement initiatives and begin development of improved cryocooler models and simulation software.
- (U) Continue development of enhanced capillary pumped loop/looped heat pipe thermal management systems and design cryogenic capillary pumped loop/looped heat pipe system for cryogenic sensor integration.

– (U) $4,017 Develop technologies for space platform structures such as spacecraft structural controls for vibration suppression and lightweight composite satellite and launch vehicle structures.
- (U) Continue the advanced adaptive structures technology development program.
- (U) Continue launch vibration isolation program.
- (U) Initiate miniature isolation system program.
- (U) Continue development of multifunctional spacecraft structures.
- (U) Continue space-based radar structures program.
- (U) Continue development of lightweight launch vehicle structure technologies.

RDT&E BUDGET ITEM JUSTIFICATION SHEET (R-2 Exhibit)		DATE February 1998
BUDGET ACTIVITY **2 - Applied Research**	PE NUMBER AND TITLE **0602601F Phillips Laboratory Exploratory Development**	PROJECT **8809**

– (U) $2,186 Develop technologies for space-based payload subsystems such as hardened sensors and satellite communications.
- (U) Investigate suitability of long wavelength quantum well infrared photodetector technology for space-based surveillance systems.
- (U) Begin analysis and development of alternative technologies (e.g., antenna design) for low altitude space-based radar systems.

– (U) $3,862 Develop technologies for space-based payload components such as hardened electronics and memories.
- (U) Continue evaluation and fabrication of advanced packaging technology whose goal is a 90% reduction in size/volume/weight.
- (U) Identify methods and techniques for exploiting commercial electronic advancements to develop low-power, high-performance, radiation-hardened devices and circuits for DoD space programs
- (U) Evaluate suitability of micro-electro-mechanical technologies for use in space-based systems.

– (U) $2,601 Develop technologies for satellite control, astrodynamics, modeling and simulation, and autonomous operations.
- (U) Complete development of satellite control software for applications such as multi-mission advanced ground intelligent control.
- (U) Continue development of next generation astrodynamics models for orbit determination and collision risk assessment.
- (U) Continue development of simulation architecture for space-based surveillance models for wargaming, training, and concept of operations (CONOPs).
- (U) Determine requirements for software for distributed networks for battlespace observation, and data collection, processing, and dissemination.
- (U) Begin development of software for autonomous space technology products.

– (U) $11,103 Develop ground and small satellite integration technologies for space and near-space experiments.
- (U) Launch MightySat I from Space Shuttle mission STS-88. Conduct flight operations. One year on-orbit will validate space applied research technologies minimizing the risk of inserting advanced technology into operational satellites.
- (U) Continue fabrication of MightySat II.1 spacecraft bus and begin integration of experiments for FY 2000 launch.
- (U) Begin integration of technologies manifested for MightySat II.2 which tentatively include autonomous navigation and control, autonomous decision-making, threat-warning component technologies, a flywheel energy storage device, and space-based space surveillance
- (U) Demonstrate the capability to dynamically control the position of a large aperture, sparse optical array via a fully integrated UltraLITE ground demonstration.
- (U) Continue the development of near-space capabilities and bus technologies for experiments requiring high altitudes and guided recovery systems.

RDT&E PROGRAM ELEMENT/PROJECT COST BREAKDOWN (R-3)		DATE February 1998
BUDGET ACTIVITY 2 - Applied Research	PE NUMBER AND TITLE 0602601F Phillips Laboratory Exploratory Development	PROJECT 8809

– (U) $1,289 Develop technologies such as guidance, navigation, and control avionics to support launch vehicles and ballistic missile flights.
- (U) Complete improved techniques to determine accurate gravity field values, a major source of error in space inertial navigation systems.

– (U) $5,804 Conduct Phase III of the Terabit fiber optic technology program.

– (U) $35,585 Total

(U) FY 1999 ($ in Thousands):

– (U) $5,040 Develop technologies for space platform subsystems such as cryocoolers, space vehicle thermal management, compact solar power cells, lightweight batteries, and innovative power generation concepts.
- (U) Continue development of ultra-high efficiency four-junction photovoltaic and thermal electric cells.
- (U) Conduct in-house electrical characterization of 35-40% efficient four-junction solar cells.
- (U) Continue interagency cooperative development of lithium ion battery technology; integrate deliverable into flight experiment.
- (U) Initiate new integrated power chip program for microsatellites.
- (U) Begin development of electrochromic thermal coatings for advanced deployable thermal radiators.
- (U) Continue development and enhance cryocooler models and simulation software.
- (U) Continue development of enhanced capillary pumped loop/looped heat pipe thermal management systems for space vehicles.

– (U) $5,137 Develop technologies for space platform structures such as spacecraft structural controls for vibration suppression and lightweight composite satellite and launch vehicle structures.
- (U) Complete the advanced adaptive structures technology development program.
- (U) Continue launch vibration isolation program.
- (U) Continue design efforts for the miniature isolation system program.
- (U) Initiate the autonomous active structural control program.
- (U) Initiate advanced gimbal program.
- (U) Continue development of multifunctional spacecraft structures.
- (U) Continue space-based radar structures program.
- (U) Continue development of lightweight launch vehicle structure technologies.

– (U) $2,041 Develop technologies for space-based payload subsystems such as hardened sensors and satellite communications.
- (U) Begin development of advanced infrared photodetectors (e.g., multi-spectral quantum wells) for space applications.
- (U) Continue analysis and development of alternative technologies (e.g., antenna design) for low altitude space-based radar systems.

RDT&E BUDGET ITEM JUSTIFICATION SHEET (R-2 Exhibit)		DATE February 1998
BUDGET ACTIVITY **2 - Applied Research**	PE NUMBER AND TITLE **0602601F Phillips Laboratory Exploratory Development**	PROJECT **8809**

– (U) $3,955 Develop technologies for space-based payload components such as hardened electronics and memories.
- (U) Continue evaluation and fabrication of advanced packaging technology whose goal is 90% reduction in size/volume/weight.
- (U) Continue to identify methods and techniques for exploiting commercial electronic advancements to develop low-power, high-performance, radiation-hardened devices and circuits for DoD space programs.
- (U) Begin development of guidance and navigation components based on micro-electro-mechanical system (MEMS) technologies.

– (U) $3,273 Develop technologies for satellite control, astrodynamics, modeling and simulation, and autonomous operations.
- (U) Continue development of next generation astrodynamics models for orbit determination and collision risk assessment.
- (U) Continue development of simulation architecture for space-based surveillance models for wargaming, training, and concept of operations (CONOPs).
- (U) Design architecture and start development of software for distributed networks for battlespace observation, and data collection, processing, and dissemination.
- (U) Continue development of software for autonomous space technology products.

– (U) $11,673 Develop ground and small satellite integration technologies for space and near-space experiments.
- (U) Conclude MightySat I flight operations. Develop and distribute final report.
- (U) Complete fabrication of MightySat II.1. Complete payload integration and launch vehicle integration of MightySat II.1 to launch aboard Orbital-Suborbital Program launch vehicle in FY 2000.
- (U) Begin initial design of modifications to baseline MightySat II vehicle to accommodate experiments on autonomous navigation and control, autonomous decision-making, threat-warning component technologies, a flywheel energy storage device, and space-based space surveillance.
- (U) Develop microsatellite technologies in support of near-earth object inspection and asteroid fly-by mission.
- (U) Begin integration of the second integrated ground, hardware-in-the-loop demonstration which will demonstrate integrated spacecraft energy storage and attitude control.
- (U) Continue the development of near-space capabilities and bus technologies for experiments requiring high altitudes and guided recovery systems.

– (U) $31,119 Total

RDT&E BUDGET ITEM JUSTIFICATION SHEET (R-2 Exhibit)	DATE February 1998	
BUDGET ACTIVITY **2 - Applied Research**	PE NUMBER AND TITLE **0602601F Phillips Laboratory Exploratory Development**	PROJECT **8809**

(U) B. Program Change Summary ($ in Thousands):

	FY 1997	FY 1998	FY 1999	Total Cost
(U) Previous President's Budget (FY 1998 PB)	53,513	28,469	31,263	Cont
(U) Current Budget Submit/FY 1999 PB	49,667	35,585	31,119	Cont

(U) Change Summary Explanation:

Funding: Changes to this project since the previous President's Budget are due to higher priorities within the Science and Technology (S&T) Program.

Schedule: Not Applicable.

Technical: Not Applicable.

(U) C. Other Program Funding Summary:

(U) Related Activities:

- (U) PE 0602203F, Aerospace Propulsion.
- (U) PE 0602102F, Materials.
- (U) PE 0603302F, Space and Missile Rocket Propulsion.
- (U) PE 0603311F, Ballistic Missile Technology.
- (U) PE 0603401F, Advanced Spacecraft Technology.
- (U) PE 0603410F, Space Systems Environmental Interactions.
- (U) This project has been coordinated through the Reliance process to harmonize efforts and eliminate duplication.

(U) D. Schedule Profile: Not Applicable.