

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

DATE

February 2000

BUDGET ACTIVITY

PE NUMBER AND TITLE

03 - Advanced Technology Development

0603302F Space and Missile Rocket Propulsion

COST (\$ in Thousands)	FY 1999 Actual	FY 2000 Estimate	FY 2001 Estimate	FY 2002 Estimate	FY 2003 Estimate	FY 2004 Estimate	FY 2005 Estimate	Cost to Complete	Total Cost
Total Program Element (PE) Cost	22,283	16,526	24,283	21,382	21,326	22,771	24,433	Continuing	TBD
630003 Launch Vehicle Technology	532	0	0	0	0	0	0	Continuing	TBD
634373 Launch and Orbit Transfer Propulsion Technology	20,115	14,771	19,386	18,450	18,350	21,251	22,883	Continuing	TBD
636339 Tactical Propulsion Technology	266	286	0	0	0	0	0	0	TBD
636340 Satellite Control and Maneuvering Propulsion Technology	1,370	1,469	4,897	2,932	2,976	1,520	1,550	Continuing	TBD
Quantity of RDT&E Articles	0	0	0	0	0	0	0	0	0

Note: Project 630003 transfers to PE 0603401F, Project 631026, starting in FY 2000. Strategic sustainment efforts have been consolidated in Project 634373; this involved moving the Post-Boost Control and Non-Destructive Evaluation efforts and associated funding from Project 636340 to Project 634373. The electric propulsion efforts, originally in Project 634373, have been moved to Project 636340. Efforts in Project 636339 will be terminated at the end of FY 2000. Finally, solar thermal efforts have been moved from Project 636340 to Project 634373.

(U) A. Mission Description

This program develops and demonstrates advanced rocket propulsion and space launch technologies. This program provides the technological step necessary to transition the most promising rocket propulsion and space launch technologies to applications using full-scale, proof-of-principle demonstrations. The projects within this program are structured to support Air Force Space Command's and Air Combat Command's mission area requirements for space and missile technologies which include the goals established in the Integrated High Payoff Rocket Propulsion Technology (IHRPT) Initiative, a multi-agency/industry effort to focus the development of U.S. rocket propulsion technology. New and improved components will be integrated with the environmentally improved propellants developed in this program to create new propulsion systems for the next generation of launch vehicles and satellites. Anticipated technological advances in this program will improve the performance of expendable systems' payload capabilities by 21% and reduce the launch and operations and support (O&S) costs by 28%. In a reusable launch system, the anticipated improvements are an increase in payload capability of 170% and a reduction in launch and O&S costs of 79%. The advances in propulsion in this program result from the achievement of the 2010 goals of the IHRPT Initiative. The development of these technologies has been coordinated with National Aeronautics and Space Administration (NASA) to eliminate duplication of efforts. The space launch and missile propulsion industry will leverage the technologies

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(U) **A. Mission Description Continued**
 from this program to enhance the country's industrial competitiveness. Note: Congress added \$3 million in FY 1999 and \$5.5 million in FY 2000 for Integrated High Payoff Rocket Propulsion Technology (IHRPT).

(U) **B. Budget Activity Justification**
 This program is in Budget Activity 3, Advanced Technology Development, since it develops and demonstrates technologies for existing system upgrades and/or new system developments that have military utility and address warfighter needs.

(U) **C. Program Change Summary (\$ in Thousands)**

	<u>FY 1999</u>	<u>FY 2000</u>	<u>FY 2001</u>	<u>Total Cost</u>
(U) Previous President's Budget (FY 2000 PBR)	23,982	11,231	10,863	
(U) Appropriated Value	24,121	16,731		
(U) Adjustments to Appropriated Value				
a. Congressional/General Reductions	-139	-6		
b. Small Business Innovative Research	-682			
c. Omnibus or Other Above Threshold Reprogram		-91		
d. Below Threshold Reprogram	-892			
e. Rescissions	-125	-108		
f. Other				TBD
(U) Adjustments to Budget Years Since FY 2000 PBR			13,420	
(U) Current Budget Submit/FY 2001 PBR	22,283	16,526	24,283	TBD

(U) **Significant Program Changes:**
 The increase in FY 2001 will be used to restore the demonstrations of Boost and Orbit Transfer Vehicle technologies for the Integrated High Payoff Rocket Propulsion Technology program.

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BUDGET ACTIVITY 03 - Advanced Technology Development				PE NUMBER AND TITLE 0603302F Space and Missile Rocket Propulsion				PROJECT 630003		
COST (\$ in Thousands)		FY 1999 Actual	FY 2000 Estimate	FY 2001 Estimate	FY 2002 Estimate	FY 2003 Estimate	FY 2004 Estimate	FY 2005 Estimate	Cost to Complete	Total Cost
630003	Launch Vehicle Technology	532	0	0	0	0	0	0	Continuing	TBD
<p>(U) <u>A. Mission Description</u> This project develops advanced and innovative launch vehicles technologies in the areas of structures (i.e., fairings, interstages, struts, thermal protection systems, etc.), tanks, and operations.</p> <p>(U) <u>FY 1999 (\$ in Thousands)</u></p> <p>(U) \$150 Continued to define technological needs for future reusable military launch vehicles including operations technologies, lightweight airframe structures, durable composite cryogenic tanks, and structure multifunctionality including thermal and acoustic tailorability.</p> <p>(U) \$100 Continued to define technological needs for future expendable launch vehicles including operations technologies, lightweight airframe structures, durable composite cryogenic tanks, and structure multifunctionality including thermal and acoustic tailorability.</p> <p>(U) \$282 Developed advanced composite launch vehicle structures including grid stiffened shrouds.</p> <p>(U) \$532 Total</p> <p>(U) <u>FY 2000 (\$ in Thousands)</u></p> <p>(U) \$0 Effort moved to PE 0603401F/Project 631026.</p> <p>(U) \$0 Total</p> <p>(U) <u>FY 2001 (\$ in Thousands)</u></p> <p>(U) \$0 Effort moved to PE 0603401F/Project 631026.</p> <p>(U) \$0 Total</p> <p>(U) <u>B. Project Change Summary</u> Not Applicable.</p> <p>(U) <u>C. Other Program Funding Summary (\$ in Thousands)</u></p> <p>(U) Related Activities:</p> <p>(U) PE 0602102F, Materials.</p> <p>(U) PE 0602601F, Spacecraft Technology.</p> <p>(U) PE 0603401F, Advanced Spacecraft Technology.</p> <p>(U) PE 0603853F, Evolved Expendable Launch Vehicle Program.</p>										

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BUDGET ACTIVITY 03 - Advanced Technology Development	PE NUMBER AND TITLE 0603302F Space and Missile Rocket Propulsion	PROJECT 630003
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- (U) **C. Other Program Funding Summary (\$ in Thousands)**
- (U) This project has been coordinated through the Reliance process to harmonize efforts and eliminate duplication.
- (U) **D. Acquisition Strategy**
Not Applicable.
- (U) **E. Schedule Profile**
- (U) Not Applicable.

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BUDGET ACTIVITY 03 - Advanced Technology Development				PE NUMBER AND TITLE 0603302F Space and Missile Rocket Propulsion				PROJECT 634373		
COST (\$ in Thousands)		FY 1999 Actual	FY 2000 Estimate	FY 2001 Estimate	FY 2002 Estimate	FY 2003 Estimate	FY 2004 Estimate	FY 2005 Estimate	Cost to Complete	Total Cost
634373	Launch and Orbit Transfer Propulsion Technology	20,115	14,771	19,386	18,450	18,350	21,251	22,883	Continuing	TBD
<p>(U) <u>A. Mission Description</u> This project develops advanced and innovative, low-cost rocket turbomachinery and components, low-cost space and missile launch propulsion system manufacturing technologies, and advanced propellants. Characteristics such as environmental acceptability, affordability, reliability, reduced weight, reduced operation and launch costs, and increased life and performance of propulsion systems are emphasized in this project. Technological advances developed in this program will improve the performance of expendable systems' payload capabilities by 21% and reduce the launch and operations and support (O&S) costs by 28%. The advances in propulsion in this program will result from the achievement of the 2010 goals of the Integrated High Payoff Rocket Propulsion Technology Initiative.</p>										
<p>(U) <u>FY 1999 (\$ in Thousands)</u></p>										
(U)	\$13,713	Continued to develop propulsion technologies for existing and future launch vehicles. Completed fabrication of oxygen and hydrogen turbopump assemblies and preburner components for integration into an advanced liquid engine test bed.								
(U)	\$3,402	Continued to develop propulsion technologies for existing and future upper stage and orbit transfer vehicles. Completed component testing and began integration of components into demonstrator engine.								
(U)	\$3,000	Developed technologies for the sustainment of strategic systems. Continued development of a multi-use, less detonable (Class 1.3) solid propellant which meets all Intercontinental Ballistic Missile (ICBM) requirements, reduces hardware costs by 25%, and sustains current performance levels. Continued development of evaluation techniques to accurately predict service life.								
(U)	\$20,115	Total								
<p>(U) <u>FY 2000 (\$ in Thousands)</u></p>										
(U)	\$1,864	Continue to develop components of turbomachinery components for integration into advanced liquid test bed demonstrator. Continue to develop turbomachinery components for integration in to advanced liquid test bed demonstrator. Initiate fabrication and assembly of combustion chamber and injector. Continue fabrication of oxygen turbopump for integration into an advanced liquid booster engine. Initiate testing of oxygen and hydrogen turbopump assemblies and preburner components for integration into an advanced liquid booster engine. These demonstrated turbomachinery technologies will significantly reduce the life cycle cost of future expendable and reusable liquid rocket engines.								
(U)	\$3,707	Develop propulsion technologies for existing and future upper stage and orbit transfer vehicles. Continue integration of turbopump and chamber into high-pressure cryogenic upper stage test bed engine. Demonstrate these components in engine level tests. Demonstrate the Phase I goals of increased thrust to weight of 30%, decreased hardware/support costs by 15%, and increased reliability by 25% for the 50k lbs. thrust expander cycle upper stage cryogenic engine. Advanced upper stage engine technology will create significant payloads increases for future launch								
Project 634373			Page 5 of 11 Pages				Exhibit R-2A (PE 0603302F)			

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BUDGET ACTIVITY		PROJECT
03 - Advanced Technology Development	0603302F Space and Missile Rocket Propulsion	February 2000 634373
(U)	<u>A. Mission Description Continued</u>	
(U)	<u>FY 2000 (\$ in Thousands) Continued</u>	
(U)	\$1,700	vehicles. Demonstrate solar thermal propulsion technologies on ground tests for orbit transfer and maneuvering propulsion technology. Develop technologies for the sustainment of strategic systems. Continue development of a multi-use, non-detonable (Class 1.3) solid propellant which meets all Intercontinental Ballistic Missile (ICBM) requirements, reduces hardware costs by 25%, and maintains current performance levels. Initiate the Strategic Sustainment Demonstration program which integrates advanced propellant, case, and nozzle technologies and demonstrates all cost and performance goals. Continue developing non-destructive evaluation (NDE) technology for large solid rocket motors (SRMs).
(U)	\$2,000	Develop propulsion technologies for future orbit transfer vehicles (OTVs). Complete high performance Hall thruster propulsion technologies for orbit transfer and maneuvering propulsion technology. Complete component tests, integration of components, and scheduled ground demonstration of flight qualified high performance Hall thruster system. Analyze flight data and correlate with ground test data to complete final report on the 30kW ammonia arcjet thruster.
(U)	\$5,500	Continue developing propulsion technologies to support the Integrated High Payoff Rocket Propulsion Technology (IHRPT) Program. Complete the fabrication of the oxygen turbopump for integration into an advance liquid booster engine. Complete the Phase 1 Solid Boost Demo program which develops propulsion technologies for the next generation of space boosters.
(U)	\$14,771	Total
(U)	<u>FY 2001 (\$ in Thousands)</u>	
(U)	\$6,547	Continue to develop propulsion technology for existing and future launch vehicles. Continue to develop turbomachinery components for integration in to advanced liquid test bed demonstrator. Continue fabrication and assembly of combustion chamber and injector. Continue fabrication of oxygen turbopump for integration into an advanced liquid booster engine. Continue testing of oxygen and hydrogen turbopump assemblies and preburner components for integration into an advanced liquid booster engine. These demonstrated turbomachinery technologies will significantly reduce the life cycle cost of future expendable and reusable liquid rocket engines. Install oxygen turbopump assembly into test facility and prepare for hot fire testing of pump assembly.
(U)	\$8,839	Develop propulsion technologies for existing and future upperstage and orbit transfer vehicles. Complete integration of turbopump and chamber into high-pressure cryogenic upper stage test bed engine. Complete demonstration of these components in engine level tests. Continue to demonstrate solar thermal propulsion technologies, such as strut development and pointing and tracking, for orbit transfer and maneuvering propulsion technology. Continue development of high-power Hall thrusters for orbit transfer. Continue program to develop electric propulsion systems for orbit-transfer by developing a high-power Hall thrusters capable of low earth orbit-geosynchronous orbit transfer. Initiate advanced smallsat propulsion demonstration to develop microsat formation flying capability for Air Force imaging requirements.
(U)	\$4,000	Develop technologies for the sustainment of strategic systems. Initiate the post boost control system (PBCS) program to demonstrate component
Project 634373		Exhibit R-2A (PE 0603302F)

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BUDGET ACTIVITY 03 - Advanced Technology Development	PE NUMBER AND TITLE 0603302F Space and Missile Rocket Propulsion	PROJECT 634373
<p>(U) <u>A. Mission Description Continued</u></p> <p>(U) <u>FY 2001 (\$ in Thousands) Continued</u> technologies with readily available materials to reduce hardware costs, a 90% reduction in hydrazine leakage, and a 5X increase in service life for liquid fuels ballistic missiles. Continue the Strategic Sustainment Demonstration program which integrates advanced propellant, case, and nozzle technologies and demonstrates all cost and performance goals.</p> <p>(U) \$19,386 Total</p> <p>(U) <u>B. Project Change Summary</u> Not Applicable.</p> <p>(U) <u>C. Other Program Funding Summary (\$ in Thousands)</u></p> <p>(U) Related Activities:</p> <p>(U) PE 0602203F, Aerospace Propulsion.</p> <p>(U) PE 0602601F, Spacecraft Technology.</p> <p>(U) PE 0603853F, Evolved Expendable Launch Vehicle Program.</p> <p>(U) This project has been coordinated through the Reliance process to harmonize efforts and eliminate duplication.</p> <p>(U) <u>D. Acquisition Strategy</u> Not Applicable.</p> <p>(U) <u>E. Schedule Profile</u></p> <p>(U) Not Applicable.</p>		
Project 634373	Page 7 of 11 Pages	Exhibit R-2A (PE 0603302F)

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BUDGET ACTIVITY 03 - Advanced Technology Development				PE NUMBER AND TITLE 0603302F Space and Missile Rocket Propulsion				PROJECT 636339		
COST (\$ in Thousands)		FY 1999 Actual	FY 2000 Estimate	FY 2001 Estimate	FY 2002 Estimate	FY 2003 Estimate	FY 2004 Estimate	FY 2005 Estimate	Cost to Complete	Total Cost
636339	Tactical Propulsion Technology	266	286	0	0	0	0	0	0	TBD
<p>(U) <u>A. Mission Description</u> This project develops highly energetic propellants and propulsion systems. Improved case, insulation, and propellant interfaces as well as better performing nozzles will be developed. Technology such as thrust vector control, thrust modulation, signature characterization, and signature reduction will be developed in this project. The emphasis in this project is on rocket propulsion system affordability and weight reduction. Anticipated payoffs from these developments, identified through the Integrated High Payoff Rocket Propulsion Technology Initiative (IHRPT), include a 49% range increase, 50% size reduction, 100% payload increase, and 21% reduction in time-to-target.</p> <p>(U) <u>FY 1999 (\$ in Thousands)</u> (U) \$266 Began scale-up of selected solid propellant formulations that can be incorporated into the design and manufacture of future air-to-air missile systems for the U.S., France, Germany, and the United Kingdom. These propellants have acceptable hazards, higher performance, lower environmental impact, and reduced exhaust signature characteristics. Completed solid propellant scale-up and finalized rheological and hazards properties. Completed ballistic performance evaluation in U.S. test motors (15 lbs.) and manufactured initial European test motors for their internal evaluation.</p> <p>(U) \$266 Total</p> <p>(U) <u>FY 2000 (\$ in Thousands)</u> (U) \$286 Develop tactical missile technologies. Integrate component technologies and an advanced tactical missile propellants that improve missile thrust and reduce plume exhaust signatures. Manufacture European test motors and selected propellant samples incorporating an advanced high performance, acceptable hazards, low environmental impact, and reduced signature propellant. Ship these rocket test motors to our European partners (France, Germany, and the United Kingdom) and participate in their evaluations of performance, signature, hazards, mechanical, and aging properties.</p> <p>(U) \$286 Total</p> <p>(U) <u>FY 2001 (\$ in Thousands)</u> (U) \$0 No Activity. (U) \$0 Total</p>										
Project 636339			Page 8 of 11 Pages				Exhibit R-2A (PE 0603302F)			

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BUDGET ACTIVITY	PE NUMBER AND TITLE	PROJECT
03 - Advanced Technology Development	0603302F Space and Missile Rocket Propulsion	636339
<p>(U) <u>B. Project Change Summary</u> Not Applicable.</p> <p>(U) <u>C. Other Program Funding Summary (\$ in Thousands)</u> (U) Related Activities: (U) PE 0602601F, Spacecraft Technology. (U) PE 0602303A, Missile Technology. (U) PE 0603313A, Missile and Rocket Advanced Technology. (U) PE 0603792N, Advanced Technology Transition. (U) This project has been coordinated through the Reliance process to harmonize efforts and eliminate duplication.</p> <p>(U) <u>D. Acquisition Strategy</u> Not Applicable.</p> <p>(U) <u>E. Schedule Profile</u> (U) Not Applicable.</p>		
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BUDGET ACTIVITY 03 - Advanced Technology Development				PE NUMBER AND TITLE 0603302F Space and Missile Rocket Propulsion				PROJECT 636340		
COST (\$ in Thousands)		FY 1999 Actual	FY 2000 Estimate	FY 2001 Estimate	FY 2002 Estimate	FY 2003 Estimate	FY 2004 Estimate	FY 2005 Estimate	Cost to Complete	Total Cost
636340	Satellite Control and Maneuvering Propulsion Technology	1,370	1,469	4,897	2,932	2,976	1,520	1,550	Continuing	TBD
<p>(U) <u>A. Mission Description</u> Chemical, electric, and solar rocket propulsion system technologies for station keeping and on-orbit maneuvering applications are developed in this project. Technology areas investigated include ground demonstrations of compact, lightweight, advanced propulsion systems, higher efficiency energy conversion systems (derived from an improved understanding of combustion fundamentals), and high-energy chemical propellants. The payoffs for the Integrated High Payoff Rocket Propulsion Technology Initiative (IHRPT) include a seven-year increase in satellite on-orbit time, a 50% increase in satellite maneuvering capability, a 25% reduction in orbit transfer operational costs, and a 15% increase in satellite payload.</p> <p>(U) <u>FY 1999 (\$ in Thousands)</u></p> <p>(U) \$913 Completed test flight and data collection of the Electric Space Experiment (ESEX) space flight aboard the ARGOS satellite.</p> <p>(U) \$357 Compiled and analyzed data from the ESEX experiment.</p> <p>(U) \$100 Completed selection of advanced pulsed-plasma propulsion for engineering model ground test to support MightySat II.2 space flight experiment and TechSat 21.</p> <p>(U) \$1,370 Total</p> <p>(U) <u>FY 2000 (\$ in Thousands)</u></p> <p>(U) \$269 Develop propulsion systems for satellite formation flying. Complete design of pulsed plasma thruster for use in satellite formation flying. Complete data analysis of the Electric Space Experiment (ESEX) space flight.</p> <p>(U) \$200 Develop propulsion for satellite stationkeeping and repositioning. Initiate fabrication of brass board test hardware of the pulsed plasma thruster. Complete fabrication of power conditioning systems for ground testing of complete PPT system.</p> <p>(U) \$1,000 Continue to test propulsion systems for use in satellite propulsion. Begin integration of flight hardware onto the MightySat II.2 satellite. Once integration is complete, begin testing of the propulsion system.</p> <p>(U) \$1,469 Total</p>										
Project 636340		Page 10 of 11 Pages				Exhibit R-2A (PE 0603302F)				

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BUDGET ACTIVITY	PE NUMBER AND TITLE	PROJECT
03 - Advanced Technology Development	0603302F Space and Missile Rocket Propulsion	636340
(U) <u>A. Mission Description Continued</u>		
(U) <u>FY 2001 (\$ in Thousands)</u>		
(U) \$538	Continue to develop propulsion systems for satellite formation flying. Begin development of mathematical models to address different propulsion technologies that could be used for small satellite formation flying. Using these models, downselect the optimum propulsion system for use in these types of systems.	
(U) \$414	Continue to develop propulsion for satellite stationkeeping and repositioning. Initiate brass board level testing of a pulsed plasma thruster system. Hot fire test the thruster in conjunction with the power processing unit.	
(U) \$3,945	Continue to test propulsion systems for use in satellite propulsion. Continue testing of flight hardware onto the MightySat II.2 satellite. Once integration is complete, begin testing of the propulsion system. Prepare for launch of MightySat II.2.	
(U) \$4,897	Total	
(U) <u>B. Project Change Summary</u>		
	Not Applicable.	
(U) <u>C. Other Program Funding Summary (\$ in Thousands)</u>		
(U)	Related Activities:	
(U)	PE 0602203F, Aerospace Propulsion.	
(U)	PE 0602601F, Spacecraft Technology.	
(U)	This project has been coordinated through the Reliance process to harmonize efforts and eliminate duplication.	
(U) <u>D. Acquisition Strategy</u>		
	Not Applicable.	
(U) <u>E. Schedule Profile</u>		
(U)	Not Applicable.	