Exhibit R-2, RDT&E Budget Item Justification: PB 2016 Air Force											Date: February 2015	
Appropriation/Budget Activity 3600: *Research, Development, Test & Evaluation, Air Force* / BA 2: *Applied Research*					R-1 Program Element (Number/Name) PE 0602203F / *Aerospace Propulsion*							
COST ($ in Millions)	**Prior Years**	**FY 2014**	**FY 2015**	**FY 2016 Base**	**FY 2016 OCO**	**FY 2016 Total**	**FY 2017**	**FY 2018**	**FY 2019**	**FY 2020**	**Cost To Complete**	**Total Cost**
Total Program Element	-	193.204	172.550	182.326	-	182.326	174.471	182.673	185.275	188.001	Continuing	Continuing
623012: *Advanced Propulsion Technology*	-	21.814	17.646	19.670	-	19.670	22.471	23.223	23.847	24.298	Continuing	Continuing
623048: *Combustion and Mechanical Systems*	-	12.944	12.008	11.652	-	11.652	11.873	12.192	12.415	12.664	Continuing	Continuing
623066: *Turbine Engine Technology*	-	75.742	57.245	63.712	-	63.712	51.687	54.771	55.249	55.341	Continuing	Continuing
623145: *Aerospace Power Technology*	-	26.003	29.393	28.213	-	28.213	29.752	30.120	30.730	31.359	Continuing	Continuing
624847: *Rocket Propulsion Technology*	-	51.494	51.287	54.232	-	54.232	53.696	57.231	57.818	59.020	Continuing	Continuing
625330: *Aerospace Fuel Technology*	-	5.207	4.971	4.847	-	4.847	4.992	5.136	5.216	5.319	Continuing	Continuing

A. Mission Description and Budget Item Justification

This program develops propulsion and power technologies to achieve enabling and revolutionary aerospace technology capabilities. The program has six projects, each focusing on a technology area critical to the Air Force. The Advanced Propulsion Technology project develops high-speed air breathing propulsion engines to include combined cycle, ramjet, and hypersonic scramjet technologies to enable revolutionary propulsion capability for the Air Force. The Combustion and Mechanical Systems project evaluates lubricants and combustion concepts and technologies for new and existing engines. The Turbine Engine Technology project develops enabling capabilities to enhance performance and affordability of existing weapon systems and develops component technologies for ultra high pressure ratio, substantially improved durability, and adaptive cycle engine architecture to provide optimized performance, fuel efficiency, and life for widely varying mission needs. The Aerospace Power Technology project develops electrical power and thermal management technologies for military applications that are part of energy optimized aircraft development. The Rocket Propulsion Technology project develops advances in rocket propulsion technologies for space access, space maneuver, missiles, the sustainment of strategic systems, and tactical rockets. The Aerospace Fuel Technology project evaluates hydrocarbon-based fuels for legacy and advanced turbine engines, scramjets, pulse detonation, and combined-cycle engines. Efforts in this program have been coordinated through the Department of Defense (DoD) Science and Technology (S&T) Executive Committee process to harmonize efforts and eliminate duplication.

This program is in Budget Activity 2, Applied Research because this budget activity includes studies, investigations, and non-system specific technology efforts directed toward general military needs with a view toward developing and evaluating the feasibility and practicality of proposed solutions and determining their parameters.

Exhibit R-2, RDT&E Budget Item Justification: PB 2016 Air Force					Date: February 2015
Appropriation/Budget Activity 3600: *Research, Development, Test & Evaluation, Air Force* / BA 2: *Applied Research*		R-1 Program Element (Number/Name) PE 0602203F / *Aerospace Propulsion*			
B. Program Change Summary ($ in Millions)	**FY 2014**	**FY 2015**	**FY 2016 Base**	**FY 2016 OCO**	**FY 2016 Total**
Previous President's Budget	197.546	172.550	185.363	-	185.363
Current President's Budget	193.204	172.550	182.326	-	182.326
Total Adjustments	-4.342	-	-3.037	-	-3.037
• Congressional General Reductions	-	-			
• Congressional Directed Reductions	-	-			
• Congressional Rescissions	-	-			
• Congressional Adds	-	-			
• Congressional Directed Transfers	-	-			
• Reprogrammings	-	-			
• SBIR/STTR Transfer	-4.341	-			
• Other Adjustments	-0.001	-	-3.037	-	-3.037

Change Summary Explanation

Decrease in FY16 is due to higher DoD priorities.

Exhibit R-2A, RDT&E Project Justification: PB 2016 Air Force			Date: February 2015
Appropriation/Budget Activity 3600 / 2	R-1 Program Element (Number/Name) PE 0602203F / *Aerospace Propulsion*	Project (Number/Name) 623012 / *Advanced Propulsion Technology*	

COST ($ in Millions)	Prior Years	FY 2014	FY 2015	FY 2016 Base	FY 2016 OCO	FY 2016 Total	FY 2017	FY 2018	FY 2019	FY 2020	Cost To Complete	Total Cost
623012: *Advanced Propulsion Technology*	-	21.814	17.646	19.670	-	19.670	22.471	23.223	23.847	24.298	Continuing	Continuing

A. Mission Description and Budget Item Justification

This project develops combined/advanced cycle air breathing high-speed (up to Mach 4) and hypersonic (Mach 5 to 7) propulsion technologies to provide revolutionary propulsion options for the Air Force. These new engine technologies will enable future high-speed/hypersonic weapons and aircraft concepts. The primary focus is on hydrocarbon-fueled engines capable of operating over a broad range of flight Mach numbers. Efforts include modeling, simulations, and proof of concept demonstrations of critical components; advanced component development; and ground-based demonstrations.

B. Accomplishments/Planned Programs ($ in Millions)	FY 2014	FY 2015	FY 2016
Title: Hypersonic Scramjet Technologies	21.814	17.646	19.670

Description: Develop robust hydrocarbon fueled scramjet engine components and technologies to improve performance, operability, durability, and scalability for future platforms.

FY 2014 Accomplishments:
Developed advanced engine components to improve scramjet operating margin and to refine scramjet scaling laws for reusable applications. Developed techniques to decrease the minimum scramjet ignition from Mach 4.5 to Mach 3.5 to provide robust options for Combined Cycle Engines (CCEs). Developed low drag flame stabilization devices and flight test components. Initiated fabrication of common test hardware for direct testing of medium scale (ten times) scramjet engines operating at Mach 3.5 to Mach 7 conditions. Initiated test facility characterization for direct connect testing with new test facility primary flow nozzles and test facility primary flow distortion generator to simulate inlet flow conditions.

FY 2015 Plans:
Continue to develop advanced engine components to improve scramjet operating margin and to refine scramjet scaling laws for reusable applications. Continue to develop techniques to decrease scramjet take-over from Mach 4.5 to Mach 3.5 to provide robust options for CCEs. Assess distortion impact on isolator operability. Continue to develop low internal drag flame stabilization devices and flight test engine components. Fabricate heavyweight direct connect scramjet combustors in medium scale (ten times). Initiate direct connect testing of first performing contractor medium scale (ten times) scramjet combustors from Mach 3.5 to Mach 7.

FY 2016 Plans:
Continue to develop advanced engine components to improve scramjet operating margin and to refine scramjet scaling laws for reusable applications. Continue to develop techniques to decrease scramjet take-over from Mach 4.5 to Mach 3.5 to provide robust options for CCEs. Continue to develop low internal drag flame stabilization devices and flight test engine components. Test advanced materials for application to scramjet engines. Fabricate heavyweight direct connect scramjet combustors in medium

Exhibit R-2A, RDT&E Project Justification: PB 2016 Air Force		Date: February 2015
Appropriation/Budget Activity 3600 / 2	**R-1 Program Element (Number/Name)** PE 0602203F / *Aerospace Propulsion*	**Project (Number/Name)** 623012 / *Advanced Propulsion Technology*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2014	FY 2015	FY 2016
scale (ten times). Complete direct connect testing of first performing contractor medium scale (ten times) scramjet combustor from Mach 3.5 to Mach 7. Complete fabrication of second performing contractor medium scale scramjet combustor.			
Accomplishments/Planned Programs Subtotals	21.814	17.646	19.670

C. Other Program Funding Summary ($ in Millions)

N/A

Remarks

D. Acquisition Strategy

N/A

E. Performance Metrics

Please refer to the Performance Base Budget Overview Book for information on how Air Force resources are applied and how those resources are contributing to Air Force performance goals and most importantly, how they contribute to our mission.

Exhibit R-2A, RDT&E Project Justification: PB 2016 Air Force			Date: February 2015
Appropriation/Budget Activity 3600 / 2	R-1 Program Element (Number/Name) PE 0602203F / *Aerospace Propulsion*	Project (Number/Name) 623048 / *Combustion and Mechanical Systems*	

COST ($ in Millions)	Prior Years	FY 2014	FY 2015	FY 2016 Base	FY 2016 OCO	FY 2016 Total	FY 2017	FY 2018	FY 2019	FY 2020	Cost To Complete	Total Cost
623048: *Combustion and Mechanical Systems*	-	12.944	12.008	11.652	-	11.652	11.873	12.192	12.415	12.664	Continuing	Continuing

A. Mission Description and Budget Item Justification

This project evaluates lubricants, mechanical systems, and combustion concepts for advanced turbine engines, pulse detonation engines, and combined cycle engines. This project also develops technologies to increase turbine engine operational reliability, durability, mission flexibility, maintainability, and performance while reducing weight, fuel consumption, and cost of ownership. Applications include missiles, aircraft, and re-usable high-speed vehicles. Analytical and experimental areas of emphasis include lubricants, bearings, mechanical systems diagnostics, mechanical systems prognostics, rotor dynamics, oil-less engine technology, optical diagnostics, fundamental combustion, detonations, combustors, and afterburners. Lubricants for these engines must be thermally stable, cost-effective, and operate over a broad range of conditions. Advanced combustion concepts must be cost-effective, durable, and reduce pollutant emissions. A portion of this project supports adaptive cycle technologies. This effort develops component technology for an adaptive cycle engine architecture that provides both optimized performance and fuel efficiency for widely varying mission needs.

B. Accomplishments/Planned Programs ($ in Millions)	FY 2014	FY 2015	FY 2016
Title: Combustion Technologies	5.004	4.658	4.520
Description: Develop, test, and evaluate revolutionary combustion and propulsion concepts for gas turbine, pulse detonation, and combined cycle engines for missiles, manned and unmanned systems.			
FY 2014 Accomplishments: Designed and tested full-annular ultra compact combustors. Evaluated augmentor technologies for screech reduction. Fabricated and tested reference combustors for alternative fuels. Implemented new technologies to operate small-scale propulsion systems with reduced octane fuels. Developed new rotational detonation engine (RDE) concepts.			
FY 2015 Plans: Begin to develop combustor, augmentor and constant volume combustion or pressure gain combustion technologies such as pulse detonation engines (PDEs) or rotational detonation engines (RDEs) to enable the next generation of gas turbine engines, new engine cycles, and combined-cycles. Explore the interactions and effects of compressor and turbine components on the combustor and combustor materials, to reduce engine weight and increase efficiency. Continue using advanced diagnostics to obtain high-quality datasets that can be made available to and used by academia and industry for model development. Maintain efforts to determine necessary reference performance and operability combustion systems and metrics to decrease the cost of certifying new and alternative fuels in weapon systems.			
FY 2016 Plans:			

Exhibit R-2A, RDT&E Project Justification: PB 2016 Air Force		Date: February 2015
Appropriation/Budget Activity 3600 / 2	**R-1 Program Element (Number/Name)** PE 0602203F / *Aerospace Propulsion*	**Project (Number/Name)** 623048 / *Combustion and Mechanical Systems*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2014	FY 2015	FY 2016
Continue development of combustor, augmentor and constant volume combustion or pressure gain combustion technologies such as pulse detonation engines (PDEs) or rotational detonation engines (RDEs) to enable the next generation of gas turbine engines.			
Title: Diagnostic Technologies ***Description:*** Develop and demonstrate optical, electromechanical, and laser diagnostic tools and sensors for application to revolutionary propulsion technologies. ***FY 2014 Accomplishments:*** Developed high-speed laser systems to measure combustion species, temperature, and velocity. Applied new diagnostics to combustion systems at relevant engine conditions. Refined fiber optic methods for high-power laser diagnostics use. ***FY 2015 Plans:*** Develop and demonstrate diagnostic systems for high-bandwidth (kHZ-MHz) measurements of combustion chemistry and physics based on 1) time-division-multiplexed hyperspectral absorption spectroscopy, 2) pulse-burst lasers, and 3) ultrashort-pulse (picosecond, femtosecond) lasers. Apply to laboratory flame test rigs, engine test cells, and fielded systems. ***FY 2016 Plans:*** Continue development and demonstration of diagnostic systems for high-bandwidth (kHZ-MHz) measurements of combustion chemistry and physics based on 1) time-division-multiplexed hyperspectral absorption spectroscopy, 2) pulse-burst lasers, and 3) ultrashort-pulse (picosecond, femtosecond) lasers. Continue application to engine test cells, and fielded systems.	0.969	0.884	0.900
Title: Lubricant Technologies ***Description:*** Develop, test, and qualify advanced turbine engine lubricants. Generate and maintain military specifications for aviation engine lubricants. ***FY 2014 Accomplishments:*** Finalized transition plans of enhanced ester oil to current and future engines. Qualified additional enhanced ester oil candidates for field use. Demonstrated advanced mechanical system health monitoring algorithms on full-scale demonstrator engine. Continued investigating advanced lube system thermal management technologies for fuel efficient engines. Incorporated new traction models into bearing heat generation models. ***FY 2015 Plans:*** Execute plan for transitioning Enhanced Ester (EE) oils into the fleet. Develop transition plans for mechanical system health monitoring system technologies. Continue investigating advanced lube system thermal management technologies for fuel efficient and hi-mach engine applications. ***FY 2016 Plans:***	3.413	3.123	3.030

Exhibit R-2A, RDT&E Project Justification: PB 2016 Air Force		Date: February 2015
Appropriation/Budget Activity 3600 / 2	**R-1 Program Element (Number/Name)** PE 0602203F / *Aerospace Propulsion*	**Project (Number/Name)** 623048 / *Combustion and Mechanical Systems*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2014	FY 2015	FY 2016
Demonstrate Enhanced Ester (EE) oils on Adaptive Engine Technology Demonstrator (AETD) engine cores. Demonstrate mechanical system health monitoring system technologies on fielded systems. Continue investigating advanced lube system thermal management technologies for fuel efficient and hi-mach engine applications.			
Title: Bearing Technologies ***Description:*** Develop and test advanced bearing material technology and bearing concepts for small, intermediate, and large-scale turbine engine applications. ***FY 2014 Accomplishments:*** Conducted full-scale bearing tests in support of adaptive turbine engines. Conducted foil bearing rig tests in support of expendable supersonic turbine engine follow-on development. Developed improved bearing material life model. Matured autonomous active thrust bearing system. Finalized transition plans of hybrid ceramic/metallic bearings into upgrades of current aircraft. ***FY 2015 Plans:*** Continue full-scale bearing rig testing in support of adaptive, fuel efficient engines. Continue oil-free, foil bearing R&D in support of supersonic expendable engines and remotely piloted aircraft. Continue developing improved bearing material life model. Continue maturing active bearing thrust control system and fuse with engine prognostics health monitoring system for future fuel efficient engines. ***FY 2016 Plans:*** Complete full-scale bearing rig testing in support of adaptive, fuel efficient engines. Complete oil-free, foil bearing research and development in support of supersonic expendable engines and remotely piloted aircraft. Experimentally validate improved bearing material life model. Investigate failure mechanisms of advanced bearing alloys. Continue maturing active bearing thrust control system and fuse with engine prognostics health monitoring system for future efficient engines.	3.558	3.343	3.202
Accomplishments/Planned Programs Subtotals	12.944	12.008	11.652

C. Other Program Funding Summary ($ in Millions)

N/A

Remarks

D. Acquisition Strategy

N/A

Exhibit R-2A, RDT&E Project Justification: PB 2016 Air Force		Date: February 2015
Appropriation/Budget Activity 3600 / 2	**R-1 Program Element (Number/Name)** PE 0602203F / *Aerospace Propulsion*	**Project (Number/Name)** 623048 / *Combustion and Mechanical Systems*

E. Performance Metrics

Please refer to the Performance Base Budget Overview Book for information on how Air Force resources are applied and how those resources are contributing to Air Force performance goals and most importantly, how they contribute to our mission.

Exhibit R-2A, RDT&E Project Justification: PB 2016 Air Force			Date: February 2015
Appropriation/Budget Activity 3600 / 2	R-1 Program Element (Number/Name) PE 0602203F / *Aerospace Propulsion*	Project (Number/Name) 623066 / *Turbine Engine Technology*	

COST ($ in Millions)	Prior Years	FY 2014	FY 2015	FY 2016 Base	FY 2016 OCO	FY 2016 Total	FY 2017	FY 2018	FY 2019	FY 2020	Cost To Complete	Total Cost
623066: *Turbine Engine Technology*	-	75.742	57.245	63.712	-	63.712	51.687	54.771	55.249	55.341	Continuing	Continuing

A. Mission Description and Budget Item Justification

This project develops technology to increase turbine engine operational reliability, durability, mission flexibility, and performance, while reducing weight, fuel consumption, and cost of ownership. Analytical and experimental areas of emphasis are fans and compressors, high temperature combustors, turbines, internal flow systems, controls, augmentor and exhaust systems, integrated power and thermal management systems, engine inlet integration, mechanical systems, adaptive cycle technologies, and structural design. This project develops component technology for an adaptive cycle engine architecture that provides both optimized performance and fuel efficiency for widely varying mission needs. This project supports joint Department of Defense, agency, and industry efforts to focus turbine propulsion technology on national needs. The program plan is relevant across capability areas for global responsive strike, tactical and global mobility, responsive space lift, and persistent intelligence, surveillance, and reconnaissance (ISR).

B. Accomplishments/Planned Programs ($ in Millions)	FY 2014	FY 2015	FY 2016
Title: Turbofan/Turbojet Engine Core Technologies	34.292	27.905	31.057

Description: Develop core turbofan/turbojet engine components (i.e., compressors, combustors, and turbines) for fighters, bombers, sustained supersonic/hypersonic cruise vehicles, and transports.

FY 2014 Accomplishments:
Developed modeling and simulation tools for advanced components including coupled aerothermal models; highly loaded, low emissions combustion systems; and turbine durability designs. Performed structural assessment research of combustor and turbine components operating in a realistic engine environment. Continued to develop improved compressor aerodynamic design tools to extend engine operability and increasae efficiency. Initiated conceptual design of efficient, very high pressure ratio core component technologies. Completed Adaptive Versatile Engine Technology (ADVENT) effort.

FY 2015 Plans:
Continue developing modeling and simulation tools for advanced components including coupled aerothermal models; highly loaded, low emissions combustion systems; and turbine durability designs. Perform structural assessment research of combustor and turbine components operating in a realistic engine environment. Continue to develop improved compressor aerodynamic design tools to extend engine operability and efficiency. Complete conceptual design, and initiate detailed design of efficient, very high pressure ratio core component technologies.

FY 2016 Plans:
Complete development of modeling and simulation tools for advanced components including coupled aerothermal models; highly loaded, low emissions combustion systems; and turbine durability designs. Perform structural assessment research of mechanical and turbine components operating in a realistic engine environment. Continue development of improved compressor aerodynamic

Exhibit R-2A, RDT&E Project Justification: PB 2016 Air Force		Date: February 2015
Appropriation/Budget Activity 3600 / 2	**R-1 Program Element (Number/Name)** PE 0602203F / *Aerospace Propulsion*	**Project (Number/Name)** 623066 / *Turbine Engine Technology*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2014	FY 2015	FY 2016
design tools to extend engine operability and efficiency. Complete detailed design of efficient, very high pressure ratio core component technologies.			
Title: Turbofan/Turbojet Engine Fan, Low Pressure Turbine, and Integration Technologies ***Description:*** Develop turbofan/turbojet engine components (i.e., fans, nozzles, etc.) used in engines for fighters, bombers, sustained supersonic strike and hypersonic cruise vehicles, and transports. ***FY 2014 Accomplishments:*** Developed modeling and simulation tools, including methods to predict behavior of serpentine inlets and nozzles. Developed modeling and simulation tools to predict fan/inlet interaction for both podded and embedded propulsion systems. Developed a probabilistic ignition prediction tool for advanced augmentor design. Developed models to validate function and durability of high temperature electronics for engine control. ***FY 2015 Plans:*** Initiate adaptive engine conceptual designs to reduce specific fuel consumption reduction by up to 35% for embedded high bypass turbofans, and for sustained supersonic strike applications. Continue to develop modeling and simulation tools, including methods to predict behavior of serpentine inlets and nozzles. Conduct bench and rig tests to validate modeling and simulation tools to predict fan/inlet interaction for both podded and embedded propulsion systems. Conduct bench and rig tests to validate probabilistic ignition prediction tool for advanced augmentor design system. Develop models to validate function and durability of high temperature electronics for engine control. ***FY 2016 Plans:*** Complete preliminary designs of an adaptive engine to reduce specific fuel consumption reduction by up to 35% for embedded high bypass turbofans, and for sustained supersonic strike applications. Continue development of modeling and simulation tools, including methods to predict behavior of serpentine inlets and nozzles. Complete rig tests to validate modeling and simulation tools to predict fan/inlet interaction for both podded and embedded propulsion systems. Complete rig tests to validate probabilistic ignition prediction tool for advanced augmentor design system. Validate models for function and durability of high temperature electronics for engine control.	7.997	23.738	26.283
Title: Missile and Remotely Piloted Aircraft Engine Technologies ***Description:*** Develop limited life engine components for missile and remotely piloted aircraft (RPA) applications, including long-range supersonic and hypersonic vehicles. ***FY 2014 Accomplishments:***	3.814	4.541	5.054

Exhibit R-2A, RDT&E Project Justification: PB 2016 Air Force		Date: February 2015
Appropriation/Budget Activity 3600 / 2	**R-1 Program Element (Number/Name)** PE 0602203F / *Aerospace Propulsion*	**Project (Number/Name)** 623066 / *Turbine Engine Technology*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2014	FY 2015	FY 2016
Developed and applied advanced modeling and simulation tools for variable cycle component design, advanced cooling concepts, compact augmentors, and composite structures. Demonstrated advanced designs in rig testing. Developed and validated a test protocol for small engine augmentor designs. ***FY 2015 Plans:*** Continue to develop and apply advanced modeling and simulation tools for variable cycle component design, advanced cooling concepts, compact augmentors, and composite structures. Continue to demonstrate advanced designs in rig testing. Utilize validation data to develop improved test protocol for small engine augmentor designs. ***FY 2016 Plans:*** Complete development of advanced modeling and simulation tools for variable cycle component design, advanced cooling concepts, compact augmentors, and composite structures. Continue to demonstrate advanced component designs in rig testing. Utilize validation data to develop improved test protocol for small engine augmentor designs.			
Title: Turboshaft/Turboprop and Small Turbofan Engine Technologies ***Description:*** Develop components for turboshaft/turboprop and small turbofan engines for trainers, rotorcraft, special operations aircraft, and theater transports. ***FY 2014 Accomplishments:*** Developed and applied advanced modeling and simulation tools for advanced cooling concepts, high efficiency gearboxes, and high performance airfoils. Developed advanced vibration and temperature sensors for use in demonstration of engine durability requirements. ***FY 2015 Plans:*** Continue to refine and develop and apply advanced modeling and simulation tools for advanced cooling concepts, high efficiency gearboxes, and high performance airfoils. Continue to develop advanced vibration and temperature sensors for use in demonstration of engine durability requirements. ***FY 2016 Plans:*** Continue to refine and apply advanced modeling and simulation tools for advanced cooling concepts, high efficiency gearboxes, and high performance airfoils. Demonstrate advanced vibration and temperature sensors for use in engine durability testing.	1.590	1.061	1.318
Title: Adaptive Turbine Engine Technologies ***Description:*** Develop high performance, durable components which enable adaptive turbine engine technologies. ***FY 2014 Accomplishments:***	28.049	-	-

Exhibit R-2A, RDT&E Project Justification: PB 2016 Air Force		Date: February 2015
Appropriation/Budget Activity 3600 / 2	**R-1 Program Element (Number/Name)** PE 0602203F / *Aerospace Propulsion*	**Project (Number/Name)** 623066 / *Turbine Engine Technology*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2014	FY 2015	FY 2016
Completed detailed design of at least two unique adaptive fan concepts and initiated fabrication of components for ground engine testing. Conducted ground rig tests to validate preliminary design technologies and reduce risk for several parts of adaptive engines. Transitioned effort from development to demonstration of parts of adaptive engines. This effort has been completed. ***FY 2015 Plans:*** N/A ***FY 2016 Plans:*** N/A			
Accomplishments/Planned Programs Subtotals	75.742	57.245	63.712

C. Other Program Funding Summary ($ in Millions)

N/A

Remarks

D. Acquisition Strategy

N/A

E. Performance Metrics

Please refer to the Performance Base Budget Overview Book for information on how Air Force resources are applied and how those resources are contributing to Air Force performance goals and most importantly, how they contribute to our mission.

Exhibit R-2A, RDT&E Project Justification: PB 2016 Air Force			Date: February 2015
Appropriation/Budget Activity 3600 / 2	R-1 Program Element (Number/Name) PE 0602203F / *Aerospace Propulsion*	Project (Number/Name) 623145 / *Aerospace Power Technology*	

COST ($ in Millions)	Prior Years	FY 2014	FY 2015	FY 2016 Base	FY 2016 OCO	FY 2016 Total	FY 2017	FY 2018	FY 2019	FY 2020	Cost To Complete	Total Cost
623145: *Aerospace Power Technology*	-	26.003	29.393	28.213	-	28.213	29.752	30.120	30.730	31.359	Continuing	Continuing

A. Mission Description and Budget Item Justification

This project develops electrical and thermal management technologies for military aerospace applications. Power component technologies are developed to increase reliability, maintainability, commonality, affordability, and supportability of aircraft and flight line equipment. Research is conducted in energy storage and hybrid power system technologies to enable special purpose applications. Electrical power and thermal management technologies enable future military megawatt level power and thermal management needs. This project supports development of electrical power and thermal management component and systems suitable for applications to legacy and future aircraft platforms including strike and mobility concepts. Lightweight power systems suitable for other aerospace applications are also developed.

B. Accomplishments/Planned Programs ($ in Millions)	FY 2014	FY 2015	FY 2016
Title: High Power System Technologies	26.003	29.393	28.213
Description: Develop integrated system architecture and component technologies to provide for the large amounts of electrical power needed, and concurrent thermal mitigation required, by current and future manned and unmanned systems. ***FY 2014 Accomplishments:*** Initiated testing of adaptive power and thermal management subsystems hardware for next generation air platforms in conjunction with continued platform level tip-to-tail modeling and simulation energy optimization. Initiated architecture study, to include propulsion integration, for future air dominance platforms. ***FY 2015 Plans:*** Continue development of system and component electrical power, electro-mechanical, and thermal technologies for high-power applications. Continue development of hybrid approaches to power generation, storage, and application as well as thermal management. Continue testing of subsystems hardware in conjunction with continued platform level tip-to-tail modeling and simulation energy optimization. Initiate integrated ground demonstration of adaptive power and thermal management system for next generation air platforms. Initiate development of advanced, safe energy storage, power distribution, and management systems to include Silicon Carbide applications and batteries. ***FY 2016 Plans:*** Continue development of system and component electrical power, electro-mechanical, and thermal technologies for high-power applications. Continue development of hybrid approaches to power generation, storage, and application as well as thermal management. Complete integrated ground demonstration of adaptive power and thermal management system for next generation air platforms. Complete power, thermal and propulsion architecture study for future air platforms, initiate component development.			
Accomplishments/Planned Programs Subtotals	26.003	29.393	28.213

Exhibit R-2A, RDT&E Project Justification: PB 2016 Air Force		Date: February 2015
Appropriation/Budget Activity 3600 / 2	**R-1 Program Element (Number/Name)** PE 0602203F / *Aerospace Propulsion*	**Project (Number/Name)** 623145 / *Aerospace Power Technology*

C. Other Program Funding Summary ($ in Millions)

N/A

Remarks

D. Acquisition Strategy

N/A

E. Performance Metrics

Please refer to the Performance Base Budget Overview Book for information on how Air Force resources are applied and how those resources are contributing to Air Force performance goals and most importantly, how they contribute to our mission.

Exhibit R-2A, RDT&E Project Justification: PB 2016 Air Force			Date: February 2015
Appropriation/Budget Activity 3600 / 2	R-1 Program Element (Number/Name) PE 0602203F / *Aerospace Propulsion*	Project (Number/Name) 624847 / *Rocket Propulsion Technology*	

COST ($ in Millions)	Prior Years	FY 2014	FY 2015	FY 2016 Base	FY 2016 OCO	FY 2016 Total	FY 2017	FY 2018	FY 2019	FY 2020	Cost To Complete	Total Cost
624847: *Rocket Propulsion Technology*	-	51.494	51.287	54.232	-	54.232	53.696	57.231	57.818	59.020	Continuing	Continuing

A. Mission Description and Budget Item Justification

This project develops rocket propulsion technologies for space access, space maneuver, the sustainment of strategic systems (including solid boost/missile propulsion, post boost control, aging and surveillance efforts), and tactical missiles. Analytical and experimental areas of emphasis are propellants, propellant management, combustion, rocket material applications, technology for sustainment of strategic systems, and innovative space propulsion concepts. Technologies of interest will improve reliability, performance, survivability, affordability, and environmental compatibility of these systems. Technologies are developed to reduce the weight and cost of components using new materials and improved designs and manufacturing techniques. All efforts in this project contribute to the sustainment of the rocket propulsion industry, providing rocket propulsion technology for the entire DoD. Technologies developed under this program enable capabilities of interest to both DoD and NASA. Efforts include modeling and simulation, proof of concept tests of critical components, advanced component development, and ground-based tests. Aging and surveillance efforts could reduce lifetime prediction uncertainties for individual motors by 50%, enabling motor replacement for cause. All efforts are part of the Rocket Propulsion 21 (RP21) program and reviewed by a DoD level steering committee yearly for relevance to DoD missions and achievement of RP21 Goals.

B. Accomplishments/Planned Programs ($ in Millions)	FY 2014	FY 2015	FY 2016
Title: Fuel Technologies	5.951	6.927	7.372
Description: Develop, characterize, and test advanced hydrocarbons, energetics, solid propellants, and monopropellants to increase space launch payload capability and refine new synthesis methods.			
FY 2014 Accomplishments: Evaluated methods for removing components from fuels that adversely affect fuel coking in rocket engine environments. Evaluated scaled-up propellants in advanced combustion devices to determine materials compatibility and performance to include supporting large-scale motor tests. Continued development and characterization of next generation ionic liquid propellants for use in spacecraft and missile defense applications. Completed scale-up capability for advanced solid propellant ingredients. Evaluated and modified polymeric systems for use in rocket applications.			
FY 2015 Plans: Scale up methods for removing components from fuels that adversely affect fuel coking in rocket engine environments. Evaluate scaled-up propellants in advanced combustion devices to determine materials compatibility and performance to include supporting large-scale motor tests. Develop advanced binder systems to enable use of advance solid propellant ingredients with significant improvements over state of the art. Complete scale-up capability of to sixty liters for advanced solid propellant ingredients and begin testing these ingredients in large scale motors. Continue development and characterization of next generation ionic liquid propellants for use in spacecraft and missile defense applications.			
FY 2016 Plans:			

Exhibit R-2A, RDT&E Project Justification: PB 2016 Air Force		Date: February 2015
Appropriation/Budget Activity 3600 / 2	**R-1 Program Element (Number/Name)** PE 0602203F / *Aerospace Propulsion*	**Project (Number/Name)** 624847 / *Rocket Propulsion Technology*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2014	FY 2015	FY 2016
Complete scale up methods for removing components from fuels that adversely affect fuel coking in rocket engine environments. Evaluate scaled-up propellants in advanced combustion devices to determine materials compatibility and performance to include supporting large-scale motor tests. Develop advanced binder systems to enable use of advance solid propellant ingredients with significant improvements over state of the art. Continue using 60 liter reactor for advanced solid propellant ingredients and continue testing these ingredients in large scale motors to determine propellant feasibility and payoffs. Continue development and characterization of next generation ionic liquid propellants for use in spacecraft and missile defense applications.			
Title: Liquid Engine Combustion Technologies	6.043	5.780	5.958
Description: Develop advanced liquid engine combustion technology for improved performance, while preserving chamber lifetime and reliability needs for engine uses in heavy lift space vehicles.			
FY 2014 Accomplishments: Began evaluation of injector concepts in hot fire conditions. Continued efforts looking at multi-injector designs and control effectors. Continued transition of candidate injector technologies to performing contractor for use in Hydrocarbon Boost (HCB), a rocket engine ground demonstration. Continued hot fire tests in combustion stability rig and feed data to HCB to influence supporting design efforts. Incorporated data from HCB sub-scale preburner testing into combustion models. Developed and demonstrated in-house, moderate scale liquid rocket component testing capability; completed hot fire capability to support risk reduction in hydrocarbon boost technology. Continued to develop high performance compact liquid rocket engine technologies. Continued characterization of novel cooling channels and transferred info to HCB to influence rocket engine thrust chamber design. Continued developing understanding of hydrocarbon fuel production, what components affect fuel coking and should be removed from the fuel (or added) during the production process, and how can fuels be engineered with a purpose. Continued to evaluate and develop advanced material solutions for high temperature components in rocket engines.			
FY 2015 Plans: Continue evaluation of injector concepts in hot fire conditions. Continue efforts looking at multi-injector designs and control effectors. Continue transition of candidate injector technologies to performing contractor for use in Hydrocarbon Boost (HCB), a rocket engine ground demonstration. Continue hot fire tests in combustion stability rig and feed data to HCB to influence supporting design efforts. Continue combustion stability modeling critical to supporting Hydrocarbon Boost Demonstration and all future hydrocarbon fueled liquid rocket engines. Release beta version of analysis/design code to rocket community. Complete characterization of novel cooling channels and transfer info to HCB to influence rocket engine thrust chamber design. Continue developing understanding of hydrocarbon fuel production, what components affect fuel coking and should be removed from the fuel (or added) during the production process, how can fuels be engineered with a purpose. Design advanced high heat flux rig to test fuels using orders of magnitude less fuel and time to determine feasibility of fuel for further use/consideration. Continue to evaluate and develop advanced material solutions for high temperature components in rocket engines. Continue to develop and demonstrate in-house, moderate scale liquid rocket component testing capability; begin testing a sub-scale preburner in the facility			

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2014	FY 2015	FY 2016
to provide additional risk reduction for future engine designs. Continue to develop high performance compact liquid rocket engine technologies. ***FY 2016 Plans:*** Continue evaluation of injector concepts in hot fire conditions. Continue efforts looking at multi-injector designs and control effectors. Continue transition of candidate injector technologies to performing contractor for use in Hydrocarbon Boost (HCB), a rocket engine ground demonstration. Continue hot fire tests in combustion stability rig and feed data to HCB to influence supporting design efforts. Continue combustion stability modeling critical to supporting Hydrocarbon Boost Demonstration and all future hydrocarbon fueled liquid rocket engines. Release beta version of analysis/design code to rocket community. Complete characterization of novel cooling channels and transfer info to HCB to influence rocket engine thrust chamber design. Continue developing understanding of hydrocarbon fuel production, what components affect fuel coking and should be removed from the fuel (or added) during the production process, how can fuels be engineered with a purpose. Design advanced high heat flux rig to test fuels using orders of magnitude less fuel and time to determine feasibility of fuel for further use/consideration. Continue to evaluate and develop advanced material solutions for high temperature components in rocket engines. Continue to develop and demonstrate in-house, moderate scale liquid rocket component testing capability; begin testing a sub-scale preburner in the facility to provide additional risk reduction for future engine designs. Continue to develop high performance compact liquid rocket engine technologies.			
Title: Advanced Liquid Engine Technologies ***Description:*** Develop advanced liquid engine technologies for improved performance, while increasing life and reliability needs for engine uses in expendable and reusable launch vehicles. ***FY 2014 Accomplishments:*** Continued to develop enabling hydrocarbon boost technology for future spacelift concepts and continued risk reduction activities for the development of hydrocarbon boost technologies such as subscale turbopump assembly and thrust chamber assembly. ***FY 2015 Plans:*** Continue to develop enabling hydrocarbon boost technology for future spacelift concepts and continue risk reduction activities for the development of hydrocarbon boost technologies such as subscale turbopump assembly and thrust chamber assembly. ***FY 2016 Plans:*** Continue to develop enabling hydrocarbon boost technology for future spacelift concepts and continue risk reduction activities for the development of hydrocarbon boost technologies (subscale turbopump assembly, thrust chamber assembly). Begin exploring engine concepts for next generation, beyond 2035, launch vehicles and concepts to effect cost reductions. Also explore changing facility needs and requirements to support characterization of components and research demonstrators.	16.224	16.900	17.255
Title: On-Orbit Propulsion Technologies	12.045	12.290	12.790

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2014	FY 2015	FY 2016
Description: Develop solar electric, solar thermal, chemical, and advanced propulsion technologies for station-keeping, repositioning, and orbit transfer for satellites and satellite constellations. ***FY 2014 Accomplishments:*** Conducted scale-up of advanced monopropellants and evaluated advanced ignition schemes and chamber concepts. Continued development of next generation high power electric spacecraft propulsion. Continued advanced modeling and simulation tool developments to improve design and analysis tools for a wide range of spacecraft propulsion concepts/technologies, incorporating multi-scale/multi-physics. Conducted experiments to understand the physics behind the wide range of spacecraft propulsion concepts/technologies and accurately model the physics. Began transition of new thruster modeling framework to spacecraft industry for use in future designs. Explored and developed new generation of chemical spacecraft thruster technologies. Began initial support for future NASA flight of the Air Force Research Laboratory's AF-M315E non-toxic monopropellant (replaces toxic Hydrazine currently used in spacecraft). ***FY 2015 Plans:*** Conduct scale-up of advanced monopropellants and evaluate advanced ignition schemes and chamber concepts. Continue development of next generation high power electric spacecraft propulsion. Continue advanced modeling and simulation tool developments to improve design and analysis tools for a wide range of spacecraft propulsion concepts/technologies, incorporating concepts/technologies and accurately model the physics. Continue transition of new thruster modeling framework to spacecraft industry for use in future designs. Explore and develop new generation of chemical spacecraft thruster technologies. Continue support of future NASA flight of AFRL's AF-M315E non-toxic monopropellant. ***FY 2016 Plans:*** Conduct scale-up of advanced monopropellants and evaluate advanced ignition schemes and chamber concepts. Continue development of next generation high power electric spacecraft propulsion. Continue advanced modeling and simulation tool developments to improve design and analysis tools for a wide range of spacecraft propulsion concepts/technologies, incorporating concepts/technologies and accurately model the physics. Continue transition of new thruster modeling framework to spacecraft industry for use in future designs. Release initial version of code to industry partners. Explore and develop new generation of chemical spacecraft thruster technologies. Continue support of NASA flight of AFRL's AF-M315E non-toxic monopropellant (replaces toxic Hydrazine currently used in spacecraft).			
Title: Space Access and Strike Applications ***Description:*** Develop missile propulsion and boost technologies for space access and strike applications. ***FY 2014 Accomplishments:*** Continued to develop advanced tactical propulsion. Continued development and evaluation of next generation of updated, physics- based modeling, simulation, and analysis tools for missile propulsion components and applications. Continued to develop	6.607	5.380	6.707

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2014	FY 2015	FY 2016
advanced component technologies for missile propulsion applications for strategic and strike systems helping to ensure their long-term sustainment. Completed propellant combustion and hazards characterization efforts. ***FY 2015 Plans:*** Continue to develop advanced tactical propulsion. Continue development and evaluation of next generation of updated, physics-based modeling, simulation, and analysis tools for missile propulsion components and applications. Continue to develop advanced component technologies for missile propulsion applications for strategic and strike systems helping to ensure their long-term sustainment. Continue propellant development efforts. ***FY 2016 Plans:*** Continue to develop advanced tactical propulsion. Continue development and evaluation of next generation of updated, physics-based modeling, simulation, and analysis tools for missile propulsion components and applications. Continue to develop advanced component technologies for missile propulsion applications for strategic and strike systems helping to ensure their long-term sustainment. Continue propellant development efforts.			
Title: Ballistic Missile Technologies ***Description:*** Develop missile propulsion technologies and aging and surveillance technologies for ballistic missiles. ***FY 2014 Accomplishments:*** Completed sub-scale testing of existing and advanced sensors to be attached to solid rocket motors and tools that can integrate sensor data into existing aging and surveillance tool suite. Completed integration of advanced aging and surveillance technologies into full-scale demonstrations to validate and verify efforts to reduce uncertainties and accurately model motor behavior. Applied next generation of chemical and aging mechanism modeling, simulation, and analysis tools, sensor schemes and tools, and non-destructive analysis tools. Completed data management system used to track and correlate aging and surveillance data for individual missiles. Began advanced sensor development efforts to further improve data acquisition and reduce uncertainty in ballistic missile life predictions. ***FY 2015 Plans:*** Apply next generation of chemical and aging mechanism modeling, simulation, and analysis tools, sensor schemes and tools, and non- destructive analysis tools. Continue advanced sensor development efforts to further improve data acquisition and reduce uncertainty in ballistic missile life predictions. Support transition of previous tools, models, data management system to user. ***FY 2016 Plans:*** Apply next generation of chemical and aging mechanism modeling, simulation, and analysis tools, sensor schemes and tools, and non-destructive analysis tools. Continue advanced sensor development efforts to further improve data acquisition and reduce uncertainty in ballistic missile life predictions. Improve the fidelity and precision of non-destructive evaluation tools, improving capability to determine flaw size, orientation, and location. Support transition of previous tools, models, data management system	4.624	4.010	4.150

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2014	FY 2015	FY 2016
to user. Begin long-term validation of tools through long-term aging of sub-scale motors. Sub-scale motors will be periodically dissected over the next seven years to validate the sensor and analytical analysis of each motor.			
Accomplishments/Planned Programs Subtotals	51.494	51.287	54.232

C. Other Program Funding Summary ($ in Millions)

N/A

Remarks

D. Acquisition Strategy

N/A

E. Performance Metrics

Please refer to the Performance Base Budget Overview Book for information on how Air Force resources are applied and how those resources are contributing to Air Force performance goals and most importantly, how they contribute to our mission.

Exhibit R-2A, RDT&E Project Justification: PB 2016 Air Force			Date: February 2015
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COST ($ in Millions)	Prior Years	FY 2014	FY 2015	FY 2016 Base	FY 2016 OCO	FY 2016 Total	FY 2017	FY 2018	FY 2019	FY 2020	Cost To Complete	Total Cost
625330: *Aerospace Fuel Technology*	-	5.207	4.971	4.847	-	4.847	4.992	5.136	5.216	5.319	Continuing	Continuing

A. Mission Description and Budget Item Justification

This project evaluates hydrocarbon-based fuels for legacy and advanced turbine engines, scramjets, pulse detonation and combined cycle engines. This project also considers fuel related concepts that can increase turbine engine operational reliability, durability, mission flexibility, energy efficiency, and performance while reducing weight, fuel consumption, and cost of ownership. Applications include missiles, aircraft, sustained high-speed vehicles, and responsive space launch. Analytical and experimental areas of emphasis include evaluations of fuel properties and characteristics of alternative fuels developed from unconventional sources (such as coal, natural gas, biomass, and combinations thereof), unique/alternate fuels and components used in integrated thermal and energy management systems including high heat sink fuel capability, fuels logistics and associated vulnerabilities, and combustion diagnostics and engine emissions measurements.

B. Accomplishments/Planned Programs ($ in Millions)	FY 2014	FY 2015	FY 2016
Title: Alternative Fuels	2.312	0.200	0.194
Description: Conduct evaluations and perform technical assessments of alternative hydrocarbon fuels derived from coal, natural gas, and biomass for use in legacy and advanced aerospace systems. ***FY 2014 Accomplishments:*** Continued evaluation of cellulosic aviation biofuels, focusing on potential fuels capable of being used at a 100% pure state rather than blends. ***FY 2015 Plans:*** Evaluate alternative fuels being considered for addition to Jet A specification (ASTM D7566), which AF will use due to conversion to Jet A/F-24. ***FY 2016 Plans:*** Continue to evaluate advanced cellulosic alternative fuels being considered for addition to Jet A specification (ASTM D7566), which AF will use due to conversion to Jet A/F-24.			
Title: Integrated Thermal and Energy Management	1.021	1.500	1.463
Description: Develop and demonstrate advanced components and conduct performance assessments of advanced aircraft integrated thermal and energy management systems for engines and aircraft. ***FY 2014 Accomplishments:***			

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2014	FY 2015	FY 2016
Developed advanced producible endothermic fuel composition with enhanced heat sink and life to support medium-scale scramjet engine demonstrations. ***FY 2015 Plans:*** Develop and evaluate nano-catalysts/nano-additives for enhancing heat sink and reducing coking. ***FY 2016 Plans:*** Evaluate fuel-based closed-loop liquid precooler systems for tactical air platforms. Optimize the composition of next generation endothermic fuel for use with catalysts for maximum heat sink and reduced coking.			
Title: Fuel Logistics ***Description:*** Study and evaluate low-cost approaches to reduce fuel logistics footprint to reduce cost. Study fuel logistics vulnerabilities and develop detection and mitigation technologies. ***FY 2014 Accomplishments:*** Developed composition-to-performance link and models for Jet A fuels for physical properties. ***FY 2015 Plans:*** Evaluate anti-microbial peptides and biological active control for mitigating biological growth an aviation fuels. ***FY 2016 Plans:*** Evaluate AF capability to reduce/eliminate additives from F-24 (commercial Jet A + additives).	0.937	1.500	1.463
Title: Combustion Emissions and Performance ***Description:*** Develop and test advanced emissions diagnostic techniques for airbreathing propulsion systems. Conduct evaluations of the combustion and emissions characteristics of aviation fuels. ***FY 2014 Accomplishments:*** Evaluated combustor operability of narrow-boiling and high/low cetane alternative fuels as well as fully-synthetic fuels. ***FY 2015 Plans:*** Evaluate advanced in-situ diagnostics to assess in-combustor engine emissions and combustion characteristics. ***FY 2016 Plans:*** Initiate combustor/hot section materials durability study as a function of fuel composition.	0.937	1.771	1.727
Accomplishments/Planned Programs Subtotals	5.207	4.971	4.847

C. Other Program Funding Summary ($ in Millions)

N/A

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C. Other Program Funding Summary ($ in Millions)

Remarks

D. Acquisition Strategy

N/A

E. Performance Metrics

Please refer to the Performance Base Budget Overview Book for information on how Air Force resources are applied and how those resources are contributing to Air Force performance goals and most importantly, how they contribute to our mission.