Exhibit R-2, RDT&E Budget Item Justification: PB 2020 Air Force											Date: February 2019	
Appropriation/Budget Activity 3600: *Research, Development, Test & Evaluation, Air Force* / BA 2: *Applied Research*					R-1 Program Element (Number/Name) PE 1206601F / *Space Technology*							
COST ($ in Millions)	**Prior Years**	**FY 2018**	**FY 2019**	**FY 2020 Base**	**FY 2020 OCO**	**FY 2020 Total**	**FY 2021**	**FY 2022**	**FY 2023**	**FY 2024**	**Cost To Complete**	**Total Cost**
Total Program Element	-	0.000	138.598	124.667	0.000	124.667	121.862	130.710	136.646	139.504	Continuing	Continuing
621010: *Space Survivability & Surveillance*	-	0.000	40.187	43.123	0.000	43.123	42.698	44.780	46.021	46.668	Continuing	Continuing
624846: *Spacecraft Payload Technologies*	-	0.000	19.981	19.047	0.000	19.047	19.229	17.944	18.488	18.731	Continuing	Continuing
625018: *Spacecraft Protection Technology*	-	0.000	18.591	18.753	0.000	18.753	18.909	19.261	19.901	20.187	Continuing	Continuing
628809: *Spacecraft Vehicle Technologies*	-	0.000	59.839	43.744	0.000	43.744	41.026	48.725	52.236	53.918	Continuing	Continuing

A. Mission Description and Budget Item Justification

This program focuses on four major areas. First, the space survivability and surveillance area develops technologies to understand space weather and the geophysics environment for mitigation and exploitation of these effects to Air Force systems. Second, the spacecraft payload technologies area improves satellite payload operations by developing advanced component and subsystem capabilities. Third, the spacecraft protection area develops technologies for protecting United States space assets in potential hostile settings. The last major area, spacecraft vehicles, focuses on spacecraft platform and control technologies, and their interactions. Efforts in this program have been coordinated through the Department of Defense Science and Technology Executive Committee process to harmonize efforts and eliminate duplication.

In FY 2019, the entirety of PE 0602601F, Space Technology, transfers to PE 1206601F, Space Technology, to provide increased transparency to the Office of the Secretary of Defense and Congress regarding Space Science and Technology Major Force Program 12 Space investment. This is an administrative only adjustment and not a new start.

This program element may include necessary civilian pay expenses required to manage, execute, and deliver science & technology capabilities. The use of program funds in this PE would be in addition to the civilian pay expenses budgeted in program elements 0601102F, 0602102F, 0602201F, 0602202F, 0602203F, 0602204F, 0602298F, 0602602F, 0602605F, and 0602788F.

As directed in the FY 2018 NDAA, Sec 825, amendment to PL 114-92 FY 2016 NDAA, Sec 828 Penalty for Cost Overruns, the FY 2018 Air Force penalty total is $14.373M. The calculated percentage reduction to each research, development, test and evaluation and procurement account will be allocated proportionally from all programs, projects, or activities under such account.

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 2020 Air Force	Date: February 2019
Appropriation/Budget Activity 3600: *Research, Development, Test & Evaluation, Air Force* / BA 2: *Applied Research*	**R-1 Program Element (Number/Name)** PE 1206601F / *Space Technology*

B. Program Change Summary ($ in Millions)	FY 2018	FY 2019	FY 2020 Base	FY 2020 OCO	FY 2020 Total
Previous President's Budget	0.000	117.645	135.795	0.000	135.795
Current President's Budget	0.000	138.598	124.667	0.000	124.667
Total Adjustments	0.000	20.953	-11.128	0.000	-11.128
• Congressional General Reductions	0.000	-0.047			
• Congressional Directed Reductions	0.000	0.000			
• Congressional Rescissions	0.000	0.000			
• Congressional Adds	0.000	21.000			
• Congressional Directed Transfers	0.000	0.000			
• Reprogrammings	0.000	0.000			
• SBIR/STTR Transfer	0.000	0.000			
• Other Adjustments	0.000	0.000	-11.128	0.000	-11.128

Congressional Add Details ($ in Millions, and Includes General Reductions)	FY 2018	FY 2019
Project: 624846: *Spacecraft Payload Technologies*		
Congressional Add: *Program increase - advanced materials and process for magnetic graphene memory systems*	0.000	4.000
Congressional Add Subtotals for Project: 624846	0.000	4.000
Project: 628809: *Spacecraft Vehicle Technologies*		
Congressional Add: *Program increase - advanced spacecraft technologies*	0.000	5.000
Congressional Add: *Program increase - MADDIE - modular arrays for energy*	0.000	12.000
Congressional Add Subtotals for Project: 628809	0.000	17.000
Congressional Add Totals for all Projects	0.000	21.000

Change Summary Explanation

Decrease in FY 2020 due to realignment of Space Science and Technology (S&T) funding from PE 1206601F, Space Technology, to PE 0603401F, Advanced Spacecraft Technology, and realignment and consolidation of Air Force Applied Research S&T funding for Future Air Force capabilities Applied Research efforts.

Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force			Date: February 2019
Appropriation/Budget Activity 3600 / 2	R-1 Program Element (Number/Name) PE 1206601F / *Space Technology*	Project (Number/Name) 621010 / *Space Survivability & Surveillance*	

COST ($ in Millions)	Prior Years	FY 2018	FY 2019	FY 2020 Base	FY 2020 OCO	FY 2020 Total	FY 2021	FY 2022	FY 2023	FY 2024	Cost To Complete	Total Cost
621010: *Space Survivability & Surveillance*	-	0.000	40.187	43.123	0.000	43.123	42.698	44.780	46.021	46.668	Continuing	Continuing

A. Mission Description and Budget Item Justification

This project develops technologies to understand and control the space environment for warfighter's future capabilities. The focus is on characterizing and forecasting the battlespace environment for more realistic space system design, modeling, and simulation, as well as the battlespace environment's effect on space systems' performance. This includes technologies to specify and forecast the space environment for planning operations, ensure uninterrupted system performance, optimize space-based surveillance operations, and provide capability to mitigate or exploit the space environment for both offensive and defensive operations. Finally, this project includes the seismic research program that supports national requirements for monitoring nuclear explosions.

Prior to FY 2019, the entirety of Project 621010, Space Survivability and Surveillance was reported under PE 0602601F, Space Technology, Project 621010, Space Survivability and Surveillance. For FY 2019 and beyond, this project is reported under PE 1206601F, Space Technology, to provide increased transparency to the Office of the Secretary of Defense and Congress regarding Space Science and Technology Major Force Program 12 Space investment. This is an administrative only change and not a new start.

B. Accomplishments/Planned Programs ($ in Millions)	FY 2018	FY 2019	FY 2020
Title: Space Environment Research	0.000	14.648	20.872
Description: Develop techniques, forecasting tools, sensors, and technologies for specifying, monitoring, predicting, and controlling space environmental conditions hazardous to Department of Defense operational space and radar systems. In FY 2018, this work was performed under Space Environment Research effort in PE 0602601F, Space Technology, Project 621010, Space Survivability & Surveillance. ***FY 2019 Plans:*** Exploit data from radiation aged electrical and optical devices to enhance predictive material property model and inform development of improved spacecraft materials. Select next-generation solar particle event model for development towards operational demonstration. Select next-generation electron specification model for development towards operational demonstration. Evaluate space environment sensor and anomaly attribution tool demonstration to identify key areas for future model improvements. Assess the performance of oblique ionosonde auto scaling technologies as applied to real-time characterization of over-the-horizon-radar performance. Assess and validate advanced regional and global assimilative ionospheric models for integration into next-generation operational support. Continue to assess impacts of the arctic ionosphere on defense radar system availability. Validate integrated version of space environment impact on space-ground radio frequency links attribution tool meeting space operations requirements for scintillation and solar impacts on satellite communications, command, and control systems. Use data from the new weather satellite constellation to evaluate and refine Global Positioning			

Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force		Date: February 2019
Appropriation/Budget Activity 3600 / 2	**R-1 Program Element (Number/Name)** PE 1206601F / *Space Technology*	**Project (Number/Name)** 621010 / *Space Survivability & Surveillance*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2018	FY 2019	FY 2020
System radio frequency exploitation algorithms for global scintillation specification. Continue improvements of state-of-the-art solar magnetic flux transport model for more reliable forecast of solar radio and extreme ultraviolet flux levels, key parameters for Air Force space weather models and forecasts. Validate the advanced assimilative ionosphere-thermosphere model using these parameters. Continue work on hybrid supersonic solver code development and validation. ***FY 2020 Plans:*** Continue exploitation and data collection of radiation aged materials for electrical and optical property changes to enhance predictive models. Identify and initiate generation-beyond-next trapped and untrapped particle specification model development efforts. Continue space environment sensor and anomaly attribution tool demonstrations to identify key model development requirements and transition roadblocks. Research and develop technologies to exploit and mitigate space environment effects to the Department of Defense's advantage. Develop and demonstrate new ground-based and space-based sensors for monitoring and specifying the state of the space environment for military applications. Continue to develop and enhance space environment modeling capabilities to better enable accurate specification and forecasting of the state of the space environment, and the resulting impacts to Department of Defense and national systems. Advance research into the physics and dynamics of the sun to better specify and forecast solar events and better understand how those events impact the near-earth space environment. Explore fundamental radio frequency and chemical interactions in the near-earth space environment to inform potential utility for military applications. Continue work on hybrid supersonic solver code development and validation, expanding the solver to include accurate Global Positioning System performance. ***FY 2019 to FY 2020 Increase/Decrease Statement:*** FY 2020 increased compared to FY 2019 by $6.224 million. Funding increased due to additional development of technology in advanced space environment sensors.			
Title: Surveillance Technologies	0.000	10.880	6.049
Description: Develop advanced target detection techniques, spectral signature libraries, and decision aids for space-based sensors and surveillance systems. In FY 2018, this work was performed under Surveillance Technologies effort in PE 0602601F, Space Technology, Project 621010, Space Survivability & Surveillance. ***FY 2019 Plans:*** Initiate technology development for missile warning systems, including target signatures, background phenomenology, satellite constellation architecture analyses, data analytics, and satellite demonstration concepts. Continue study of advanced surveillance and detection technologies for tracking emerging and evolving targets, including ballistic and non-ballistic targets, that pose new challenges for missile warning systems. Complete testing and transition innovative computational methods to Missile Warning System Program Office to significantly decrease satellite down-link bandwidth while maintaining high fidelity of missile warning			

Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force		Date: February 2019
Appropriation/Budget Activity 3600 / 2	**R-1 Program Element (Number/Name)** PE 1206601F / *Space Technology*	**Project (Number/Name)** 621010 / *Space Survivability & Surveillance*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2018	FY 2019	FY 2020
data. Continue demonstration satellite's hypertemporal imaging mission to verify innovative advanced sensor and analytic methods for this early missile warning concept, including the collection and analysis of missile and missile like data. Provide assessment of satellite's capabilities for detecting and tracking low signature targets with complex trajectories. ***FY 2020 Plans:*** Initiate development of capability metrics for new satellite constellation architectures, advanced data analytics, and satellite demonstration concepts. Continue study of advanced surveillance and detection technologies for tracking emerging and evolving targets, including ballistic and non-ballistic targets that pose new challenges for missile warning systems. Document findings of innovative computational methods for Missile Warning System Program Office to significantly decrease satellite down-link bandwidth while maintaining high fidelity of missile warning data. Document findings of analysis tasks associated with on-orbit experiments that demonstrated advanced sensor and analytic methods of innovative hypertemporal imaging early missile warning concept, including the collection and analysis of missile and missile like data. Continue investigation of on-board processing capabilities and limitations for large datasets. Continue investigation of advanced surveillance and detection technologies for an expanded range of mission applications. ***FY 2019 to FY 2020 Increase/Decrease Statement:*** FY 2020 decreased compared to FY 2019 by $4.831 million. Funding decreased due to the transition of hypertemporal imaging sensors, computational capability, and employment techniques.			
Title: Radiation Remediation Research ***Description:*** Conduct Radiation Belt Remediation research through development and validation of analytical performance models for remediation of Earth radiation belts following high altitude nuclear detonation. In FY 2018, this work was performed under Radiation Remediation Research effort in PE 0602601F, Space Technology, Project 621010, Space Survivability & Surveillance. ***FY 2019 Plans:*** Continue space experiment operations, reduction and science data exploitation to finalize the validation of the end-to-end model for space-based remediation systems. Previously planned FY 2019 space experiment work moved to FY2020 due to change in space experiment launch date. ***FY 2020 Plans:*** Complete space experiment operations, and reduction and exploitation of data sets to finalize end-to-end model validation. Conduct assessment of feasibility and system requirements for space-based and combined ground and space-based remediation systems. ***FY 2019 to FY 2020 Increase/Decrease Statement:***	0.000	0.100	1.799

Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force		Date: February 2019
Appropriation/Budget Activity 3600 / 2	**R-1 Program Element (Number/Name)** PE 1206601F / *Space Technology*	**Project (Number/Name)** 621010 / *Space Survivability & Surveillance*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2018	FY 2019	FY 2020
FY 2020 increased compared to FY 2019 by $1.669 million. Funding increased due to adjustment of space experiment launch date			
Title: Seismic Technologies ***Description:*** Develop seismic technologies to support national requirements for monitoring nuclear explosions with special focus on regional distances less than 2,000 kilometers from the sensors. In FY 2018, this work was performed under Seismic Technologies effort in PE 0602601F, Space Technology, Project 621010, Space Survivability & Surveillance. ***FY 2019 Plans:*** Test new algorithms on high performance computing capabilities to improve automation of the detection, location, and discrimination of seismic events. Assess earth models for use in high-performance computing modeling and simulation codes for operational expert analysis of difficult-to-discriminate earthquakes and explosions. Test specific algorithms for application of big data heuristics to more quickly characterize seismic events. Explore new statistical approaches to the behavior of discriminants for local (less than 200 kilometers) and regional (less than 2,000 kilometers) seismic events. ***FY 2020 Plans:*** Test new algorithms on high performance computing capabilities with special focus on improving earth structure models and the resulting automation of the discrimination of seismic events. Exercise earth models in use in high-performance computing modeling and simulation codes for operational expert analysis of difficult-to-discriminate earthquakes and explosions. Continue to test specific algorithms for application of big data heuristics to more quickly characterize seismic events. Further develop new statistical approaches to the behavior of discriminants for local (less than 200 kilometers) and regional (less than 2,000 kilometers) seismic events. ***FY 2019 to FY 2020 Increase/Decrease Statement:*** FY 2020 decreased compared to FY 2019 by $0.134 million. Justification for the decrease is described in the plans above.	0.000	5.972	5.838
Title: Alternative Navigation Technologies ***Description:*** Develop new technologies based on cold atom physics that provide autonomous jam-proof precision inertial navigation to augment Global Positioning System in case of Global Positioning System-denial. Develop atomic clocks based on new technologies to replace legacy Global Positioning System atomic clocks. In FY 2018, this work was performed under Alternative Navigation Technologies effort in PE 0602601F, Space Technology, Project 621010, Space Survivability & Surveillance. ***FY 2019 Plans:***	0.000	8.587	8.565

Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force		Date: February 2019
Appropriation/Budget Activity 3600 / 2	**R-1 Program Element (Number/Name)** PE 1206601F / *Space Technology*	**Project (Number/Name)** 621010 / *Space Survivability & Surveillance*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2018	FY 2019	FY 2020
Complete testing of advanced compact atomic clocks with improved accuracy and stability to replace legacy atomic clocks. Complete packaging of system for flight on experimental satellite system. Continue transition of advanced compact atomic clocks to industry. Begin testing of free-space, cold atom 3-axis gyroscope/accelerometer that will enable Global Positioning System free precision navigation. Start packaging of system for test on aircraft flight experiment or other suitable platform. ***FY 2020 Plans:*** Complete rad-hard component development for advanced compact atomic clocks with improved accuracy and stability to replace legacy atomic clocks. Deliver system for integration onto experimental satellite system. Continue transition of advanced atomic clocks to industry with potential on ramp onto future satellites. Continue testing of cold atom 3-axis accelerometers for improved Internal Navigation Systems in Global Position System denied environments. ***FY 2019 to FY 2020 Increase/Decrease Statement:*** FY 2020 decreased compared to FY 2019 by $ 0.022 million. Justification for the decrease is described in the plans above.			
Accomplishments/Planned Programs Subtotals	0.000	40.187	43.123

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 2020 Air Force			Date: February 2019
Appropriation/Budget Activity 3600 / 2	R-1 Program Element (Number/Name) PE 1206601F / *Space Technology*	Project (Number/Name) 624846 / *Spacecraft Payload Technologies*	

COST ($ in Millions)	Prior Years	FY 2018	FY 2019	FY 2020 Base	FY 2020 OCO	FY 2020 Total	FY 2021	FY 2022	FY 2023	FY 2024	Cost To Complete	Total Cost
624846: *Spacecraft Payload Technologies*	-	0.000	19.981	19.047	0.000	19.047	19.229	17.944	18.488	18.731	Continuing	Continuing

A. Mission Description and Budget Item Justification

This project develops advanced technologies that enhance spacecraft payload operations by improving component and subsystem capabilities. The project focuses on development of advanced, space-qualified, survivable electronics, and electronics packaging technologies; development of advanced space data generation and exploitation technologies, including infrared sensors; and development of high-fidelity space simulation models that support space-based surveillance and space asset protection research and development for the warfighter.

Prior to FY 2019, the entirety of Project 624846, Spacecraft Payload Technologies, was reported under PE 0602601F, Space Technology, Project 624846, Spacecraft Payload Technologies. For FY 2019 and beyond, this project is reported under PE 1206601F, Space Technology, to provide increased transparency to the Office of the Secretary of Defense and Congress regarding Space Science and Technology Major Force Program 12 Space investment. This is an administrative only change and not a new start.

B. Accomplishments/Planned Programs ($ in Millions)	FY 2018	FY 2019	FY 2020
Title: Space-Based Detector Technologies	0.000	3.230	3.931
Description: Develop advanced infrared device technologies that enable hardened space detector arrays with improved detection to perform acquisition, tracking, and discrimination of space objects and missile warning. In FY 2018, this work was performed under Space-Based Detector Technologies effort in PE 0602601F, Space Technology, Project 624846, Spacecraft Payload Technologies. ***FY 2019 Plans:*** Delivery of an 8000 x 8000, 10 micrometer pitch focal plane arrays that will be hardened to the natural space environment as well as focused photons. Upon delivery of said hardware it will be characterized in representative environment to verify functionality and if any shortfalls arise they will be addressed with iterative development. This will enable whole earth starring for the Launch Detection and Missile Warning mission. ***FY 2020 Plans:*** Begin design, development, and assessment of low-cost, high-volume infrared detectors and focal plane arrays for proliferated space architecture layers. Begin development of focal plane array optical data outputs for higher speed and data throughput and begin radiation tolerance characterization of photonic devices. Begin development of alternative infrared focal plane array materials and device architectures. Continue development of resilient scanning and staring digital focal plane arrays. Complete			

Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force		Date: February 2019
Appropriation/Budget Activity 3600 / 2	**R-1 Program Element (Number/Name)** PE 1206601F / *Space Technology*	**Project (Number/Name)** 624846 / *Spacecraft Payload Technologies*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2018	FY 2019	FY 2020
development of 8192 x 8192 pixels, 10 micron pixel pitch focal plane arrays hardened to the natural space environment and focused photons to enable whole-earth staring for Launch Detection and Missile Warning missions. ***FY 2019 to FY 2020 Increase/Decrease Statement:*** FY 2020 increased compared to FY 2019 by $0.701 million. Justification for the increase is described in the plans above.			
Title: Space Electronics Research ***Description:*** Develop technologies for space-based payload components such as radiation-hardened electronic devices, microelectro-mechanical system devices, and advanced electronics packaging. In FY 2018, this work was performed under Space Electronics Research effort in PE 0602601F, Space Technology, Project 624846, Spacecraft Payload Technologies. ***FY 2019 Plans:*** Continue leadership role in Deputy Assistant Secretary of Defense Systems Engineering risk reduction strategy by development of trusted manufacturing techniques that reduce risk to National Security Strategy systems. Continue to benchmark advanced algorithms on state-of-the-art electronics and transition results to acquisition community to enable data-informed architecture design decisions. Expanding capability to include assessments of classified requirements. Continue planning qualification efforts for next generation space processor. Continue research and development on ultra-low power and neuromorphic processing architectures to enable game-changing capabilities in future National Security Space systems. Continue development of alternative memory approaches for high density memory for use in space-based systems. Continue advanced transistor development, and transitioning techniques to mainstream manufacturing. ***FY 2020 Plans:*** Continue leadership role in Deputy Assistant Secretary of Defense Systems Engineering trusted and assured microelectronics strategy efforts by development of trusted manufacturing techniques that reduce risk to National Security Space systems. Improving benchmarking capabilities on state-of-the-art electronics using latest spacecraft algorithms and transitioning results to acquisition community to enable data-informed payload architecture design decisions. Initiating complete space qualification planning for next generation space processor and begin implementing plan. Continue development of alternative memory approaches for high density memory needed for next-generation space systems. Continue research and development of ultra-low power and neuromorphic/cortical processing architectures to enable game-changing capabilities in future National Security Space systems. Continue advanced transistor research and development, and transitioning techniques to mainstream manufacturing. ***FY 2019 to FY 2020 Increase/Decrease Statement:***	0.000	2.764	4.429

Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force		Date: February 2019
Appropriation/Budget Activity 3600 / 2	**R-1 Program Element (Number/Name)** PE 1206601F / *Space Technology*	**Project (Number/Name)** 624846 / *Spacecraft Payload Technologies*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2018	FY 2019	FY 2020
FY 2020 increased compared to FY 2019 by $ 1.665 million. Funding increase due to additional emphasis on radiation hardened space electronics to enable resilient operations in contested space.			
Title: Modeling and Simulation Tools for Space Applications ***Description:*** Develop modeling and simulation tools for space-based ground surveillance systems, rendezvous and proximity operations, imaging of space systems, disaggregated satellite architecture, and space control payloads. In FY 2018, this work was performed under Modeling and Simulation Tools for Space Applications effort in PE 0602601F, Space Technology, Project 624846, Spacecraft Payload Technologies. ***FY 2019 Plans:*** Conduct mission-level military utility analyses of various space sensing, satellite navigation, space control, and communication architecture approaches. Refine guidelines and checkpoints to evaluate maturity and applicability of emerging space technologies to support various Air Force Research Laboratory technical programs, Department of Defense customers and wargame events. Continue development of models and mission simulations enabling analysis of contested space environment and space enterprise capabilities. Progress the development of baseline modeling and simulation capabilities to support quick-turn analysis and trade studies. ***FY 2020 Plans:*** Complete mission-level military utility analyses of architecture approaches across multi-domain mission areas. Continue refining guidelines and checkpoints for concept maturation evaluations in context of emerging space technologies. Continue development of models and mission simulations of the National Space Defense Center's new space and space enterprise capabilities. ***FY 2019 to FY 2020 Increase/Decrease Statement:*** FY 2020 increased compared to FY 2019 by $0.215 million. Justification for the increase is described in the plans above.	0.000	5.403	5.618
Title: Alternative Positioning, Navigation, and Timing Technology ***Description:*** Identify and develop technologies that enable new, or enhance existing, United States positioning, navigation, and timing satellite capabilities by increasing resiliency and availability of accuracy, and/or increasing the affordability of providing current capabilities. Develop technologies to meet identified Air Force Space Command/Space and Missile Systems Center positioning, navigation, and timing space payload technology needs. In FY 2018, this work was performed under Alternative Positioning, Navigation, and Timing Technology effort in PE 0602601F, Space Technology, Project 624846, Spacecraft Payload Technologies. ***FY 2019 Plans:***	0.000	4.584	5.069

Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force		Date: February 2019
Appropriation/Budget Activity 3600 / 2	**R-1 Program Element (Number/Name)** PE 1206601F / *Space Technology*	**Project (Number/Name)** 624846 / *Spacecraft Payload Technologies*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2018	FY 2019	FY 2020
Begin characterization of amplifiers, multiplexers and digital waveform generators being developed under Small Business Innovation Research Phase II contracts. Continue studies to identify alternative and innovative technologies that are viable for positioning, navigation, and timing payloads and ground systems and to investigate advanced signal and system concepts. Begin integration of positioning, navigation, and timing payload components developed under various contracts into positioning, navigation, and timing payloads to explore the concept of positioning, navigation, and timing payload modularity. ***FY 2020 Plans:*** Develop advanced Precision Navigation and Timing waveforms and begin to examine the interaction of signals between the space, ground, and user equipment segments. Explore new technologies for positioning, navigation, and timing payloads that will improve performance and affordability. Continue studies that explore technologies for multi-layer space-based positioning, navigation, and timing architecture in order to improve resiliency of the space architecture. Work to develop modeling and simulation results of next generation space architecture and the impact of developing technologies. ***FY 2019 to FY 2020 Increase/Decrease Statement:*** FY 2020 increased compared to FY 2019 by $0.485 million. Justification for the increase is described in the plans above.			
Accomplishments/Planned Programs Subtotals	0.000	15.981	19.047

	FY 2018	FY 2019
Congressional Add: Program increase - advanced materials and process for magnetic graphene memory systems	0.000	4.000
FY 2018 Accomplishments: Not applicable		
FY 2019 Plans: Conduct Congressionally directed effort		
Congressional Adds Subtotals	0.000	4.000

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 2020 Air Force			Date: February 2019
Appropriation/Budget Activity 3600 / 2	R-1 Program Element (Number/Name) PE 1206601F / *Space Technology*	Project (Number/Name) 625018 / *Spacecraft Protection Technology*	

COST ($ in Millions)	Prior Years	FY 2018	FY 2019	FY 2020 Base	FY 2020 OCO	FY 2020 Total	FY 2021	FY 2022	FY 2023	FY 2024	Cost To Complete	Total Cost
625018: *Spacecraft Protection Technology*	-	0.000	18.591	18.753	0.000	18.753	18.909	19.261	19.901	20.187	Continuing	Continuing

A. Mission Description and Budget Item Justification

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

Prior to FY 2019, the entirety of Project 625018, Spacecraft Protection Technology, was reported under PE 0602601F, Space Technology, Project 625018, Spacecraft Protection Technology. For FY 2019 and beyond, this project is reported under PE 1206601F, Space Technology, to provide increased transparency to the Office of the Secretary of Defense and Congress regarding Space Science and Technology Major Force Program 12 Space investment. This is an administrative only change and not a new start.

B. Accomplishments/Planned Programs ($ in Millions)	FY 2018	FY 2019	FY 2020
Title: Threat Warning Research	0.000	18.591	18.753
Description: Develop satellite threat warning technologies and tools for space defense. Exploit on-board inherent satellite resources, satellite-as-a-sensor, and self-aware satellite technologies. Develop technologies to detect, assess, and respond to threats and anomalies. In FY 2018, this work was performed under Threat Warning Research effort in PE 0602601F, Space Technology, Project 625018, Spacecraft Protection Technology. ***FY 2019 Plans:*** Develop techniques to detect, track, identify, and characterize satellites using multi-phenomenology to address gaps in knowledge for space situational awareness. Consider the tasking, collection, processing, exploitation and dissemination needs. Assess timeliness and persistence of space situational awareness capability and develop techniques that address the growing number of objects that must be monitored. Develop techniques to mitigate the growing population of objects that need to be monitored, from newly launched objects to debris. Assess utilizing commercial and international space situational awareness sources. Continue maturation of the space resiliency testbed to enhance ability to conduct full-spectrum space control RED-vs-BLUE experimentation with ops, network, command and control, and hardware in the loop. Conduct space cyber experimentation using on-orbit science satellite. Initiate research into advanced methods for net-centric space command and control architectures, to include cloud-based paradigms and other advanced computational methods across the full scope of the ground and space-based enterprise. Continue development of advanced algorithms for sensor data fusion and satellite threat detections, assessment, response and protection. Complete space situational awareness-focused data analysis methods including physics-based sensor			

Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force		Date: February 2019
Appropriation/Budget Activity 3600 / 2	**R-1 Program Element (Number/Name)** PE 1206601F / *Space Technology*	**Project (Number/Name)** 625018 / *Spacecraft Protection Technology*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2018	FY 2019	FY 2020
model development for data filtering and space command and control architectures. Complete advancing filtering techniques accommodating nonlinear dynamics and non-normal random variable distributions. Mature concepts of new electro-optical and radio frequency sensors for space object identification and characterization. Continue incorporating customer feedback of closed loop sensor tasking concept for space surveillance, combining commercial and government sensor assets. Continue assessment and development of commercial remote sensing data and information to fill gaps in coverage for monitoring and tracking ground and space objects. Continue engagements and methods development with commercial space data providers for testing new enabling technologies on commercial satellites. ***FY 2020 Plans:*** Continue to develop techniques to detect, track, identify, and characterize satellites using multi-phenomenology to address gaps in knowledge for space situational awareness and consider the tasking, collection, processing, exploitation and dissemination needs. Assess timeliness and persistence of space situational awareness capability and develop techniques to mitigate the growing population of objects that need to be monitored, from newly launched objects to debris. Conduct cooperative development utilizing commercial and international space situational awareness sources. Initiate research and development on an integrated ground and space indications and warnings experiment. Utilize space resiliency testbed to integrate technology solutions, and evaluate effectiveness against notional threats to our space architectures. Develop cyber hardening technologies, and integrate space and cyber operations capabilities. Conduct end-to-end evaluations and hardware-in-the-loop experiments for threat warning and response capabilities for protection of high value space assets. Conduct experiments, integrating commercial space Command and Control capabilities into Department of Defense ground architectures. These capabilities include real-time mission planning, utilization of non-traditional Intel sources (i.e. social media), multi-path communications architectures, etc. Develop and demonstrate autonomous technologies using net-centric space command and control architectures for multi-domain command and control across the full scope of the ground and space-based enterprise. Continue development and demonstration of advanced algorithms for sensor data fusion and satellite threat detection, assessment, and response. Investigate, implement, and demonstrate integrated command and control systems at the tactical, operational, and strategic levels. Continue assessment and development of commercial capability in order to either augment or replace traditional methods for space related command and control. Continue engagements with commercial space data providers for testing new enabling technologies on commercial satellites. Continue to develop on-board autonomous satellite technologies and plan for next generation flight experiments. ***FY 2019 to FY 2020 Increase/Decrease Statement:*** FY 2020 increased compared to FY 2019 by $0.162 million. Justification for increase is described in the plans above.			
Accomplishments/Planned Programs Subtotals	0.000	18.591	18.753

C. Other Program Funding Summary ($ in Millions)

N/A

Remarks

Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force		Date: February 2019
Appropriation/Budget Activity 3600 / 2	**R-1 Program Element (Number/Name)** PE 1206601F / *Space Technology*	**Project (Number/Name)** 625018 / *Spacecraft Protection Technology*

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 2020 Air Force			Date: February 2019
Appropriation/Budget Activity 3600 / 2	R-1 Program Element (Number/Name) PE 1206601F / *Space Technology*	Project (Number/Name) 628809 / *Spacecraft Vehicle Technologies*	

COST ($ in Millions)	Prior Years	FY 2018	FY 2019	FY 2020 Base	FY 2020 OCO	FY 2020 Total	FY 2021	FY 2022	FY 2023	FY 2024	Cost To Complete	Total Cost
628809: *Spacecraft Vehicle Technologies*	-	0.000	59.839	43.744	0.000	43.744	41.026	48.725	52.236	53.918	Continuing	Continuing

A. Mission Description and Budget Item Justification

This project focuses on spacecraft platforms (for example: structures, power, and thermal management); satellite control (signal processing and control); and space experiments of maturing technologies for space qualification.

Prior to FY 2019, the entirety of Project 628809, Spacecraft Vehicle Technologies, was reported under PE 0602601F, Space Technology, Project 628809, Spacecraft Vehicle Technologies. For FY 2019 and beyond, this project is reported under PE 1206601F, Space Technology, to provide increased transparency to the Office of the Secretary of Defense and Congress regarding Space Science and Technology Major Force Program 12 Space investment. This is an administrative only change and not a new start.

B. Accomplishments/Planned Programs ($ in Millions)	FY 2018	FY 2019	FY 2020
Title: Space Power/Thermal Research	0.000	4.804	4.095
Description: Develop technologies for advanced space platform subsystems such as cryocoolers, compact, high efficiency solar power cells and arrays, and innovative power generation concepts. In FY 2018, this work was performed under Space Power/Thermal Research effort in PE 0602601F, Space Technology, Project 628809, Spacecraft Vehicle Technologies. ***FY 2019 Plans:*** Continue research into advanced space solar cells, solar array, and energy storage technologies. Continue research into approaches for greater than 40% solar cell efficiency. Begin evaluation of approaches for high radiation orbit optimized solar cells. Continue development of advanced array technologies to meet 70-80 kilowatt per cubic meter array performance. Initiate research incorporating photon management schemes into III-V devices for increased efficiency and end of-life. Initiate cell level resiliency research efforts. Develop panel level resilient approaches. ***FY 2020 Plans:*** Continue research into advanced space solar cells, solar array, and energy storage technologies. Focus on support for current heritage space systems, while also pivoting towards support of smaller space vehicles that will be utilized for the Space Warfighting Construct. Improve solar cells end of life performance to above 28% power conversion efficiency. Develop solar array structures tailored for small to large missions with specific power greater than 100 watts per kilogram. Develop energy storage			

Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force		Date: February 2019
Appropriation/Budget Activity 3600 / 2	**R-1 Program Element (Number/Name)** PE 1206601F / *Space Technology*	**Project (Number/Name)** 628809 / *Spacecraft Vehicle Technologies*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2018	FY 2019	FY 2020
chemistries with cell-level specific energy greater than 300 watt-hours per kilogram. Further develop array hardening approaches to provide drop-in replacement panels. ***FY 2019 to FY 2020 Increase/Decrease Statement:*** FY 2020 decreased compared to FY 2019 by $0.709 million. Justification for the decrease is described in the plans above.			
Title: Space Structures and Controls Research ***Description:*** Develop revolutionary and enabling technologies, including lighter weight, lower cost, high performance structures for space platforms; guidance, navigation, and controls hardware and software for next generation of space superiority systems. In FY 2018, this work was performed under Space Structures and Controls Research effort in PE 0602601F, Space Technology, Project 628809, Spacecraft Vehicle Technologies. ***FY 2019 Plans:*** Continue reactive maneuver strategies for spacecraft resiliency in laboratory simulation and initiate high-fidelity simulations/ breadboards. Continue research in verification and validation techniques for autonomous spacecraft flight software. Continue improved estimation algorithms for on-orbit navigation software. Initiate laboratory and high-fidelity simulations/breadboard implementation for navigation algorithms with hardware-in-the-loop. Transition development of United States space asset protection, threat identification, and mitigation technologies including deployable structures, structural sensing, and thermal technologies to advanced development and flight experimentation. Perform test bed develop and integrated proof-of-concept experiments for advanced, agile manufacturing and assembly technologies for satellite production to improve performance and affordability. Continue research efforts in high-power small satellite technologies and affordable, high-performance phased arrays and electrically steerable antennas for tactical communication and radar concepts for agile, intelligent targets. Initiate research in functionalized structures using multi-material additive manufacturing. ***FY 2020 Plans:*** Continue reactive maneuver strategies for spacecraft resiliency in hardware-in-the-loop testbeds. Initiate on-orbit experiment planning for reactive maneuver strategies. Apply research in verification and validation techniques for autonomous spacecraft flight software to high-fidelity simulations and brassboard laboratory experiments. Apply improved estimation algorithms for on-orbit navigation software to experimental data to assess performance and robustness. Complete laboratory and high-fidelity simulations/breadboard implementation for navigation algorithms and assess progress towards flight experiment demonstration. Continue development of integrated proof-of-concept experiments for advanced, agile manufacturing and assembly technologies for satellite production to improve performance and affordability. Continue research in functionalized structures using multi-material additive manufacturing. Transition development of research efforts in high-power small satellite technologies and	0.000	9.007	10.598

Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force		Date: February 2019
Appropriation/Budget Activity 3600 / 2	**R-1 Program Element (Number/Name)** PE 1206601F / *Space Technology*	**Project (Number/Name)** 628809 / *Spacecraft Vehicle Technologies*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2018	FY 2019	FY 2020
affordable, high-performance phased arrays and electrically steerable antennas for tactical communication and radar concepts for agile, intelligent targets to advanced development and flight experimentation. ***FY 2019 to FY 2020 Increase/Decrease Statement:*** FY 2020 increased compared to FY 2019 by $1.591 million. Funding increased due to additional development of responsive satellite maneuver capabilities.			
Title: Space Experiments ***Description:*** Develop flight experiments to improve the capabilities of existing operational space systems and to enable new transformational space capabilities. In FY 2018, this work was performed under Space Experiments effort in PE 0602601F, Space Technology, Project 628809, Spacecraft Vehicle Technologies. ***FY 2019 Plans:*** Continue and complete one year of experimental satellite on-orbit operations. Complete program and close-out. Conclude on-orbit testing and verification of a fourth geosynchronous orbit based missile warning payload to demonstrate hypertemporal imaging capabilities to detect missile launches under sun-lit clouds, potentially enabling all weather early missile detection. Conclude on-orbit testing and verification of an integrated, on-board sensing, assessment, and autonomy technology demonstration payload at geosynchronous orbit, demonstrating geosynchronous orbit asset resiliency to a specific set of on-orbit events enabling system mission assurance in a degraded space environment. On-orbit demonstration of the first geosynchronous orbit CubeSat providing enhanced capability to the space enterprise. On-orbit demonstration of three formation flying satellites for near autonomous formation control. Refine on-orbit experiment plan and mission objectives to align with payload development progress, and continue developing data requirements and risk management plan for space-based integrated demonstration of an advanced Global Positioning System payload for contested environments. ***FY 2020 Plans:*** Conduct on-orbit small satellite demonstration of the first ever Link-16 from space to the tactical user enabling a Common Operating Picture for the Warfighter in a contested/degraded environment in support of Multi-Domain Command and Control. On-orbit small satellite demonstration capable of measuring radiation in the inner magnetosphere giving insight into the particle radiation space environment. Conduct a flight selection process and perform trade studies to determine the next flight experiment(s). Develop and mature a reference design, technical objectives, and experiment plan in coordination with Air Force Space Command, Space and Missile Systems Center and/or other mission partners. Begin working long term items such as contracting strategy, parts, frequency allocation, and information assurance strategies. ***FY 2019 to FY 2020 Increase/Decrease Statement:***	0.000	21.705	22.915

Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force		Date: February 2019
Appropriation/Budget Activity 3600 / 2	**R-1 Program Element (Number/Name)** PE 1206601F / *Space Technology*	**Project (Number/Name)** 628809 / *Spacecraft Vehicle Technologies*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2018	FY 2019	FY 2020
FY 2020 increased compared to FY 2019 by $1.210 million. Funding increase due to accelerated demonstration of small satellite technologies.			
Title: Space Communication Technologies ***Description:*** Develop technologies for next-generation space communications terminals and equipment and methods/techniques to enable future space system operational command and control concepts. In FY 2018, this work was performed under Space Communication Technologies effort in PE 0602601F, Space Technology, Project 628809, Spacecraft Vehicle Technologies. ***FY 2019 Plans:*** Support launch of W and V frequency band flight instrument. Support execution of a W and V band propagation experiment. Conduct research and development to address future military satellite communications capability and technology needs, for example, high-gain antenna, high-power amplifiers, low-noise amplifiers, cognitive / resilient networks, reconfigurable satellite radios / transponders, and anti-jam signal processing technologies. Support development and demonstration of novel laser communications technology. ***FY 2020 Plans:*** Support W/V-band payload operations, telemetry analysis, and health and status monitoring. Continue to develop and conduct technology demonstrations to address future military satellite communications capability and technology needs, for example, high-gain antenna, high-power amplifiers, low-noise amplifiers, cognitive / resilient networks, reconfigurable satellite radios / transponders, and anti-jam signal processing technologies. Support development and demonstration of novel laser communications technologies such as multi-wave length optical routers. Develop network traffic models, multi-spacecraft network models, and spacecraft network simulation support, along with analysis/visualization tools to aid. ***FY 2019 to FY 2020 Increase/Decrease Statement:*** FY 2020 decreased compared to FY 2019 by $1.187 million. Funding decreased due to transition of the W/V-band technology development to a flight demonstration.	0.000	7.323	6.136
Accomplishments/Planned Programs Subtotals	0.000	42.839	43.744

	FY 2018	FY 2019
Congressional Add: Program increase - advanced spacecraft technologies ***FY 2018 Accomplishments:*** Not applicable ***FY 2019 Plans:*** Conduct Congressionally directed effort	0.000	5.000
Congressional Add: Program increase - MADDIE - modular arrays for energy	0.000	12.000

Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force		Date: February 2019
Appropriation/Budget Activity 3600 / 2	**R-1 Program Element (Number/Name)** PE 1206601F / *Space Technology*	**Project (Number/Name)** 628809 / *Spacecraft Vehicle Technologies*

	FY 2018	FY 2019
FY 2018 Accomplishments: Not applicable ***FY 2019 Plans:*** Conduct Congressionally directed effort		
Congressional Adds Subtotals	0.000	17.000

C. Other Program Funding Summary ($ in Millions)

N/A

Remarks

D. Acquisition Strategy

N/A

E. Performance Metrics

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