Exhibit R-2, RDT&E Budget Item Justification: FY 2018 Defense Advanced Research Projects Agency	Date: May 2017
Appropriation/Budget Activity 0400: *Research, Development, Test & Evaluation, Defense-Wide* / BA 3: *Advanced Technology Development (ATD)*	**R-1 Program Element (Number/Name)** PE 0603287E / *SPACE PROGRAMS AND TECHNOLOGY*

COST ($ in Millions)	Prior Years	FY 2016	FY 2017	FY 2018 Base	FY 2018 OCO	FY 2018 Total	FY 2019	FY 2020	FY 2021	FY 2022	Cost To Complete	Total Cost
Total Program Element	-	120.642	175.240	247.435	-	247.435	271.971	252.726	227.726	227.726	-	-
SPC-01: *SPACE PROGRAMS AND TECHNOLOGY*	-	120.642	175.240	247.435	-	247.435	271.971	252.726	227.726	227.726	-	-

A. Mission Description and Budget Item Justification

The Space Programs and Technology program element is budgeted in the Advanced Technology Development budget activity because it addresses high payoff opportunities to dramatically reduce costs associated with advanced space systems and provides revolutionary new system capabilities for satisfying current and projected military missions.

A space force structure that is robust against attack represents a stabilizing deterrent against adversary attacks on space assets. The keys to a secure space environment are situational awareness to detect and characterize potential threats, a proliferation of assets to provide robustness against attack, ready access to space, and a flexible infrastructure for maintaining the capabilities of on-orbit assets. Ready access to space requires the delivery of capabilities, replenishment of supplies into orbit, and rapid manufacturing of affordable space capabilities. Developing space access and spacecraft servicing technologies will lead to reduced ownership costs of space systems and new opportunities for introducing technologies for the exploitation of space.

Systems development is also required to increase the interactivity of space systems, space-derived information and services with terrestrial users. Studies under this project include technologies and systems that will enable satellites and microsatellites to operate more effectively by increasing maneuverability, survivability, and situational awareness; enabling concepts include novel power/propulsion/propellants, unique manufacturing or assembly processes, and precision control of multi-payload systems.

B. Program Change Summary ($ in Millions)	FY 2016	FY 2017	FY 2018 Base	FY 2018 OCO	FY 2018 Total
Previous President's Budget	126.692	175.240	237.435	-	237.435
Current President's Budget	120.642	175.240	247.435	-	247.435
Total Adjustments	-6.050	0.000	10.000	-	10.000
• Congressional General Reductions	0.000	0.000			
• Congressional Directed Reductions	0.000	0.000			
• Congressional Rescissions	0.000	0.000			
• Congressional Adds	0.000	0.000			
• Congressional Directed Transfers	0.000	0.000			
• Reprogrammings	0.000	0.000			
• SBIR/STTR Transfer	-6.050	0.000			
• TotalOtherAdjustments	-	-	10.000	-	10.000

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Change Summary Explanation

FY 2016: Decrease reflects the SBIR/STTR transfer.

FY 2017: N/A

FY 2018: Increase reflects Large In-Situ Manufactured Apertures (LIMA) and Blue Check new starts, offset by completion of Space Surveillance Telescope and Phoenix programs.

C. Accomplishments/Planned Programs ($ in Millions)	FY 2016	FY 2017	FY 2018
Title: Experimental Spaceplane One (XS-1)	18.485	40.000	60.000

Description: The XS-1 program will mature the technologies and operations for low cost, persistent and responsive space access and global reach. Past efforts have identified and demonstrated critical enabling technologies including composite or light weight structures, propellant tanks, thermal protection systems, rocket propulsion and advanced avionics/software. A critically important technology gap is integration into a flight demonstration able to deliver aircraft-like operability. The program will validate key technologies on the ground, and then fabricate an X-Plane to demonstrate: 1) 10 flights in 10 days, 2) up to Mach 10+ flight, and 3) design capable of a 10X lower cost space access for cargos from 3,000-5,000 lbs. to low earth orbit. A key goal is validating the critical technologies for a wide range of next generation high speed aircraft enabling new military capabilities including worldwide reconnaissance, global transport, small responsive space access aircraft and affordable spacelift. The anticipated transition partners are the Air Force, Navy and commercial sector.

FY 2016 Accomplishments:

- Concluded tailored Preliminary Design Reviews of technically and programmatically viable approaches to addressing the program goals.
- Developed structural designs based on detailed finite element models.
- Performed aerodynamic Computational Fluid Dynamics analysis and conducted multiple wind tunnel tests, including large-scale transonic, supersonic, and hypersonic aeroheating campaigns to develop aerodynamic models.
- Conducted component demonstration and validation ground tests for damage-tolerant cryogenic propellant tanks, novel low-cost thermal protection mechanical design and fabrication, high-precision large-scale hybrid composite/metallic structure, wing tip aero-elasticity, and additively-manufactured propulsion components.
- Validated operational timelines and recurring cost models via discrete event simulations and upper stage unit and integration cost analyses.
- Completed the system and subsystem designs, mass properties and configuration required to support the integrated vehicle design.
- Finalized multiple viable concepts of operation including architecture, maintenance, performance, trajectories and design reference missions.
- Developed initial plan to accomplish ground operations, facility modifications and flight demonstration.

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C. Accomplishments/Planned Programs ($ in Millions)	FY 2016	FY 2017	FY 2018
- Coordinated with the Federal Aviation Administration (FAA), DoD ranges and spaceports to accomplish preliminary flight test planning. ***FY 2017 Plans:*** - Complete remaining demonstration, testing, and validation tasks including subsonic and subscale vertical takeoff and landing into a ground-fixed landing cradle in lieu of onboard landing gear, and additional tip-fin aeroelasticity modeling/correlation to establish reliable design practice based on computational methods. - Initiate detailed design program for fabrication and flight testing. - Perform detailed wind tunnel studies of final or near-final aerodynamic design across multiple regimes including subsonic, supersonic, and hypersonic. - Validate computational analyses to support the finalization of the aerodynamic database used for Guidance, Navigation and Control (GN&C). - Complete cryogenic tank representative panel testing, and incorporate results in the final tank designs. - Begin propulsion system integration and preparation for ten engine firings in ten days ground test. - Initiate design for launch facilities/modifications and mature range planning including ground and flight test operations, and submittal of range documentation supporting operational requirements. - Coordinate with the FAA, DoD ranges and commercial spaceports. - Begin procurement of long lead flight and ground system hardware. ***FY 2018 Plans:*** - Mature the XS-1 concept through tailored Critical Design Review including complete configuration, aerodynamics and aeroheating, six degree of freedom trajectory calculations with flight software in the loop, mass properties and associated ground systems. - Conduct Critical Design Review to approve XS-1 vehicle design for component acquisition, fabrication, assembly, and integration. - Complete propulsion qualification and acceptance testing. - Complete ten engine firings in ten days ground test. - Complete designs for ground infrastructure and mature range, ground and flight test operations planning. - Submit commercial spaceport and/or DoD range documentation. - Begin fabrication of all major subsystems and initiate acceptance test planning. - Begin integration and test of major subassemblies, flight and ground systems.			
Title: Radar Net ***Description:*** The Radar Net program will develop lightweight, low power, wideband capability for radio frequency (RF) communications and remote sensing for a space based platform. The enabling technologies of interest are extremely lightweight	29.000	45.000	59.000

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C. Accomplishments/Planned Programs ($ in Millions)	FY 2016	FY 2017	FY 2018
and space capable deployable antenna structures. Current deployable antenna options have not been sufficiently developed to be dependable on small payload launches, leaving current capabilities trending to large and more costly satellite systems. These satellite systems are expected to have long operational lifetimes, which can leave them behind the pace of state-of-the-art technical developments. The technologies developed under Radar Net will enable small, low-cost sensor payloads on short timescales with rapid technology refresh capabilities. The anticipated transition partner is the Air Force. ***FY 2016 Accomplishments:*** - Developed a detailed system architecture assessment. - Began deployable antenna and software-defined radio (SDR) risk reduction efforts. - Commenced thermal cycling, power availability, and electrical system analysis. - Completed risk reduction deployable antenna pathfinder Preliminary Design Review (PDR). ***FY 2017 Plans:*** - Complete risk reduction deployable antenna proof-of-concept (POC) deployment demonstration. - Complete risk reduction deployable antenna pathfinder Critical Design Review (CDR). - Complete risk reduction deployable antenna prototype PDR. - Complete risk reduction SDR prototype PDR. - Conduct risk reduction deployable antenna prototype CDR. - Complete risk reduction SDR prototype CDR. - Conduct additional risk reduction deployable antenna POC laboratory testing. - Conduct risk reduction of demonstration system ground tests. - Conduct risk reduction SDR airborne tests. - Complete demonstration System Requirements Review (SRR). - Complete demonstration system Conceptual Design Review (CoDR). ***FY 2018 Plans:*** - Conduct risk reduction demonstration of multiple deployable antenna technologies. - Demonstrate SDR RF capability in relevant environments. - Perform risk reduction signal processing demonstration. - Integrate results from applications study and demonstration/risk reduction into prototype design. - Complete demonstration system PDR. - Complete demonstration system CDR.			
Title: Hallmark	10.000	27.000	29.000

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C. Accomplishments/Planned Programs ($ in Millions)	FY 2016	FY 2017	FY 2018

Description: The Hallmark program seeks to demonstrate a space Battle Management Command and Control (BMC2) capability to provide U.S. senior leadership the tools needed to effectively manage space assets in real time. The program will develop command and control decision support tools for full-spectrum space operations, management, and control from peace to potential conflict. Hallmark will demonstrate the ability to increase space threat awareness via use of multi-data fusion and timely sensor tasking. The program will also improve the ability to protect against threats by using modeling and simulation tools to develop courses of action for both natural events and adversary actions. The program will employ comprehension and visualization techniques to increase commander and operator awareness thereby transforming information to knowledge and effectively communicating and facilitating time-critical decision making. The anticipated transition partner is the Air Force.

FY 2016 Accomplishments:
- Initiated space BMC2 interactive simulation environment development.
- Conducted demonstration of integrated Government Furnished Equipment (GFE) space BMC2 tools.
- Performed demonstration of space BMC2 interactive simulation environment.
- Initiated the cognitive evaluation of operators and decision makers in a demonstration environment to maximize comprehension.
- Initiated real-time decision tools design development.

FY 2017 Plans:
- Develop sensor data fusion algorithms.
- Define course of action data scheme.
- Develop a research and development test bed to facilitate the rapid injection of new technologies into the Joint Space Operations Center (JSpOC), Joint Interagency Coalition Space Operations Center (JICSpOC), and other space operations centers.
- Complete preliminary system design.
- Develop intuitive applications and adaptive understanding capabilities for the next-generation space information fusion center.
- Define integration of space BMC2 interactive simulation environment with tools, fusion algorithms, and data schemes.
- Perform existing tool integration.
- Develop modeling and simulation infrastructure.
- Complete algorithm prototypes.
- Commence integration of existing space situational awareness, indications and warning, course of action, and decision support tools.

FY 2018 Plans:
- Integrate cognitive evaluations into tool development.
- Standardize evaluation methodology.

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C. Accomplishments/Planned Programs ($ in Millions)	FY 2016	FY 2017	FY 2018
- Demonstrate and document integrated tools, algorithms, and data schemes. - Evaluate integrated tools to show effectiveness with respect to enhanced decision timeliness and quality. - Allocate tool development for Phase II.			
Title: Phoenix ***Description:*** To date, servicing operations have never been conducted on spacecraft beyond low earth orbit (LEO). A large number of national security and commercial space systems operate at geosynchronous earth orbit (GEO) altitudes; furthermore, many end-of-life or failed spacecraft drift without control through portions of the GEO belt, creating a growing hazard to operational spacecraft. Technologies for servicing of spacecraft with the expectation that such servicing would involve a mix of highly autonomous and remotely (i.e., ground-based) tele-operated robotic systems have been previously pursued. The Phoenix program will build upon these legacy technologies, tackling the more complex GEO environment and expanding beyond pure traditional servicing functions. The program will examine utilization of a new commercial ride-along system to GEO called Payload Orbital Delivery (POD) system, supporting small satellite delivery as well as hardware delivery for upgrading, repairing, assembling, and reconfiguring satellites. In addition, the program will include a LEO flight experiment focused on satlets, modular building blocks for space systems, as a path of risk reduction for modular assembly on orbit. The anticipated transition partners are the Air Force, the Army, and the commercial spacecraft and spacecraft servicing providers. ***FY 2016 Accomplishments:*** - Completed environmental testing of early LEO satlet experiment. - Developed POD payload hardware and initiated environmental testing. ***FY 2017 Plans:*** - Deliver early LEO satlet experiment equipment to launch integrator. - Launch early LEO satlet experiment and conduct experiment operations. - Complete delta critical design review of satlets per lessons learned from LEO experiment. - Complete ground testing of POD hardware and deliver for launch. - Launch POD and conduct on-orbit testing. - Transition residual satlet hardware to U.S. Army.	23.300	5.402	-
Title: Robotic Servicing of Geosynchronous Satellites (RSGS) ***Description:*** A large number of national security and commercial space systems operate at geosynchronous earth orbit (GEO), providing persistence and enabling ground station antennas to point in a fixed direction. Technologies for servicing of GEO spacecraft would involve a mix of highly automated and remotely operated (from Earth) robotic systems. The Robotic Servicing of Geosynchronous Satellites (RSGS) program, an outgrowth of the Phoenix program budgeted within this Project, seeks to establish the capability to acquire robotic services in GEO suitable for a variety of potential servicing tasks, in full collaboration and	11.261	51.838	79.250

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C. Accomplishments/Planned Programs ($ in Millions)	FY 2016	FY 2017	FY 2018
cooperation with existing satellite owners and national security space operators, and with sufficient propellant for several years of follow-on capability. Key RSGS challenges include robotic tool/end effector requirements, efficient orbital maneuvering of a servicing vehicle, robotic arm systems, automation of certain spacecraft operations, and development of the infrastructure for coordinated control between the servicer and client spacecraft operations teams. The anticipated transition is to a commercial partner who will provide the satellite to carry the robotic payload and who will operate the robotic servicer. To support the development of a broadly accepted satellite servicing capability, DARPA is using the consortium for execution of rendezvous and servicing operations (CONFERS) approach to bring together experts from the private sector and Government to develop and publish non-binding, consensus-based standards for safe operational approaches. ***FY 2016 Accomplishments:*** - Continued development of servicer robotic payload initiated under the Phoenix program. - Conducted studies of suitable satellites to carry the robotic payload. - Established system requirements for the robotic payload in accordance with primary missions. - Established initial government membership of CONFERS and defined roles and responsibilities. ***FY 2017 Plans:*** - Select commercial partner as provider of satellite to carry robotic payload, and owner/operator of system on orbit. - Develop interface definition between robotic payload and satellite. - Begin flight software coding. - Begin development of operator workstations. - Begin procurement of long-life space hardware for robotic payload and instrumentation. - Develop comprehensive test plan for robotics and for integrated system. - Complete structural analysis of robotic arms and tool changer, prepare detailed designs, and begin fabrication. - Design, acquire and test payload electronic systems. - Select a Secretariat to stand up CONFERS and begin standards development. ***FY 2018 Plans:*** - Begin ground segment specification. - Continue development of comprehensive test plan for robotics and for integrated system. - Complete build and test of first flight robotic arms and tool changer. - Complete development of algorithms for automated on-orbit operations. - Complete final design of servicer satellite with commercial partner and provide technical assistance during fabrication. - Continue flight software coding and testing. - Continue development of operator workstations.			

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C. Accomplishments/Planned Programs ($ in Millions)	FY 2016	FY 2017	FY 2018
- Publish first draft of consensus on-orbit safety standards through a qualified standards development organization.			
Title: Large In-Situ Manufactured Apertures (LIMA) ***Description:*** The Large In-Situ Manufactured Apertures (LIMA) program seeks to demonstrate the structural fabrication of a high-performance radio frequency (RF) antenna attached to a microsatellite. Larger and more directional than any comparable antenna that could be deployed from a microsatellite platform, LIMA would deliver high-performance communication and data services to the dismounted warfighter at significantly lower cost while enabling signal intelligence (SIGINT) capability. The program will complete a low Earth orbit (LEO) small-scale demonstration in which a commercial communications microsatellite is augmented in situ (i.e., on orbit, in flight) with an antenna that is completely fabricated in space, and will prove by computational modeling and simulation how a constellation of full-scale microsatellites with In-situ fabricated apertures may be applied to close a high-performance RF link directly to a cellular hand set in a global tactical communications network. The program seeks to achieve greater than 50% savings in individual communications satellite system launch costs and a corresponding increase in launch opportunities due to ride sharing relative to the preferred state of the art solution. ***FY 2018 Plans:*** - Develop and demonstrate in-space fabrication process technologies in ground-based trials, including validation of key process elements in flight-like environments. - Design a compact dual-use military and commercial transponder payload and fabrication substrate (platen) for the commercial microsatellite to interface with the in-space-fabricated antenna. - Prove by analysis that the hosted payload is accommodated without an increase in constellation total launch cost compared to the constellation without the augmented microsatellites.	-	-	10.185
Title: Blue Check ***Description:*** The Blue Check program will develop space technologies to determine spacecraft identification and state data, completely independent of the spacecraft. Capabilities developed will support integrating spacecraft-derived information into the space domain awareness picture. Key efforts focus on the development of an identification and information device for every space object placed in orbit to provide accurate data. Resulting capabilities will aid in rapid determination of space objects, particularly in the case of multi-spacecraft deployments. Inherent to the space identification technology is the ability to provide forensic data for failed or anomalous spacecraft. Other areas to be investigated include leveraging small satellite mega-constellations and their networks to provide ID, state, and sensor data in support of this and other applications. ***FY 2018 Plans:*** - Initiate system architecture and trade studies.	-	-	10.000

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C. Accomplishments/Planned Programs ($ in Millions)	FY 2016	FY 2017	FY 2018
- Begin prototype and ground system design development.			
Title: Space Surveillance Telescope (SST) ***Description:*** The Space Surveillance Telescope (SST) program has developed and demonstrated an advanced ground-based optical system to enable detection and tracking of faint objects in space, while providing rapid, wide-area search capability. A major goal of the SST program, to develop the technology for large curved focal surface array sensors to enable an innovative telescope design combining high detection sensitivity, short focal length, wide field of view, and rapid step-and-settle to provide orders of magnitude improvements in space surveillance has been achieved. This capability enables ground-based detection of un-cued objects in deep space for purposes such as asteroid detection and space defense missions. The system transitioned to Air Force Space Command (AFSPC). The SST Australia effort developed advanced algorithms, equipment, and concepts of operation to achieve comparable telescope performance in the more challenging Australian atmosphere. This enhanced capability was demonstrated at White Sands Missile Range, allowing estimates of the performance in Australia to be validated. This program addressed technical challenges which arise from an Australian site, including adaptations to a different telescope environment. ***FY 2016 Accomplishments:*** - Improved Wide Field Camera (WFC) #2 for enhanced SST capability. - Installed and characterized WFC #2 at White Sands Missile Range (WSMR) site and began demonstration of performance improvement. - Developed plan to transition SST to AFSPC. ***FY 2017 Plans:*** - Complete demonstration of WFC #2 performance improvement at White Sands Missile Range (WSMR) site. - Support Joint Space Operations Center (JSpOC) data delivery. - Complete transition to AFSPC.	12.900	6.000	-
Title: Airborne Launch Assist Space Access (ALASA) ***Description:*** The ALASA program sought to make access to space more affordable by significantly reducing the cost of launch for <200 kg payloads to low earth orbit, with an ultimate goal of $1M for 50kg. In addition, the program sought to improve the responsiveness of space access by reducing the interval from call-up to launch to a single day. ***FY 2016 Accomplishments:*** - Performed propellant characterization to determine safe and effective operating envelope.	8.830	-	-

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C. Accomplishments/Planned Programs ($ in Millions)	FY 2016	FY 2017	FY 2018
- Performed development of planning tools, and autonomous flight termination technology which allow for more operational flexibility and decrease recurring launch costs. - Assessed alternative launch systems.			
Title: Space Domain Awareness (SDA) ***Description:*** The goal of the Space Domain Awareness (SDA) program was to develop and demonstrate an operational framework and responsive defense application to enhance the availability of vulnerable space-based resources. SDA investigated revolutionary technologies in two areas: 1) advanced space surveillance sensors to better detect, track, and characterize space objects, with an emphasis on deep space objects, and 2) space surveillance data collection, data archival, and data processing/ fusion to provide automated data synergy. The SDA program leveraged data fusion and advanced algorithms developed under the Space Surveillance Telescope (SST) program, and also sought to exploit new ground-breaking technologies across the electromagnetic spectrum and utilize already existing sensor technology in nontraditional or exotic ways. ***FY 2016 Accomplishments:*** - Completed an initial capability demonstration of a collaborative network of distributed sensors. - Integrated all data providers and first generation algorithms on the SDA database to autonomously detect biases, estimate uncertainties, and leverage non-accredited information for real time SDA. - Expanded the portfolio of modalities contributing to SDA to include RADAR data providers. - Developed technology and execution plan for demonstration of Low Inclined Low-Earth-Orbit Objects (LILO) sensor. - Conducted multiple capability demonstrations of collaborative network of distributed sensors and users. - Performed and documented analysis of algorithm performance.	6.866	-	-
Accomplishments/Planned Programs Subtotals	120.642	175.240	247.435

D. Other Program Funding Summary ($ in Millions)

N/A

Remarks

E. Acquisition Strategy

N/A

F. Performance Metrics

Specific programmatic performance metrics are listed above in the program accomplishments and plans section.