Exhibit R-2, RDT&E Budget Item Justification: PB 2020 Defense Advanced Research Projects Agency	Date: March 2019
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 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	-	226.988	254.671	202.606	-	202.606	168.926	142.726	131.726	137.726	-	-
SPC-01: *SPACE PROGRAMS AND TECHNOLOGY*	-	226.988	254.671	202.606	-	202.606	168.926	142.726	131.726	137.726	-	-

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. This program element will examine concepts and architectures that move the U.S. away from a dependence on monolithic, ultra-capable, vulnerable, and unsustainably costly assets; replacing them with disaggregated assets that are agile, affordable, and easily replaced/maintained. Ready access to space requires the delivery of capabilities, replenishment of supplies into orbit, and rapid manufacturing of affordable space capabilities. Development of smaller, simpler, and more agile launch vehicles and infrastructure will be pursued. In addition, developing space access and spacecraft servicing technologies as well as exploring novel in-space manufacturing technologies and techniques 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 and functionality of space systems, space-derived information, and services with terrestrial users. Studies under this program element include technologies and systems that will enable satellites and microsatellites to operate more effectively by increasing maneuverability, survivability, and situational awareness, and precision control of multi-payload systems. Studies will actively seek to take advantage of new commercial developments which may enable both rapid constitution/reconstitution of assets, and agility/functionality not previously available for military systems.

B. Program Change Summary ($ in Millions)	FY 2018	FY 2019	FY 2020 Base	FY 2020 OCO	FY 2020 Total
Previous President's Budget	247.435	254.671	190.606	-	190.606
Current President's Budget	226.988	254.671	202.606	-	202.606
Total Adjustments	-20.447	0.000	12.000	-	12.000
• Congressional General Reductions	-7.000	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	-4.307	0.000			
• SBIR/STTR Transfer	-9.140	0.000			
• TotalOtherAdjustments	-	-	12.000	-	12.000

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Change Summary Explanation

FY 2018: Decrease reflects Congressional reduction, SBIR/STTR transfer and reprogrammings.

FY 2019: N/A

FY 2020: Increase reflects initiation of the Reactor On A Rocket (ROAR) program and funding for DARPA Launch Challenge prize awards, offset by smaller program decreases.

C. Accomplishments/Planned Programs ($ in Millions)	FY 2018	FY 2019	FY 2020
Title: Experimental Spaceplane One (XSP)	61.000	59.971	51.000

Description: The goal of the Experimental Spaceplane One (XSP) program is to develop and flight demonstrate a prototype booster and expendable upper stage with responsive aircraft-like operations. Past efforts have identified and demonstrated critical enabling technologies including composite or lightweight 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 booster flights in 10 days, 2) design the objective system for >3000-lb payload at a reduced cost, 3) fly the demonstration system one time with an orbital payload of 900-lbs, and 4) fly to a high staging speed (Mach 3-10). The anticipated transition partners are the Air Force, Navy and commercial sector.

FY 2019 Plans:

- Mature the XSP 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 XSP vehicle design for component acquisition, fabrication, assembly, and integration.
- Complete designs for mobile ground infrastructure.
- Mature range, ground and flight test operations planning.
- Submit commercial spaceport and/or DoD range documentation.
- Begin fabrication of all major subsystems.
- Initiate acceptance test planning.
- Begin integration and test of major subassemblies, flight and mobile ground systems.

FY 2020 Plans:

- Complete propulsion qualification and acceptance testing.
- Continue booster assembly integrating actuation devices and control surfaces, landing gear, reaction control system, main engine, and propulsion system hardware.
- Complete Flight Operations Control Center for mobile ground system.

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C. Accomplishments/Planned Programs ($ in Millions)	FY 2018	FY 2019	FY 2020
- Complete Transporter Erector Launcher system. - Complete the construction of the Liquid Hydrogen (LH2) tank. - Complete nose landing gear assembly. ***FY 2019 to FY 2020 Increase/Decrease Statement:*** The FY 2020 decrease reflects completion of fabrication and assembly.			
Title: Robotic Servicing of Geosynchronous Satellites (RSGS)	79.988	108.700	64.606
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 seeks to establish the capability to provide robotic services in GEO suitable for a variety of potential servicing tasks, in full collaboration and 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 2019 Plans:*** - Complete build and test of first flight robotic arm and tool changer. - Begin integration of robotic payload. - Fabricate robotic operations test bed. - Continue build of flight units of robotic tools and tool holders. - Continue preparations for launch with Air Force Space Test Program. - Continue build of rendezvous and proximity operations sensors. - Complete payload structures fabrication. - Test final build of flight software. - Publish CONFERS operating practices document and consensus standards through a qualified standards development organization. - Convene CONFERS second general assembly and open forum. ***FY 2020 Plans:***			

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C. Accomplishments/Planned Programs ($ in Millions)	FY 2018	FY 2019	FY 2020
- Complete build and test of second robotic arm and tool changer. - Continue build of flight units of robotic tools and tool holders. - Complete integration of robotic payload. - Test integrated robotic payload. - Begin payload integration on spacecraft. - Complete build of rendezvous and proximity operations sensors. - Test robotic tools and integrate onto spacecraft. - Complete flight software for integration. - Publish revised CONFERS consensus standards inclusive of lessons learned from on-going commercial and government activity. - Convene CONFERS third general assembly and open forum. ***FY 2019 to FY 2020 Increase/Decrease Statement:*** The FY 2020 decrease reflects completion of fabrication and integration of payload, tools, and sensors.			
Title: Blackjack	6.000	16.400	25.000
Description: The Blackjack program will develop space technologies demonstrating a proliferated smallsat constellation capability in Low Earth Orbit (LEO). Capabilities demonstrated will provide constant custody of very large numbers of concurrent targets; target identification, tracking, and characterization; architectural resilience via massive proliferation; and rapid on-orbit technology refresh and experimentation. Blackjack will leverage commercial industry plans to build constellations in LEO to provide global commercial broadband internet service. Key efforts include low size, weight, power, and cost (SWaP-C) multi-modality smallsat sensor payloads, algorithms for autonomous payload and architecture command and control, algorithms for satellite on-board processing and data fusion, and advanced manufacturing for military payload mass production. The anticipated transition partner is the Air Force. ***FY 2019 Plans:*** - Complete satellite bus and payload interface definition documents. - Complete demonstration system Conceptual Design Review (CoDR). - Complete Preliminary Design Review (PDR) for modeling and simulation activities. - Begin development of demonstration sensor payloads. - Begin modeling and simulation with bus, payload, and autonomy element emulators for risk reduction efforts. - Begin development of autonomous control element. ***FY 2020 Plans:*** - Complete Critical Design Review for commoditized satellite bus.			

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C. Accomplishments/Planned Programs ($ in Millions)	FY 2018	FY 2019	FY 2020
- Complete Critical Design Review for sensor payloads. - Complete Critical Design Review for autonomous control element. - Initiate spacecraft bus manufacturing. - Initiate sensor payload manufacturing. - Initiate autonomous control element manufacturing. ***FY 2019 to FY 2020 Increase/Decrease Statement:*** The FY 2020 increase reflects transition from preliminary to critical design and start of component manufacturing.			
Title: Advanced Space Technology Concepts ***Description:*** Studies conducted under this program will examine and evaluate emerging technologies and concepts with the potential to provide substantial improvement in efficiency and effectiveness of operations in space. This includes the degree and scope of potential impact and improvements to military operations, mission utility, and warfighter capability. Studies are also conducted to analyze emerging threats along with possible methods and technologies to counter them. The feasibility of achieving potential improvements, in terms of resources, schedule, and technological risk, is also evaluated. The results from these studies are used, in part, to formulate future programs or refocus ongoing work. Topics of consideration include advanced or novel propulsion systems, novel sensors, advanced lightweight structures, advanced miniature radio frequency (RF) technology, navigation technologies, avionics, structures, advanced communications and on-orbit software environments. ***FY 2019 Plans:*** - Perform studies to evaluate employment of new systems and architectures. - Explore approaches for autonomous operation of spacecraft architectures. ***FY 2020 Plans:*** - Conduct feasibility studies for new system concepts. - Examine technology developments supporting small space propulsion systems. ***FY 2019 to FY 2020 Increase/Decrease Statement:*** The FY 2020 increase reflects additional planned studies.	3.000	2.000	3.500
Title: Planar Imager ***Description:*** The Planar Imager program will develop a low size, weight, and power (SWaP) electro-optical (EO) imager using photonic integrated circuits (PICs) and other novel approaches to replace conventional telescopes for high altitude, long endurance Unmanned Aerial Vehicle (UAV) persistent platforms and space-based EO sensors for Intelligence, Surveillance, and Reconnaissance (ISR). In order to increase resolution, conventional telescopes have to grow in size and weight. The Planar	-	10.000	10.000

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C. Accomplishments/Planned Programs ($ in Millions)	FY 2018	FY 2019	FY 2020
Imager program will eliminate this constraint by developing methods and technologies to replace conventional optics with digital processing, providing dramatic improvements in weight and enabling novel form factors for military imaging systems. ***FY 2019 Plans:*** - Initiate trade studies of various advanced optics approaches to Planar Imaging (PICs, Metamaterials, etc.). - Develop concept demonstrations requirements. - Initiate breadboard demonstration. ***FY 2020 Plans:*** - Demonstrate breadboard system. - Develop scaled demonstration.			
Title: DARPA Launch Challenge* ***Description:*** *Previously Responsive Access for Space Resilience Advances in technology, including networking and computing, have significantly increased the utility of small (<300kg) spacecraft that would previously have been of limited military value. For the simultaneous purposes of responsiveness and resiliency, these spacecraft are envisioned to be built on dramatically faster timelines (weeks instead of years) than are executed today. The current practice for space launch generally favors large launch vehicles with complex, one-of-a-kind infrastructure. This architecture has been matched to the large, heavy spacecraft, which compose most of DoD's space architecture today. Small spacecraft, which offer large potential value for resiliency and tactical employment, are typically required to rideshare for access to space which requires programmatic, technical, and schedule entanglement with other programs. The U.S. commercial sector has promising developments for small launch vehicles that are designed for launch on rapid timescales with minimal fixed infrastructure. To incentivize industry to deliver capability that can meet emerging DoD needs for rapid, responsive launch of small payloads, the DARPA Launch Challenge will reward competitors who can demonstrate the ability to launch a payload to orbit with minimal notification time and unknown pre-conditions regarding the payload configuration, required orbit, and launch site. The U.S. Government can make future use of commercial contracting mechanisms for rapid space launch with successful performers. The anticipated transition partners are the Air Force and NASA. ***FY 2019 Plans:*** - Select launch ranges and initiate launch site facility accommodations, as necessary. - Develop and test multi-launch site compatible downrange telemetry return capabilities. - Create scalable commercial payload packages to support range of launch capabilities. - Coordinate with the FAA's Office of Commercial Space Transportation on license applications for challenge participants.	-	5.000	38.500

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C. Accomplishments/Planned Programs ($ in Millions)	FY 2018	FY 2019	FY 2020
- Review participant challenge applications, to include operations plans demonstrating use of minimal infrastructure, and rapid launch capability. - Select challenge participants for the qualification phase and award qualification prizes. ***FY 2020 Plans:*** - Conduct first and second launches at specified ranges to demonstrate rapid timescale and flexibility. - Award challenge prizes for the first and second launches. ***FY 2019 to FY 2020 Increase/Decrease Statement:*** The FY 2020 increase reflects execution of launch events and prize payments.			
Title: Reactor On A Rocket (ROAR) ***Description:*** The Reactor On A Rocket (ROAR) program will develop and demonstrate a High-Assay Low-Enriched Uranium (HALEU) nuclear thermal propulsion (NTP) system. The capability afforded by NTP will expand the operating presence of the U.S. in space to the cislunar volume and enhance domestic operations to a new high-ground, which is in danger of being defined by the adversary. The program will initially develop the use of additive manufacturing (AM) approaches to print NTP fuel elements. In addition, the program will investigate on-orbit assembly techniques to safely assemble the individual core element subassemblies into a full demonstration system configuration, and will perform a technology demonstration. ***FY 2020 Plans:*** - Demonstrate additive manufacturing techniques using surrogate materials, followed by proof-of-principle additive manufacturing of natural uranium reactor components. - Initiate development of a modular nuclear propulsion system, including incorporation of additively manufactured fuel into a low-enriched uranium reactor and additive engine. - Complete preliminary design of the demonstration integrated nuclear propulsion system. ***FY 2019 to FY 2020 Increase/Decrease Statement:*** The FY 2020 increase reflects program initiation.	-	-	10.000
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 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-	58.000	42.600	-

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C. Accomplishments/Planned Programs ($ in Millions)	FY 2018	FY 2019	FY 2020
art technical developments. The technologies developed under Radar Net will enable small, low-cost sensor payloads on short timescales with rapid technology refresh capabilities. ***FY 2019 Plans:*** - Transition program to partner for launch and on-orbit demonstration/testing. - Complete final coordination with transition partner on fabrication, assembly, integration, and test of the demonstration system. ***FY 2019 to FY 2020 Increase/Decrease Statement:*** The FY 2020 decrease reflects program completion.			
Title: Hallmark ***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 artificial intelligence (AI) and machine learning (ML) technologies to increase commander and operator awareness thereby transforming information to knowledge and effectively communicating and facilitating time-critical decision making. Underpinning the BMC2 layer is a flexible infrastructure that enables the rapid integration of tools in order to respond to shifting adversary Tactics, Techniques, and Procedures (TTPs). The anticipated transition partner is the Air Force. ***FY 2019 Plans:*** - Release Hallmark software development kit including Hallmark in-a-box for remote development environment. - Augment the BMC2 tool suite with new technologies that AI and ML to counter complex adversary activities and produce alternative courses of action. - Transition activity for sustainment of ontology and data model continuous evolution, and for sustainment of BMC2 tool development environment. ***FY 2019 to FY 2020 Increase/Decrease Statement:*** The FY 2020 decrease reflects program completion and transition.	19.000	10.000	-
Accomplishments/Planned Programs Subtotals	226.988	254.671	202.606

D. Other Program Funding Summary ($ in Millions)

N/A

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D. Other Program Funding Summary ($ in Millions)

Remarks

E. Acquisition Strategy

N/A

F. Performance Metrics

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