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 0603286E / *ADVANCED AEROSPACE SYSTEMS*

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	-	176.200	302.463	279.741	-	279.741	217.434	228.725	188.316	204.316	-	-
AIR-01: *ADVANCED AEROSPACE SYSTEMS*	-	176.200	302.463	279.741	-	279.741	217.434	228.725	188.316	204.316	-	-

A. Mission Description and Budget Item Justification

The Advanced Aerospace Systems program element, budgeted in the Advanced Technology Budget Activity, is focused on exploiting high pay-off opportunities to provide revolutionary new system capabilities, as opposed to incremental or evolutionary advancements, in order to achieve undeterrable air presence at dramatically reduced costs. Rapid prototyping and experimentation of integrated system concepts, as well as enabling vehicle subsystems will be conducted. Programs will explore new architectural concepts that employ a mix of weapon technologies that achieve lethality through a combination of overwhelming performance and overwhelming numbers rather than through the use of singular and costly high value assets. Studies conducted under this program element include examination and evaluation of emerging aerospace threats, technologies, concepts, use of autonomy to minimize risk, and applications for missiles, munitions, and vehicle systems.

B. Program Change Summary ($ in Millions)	FY 2018	FY 2019	FY 2020 Base	FY 2020 OCO	FY 2020 Total
Previous President's Budget	155.406	277.603	379.341	-	379.341
Current President's Budget	176.200	302.463	279.741	-	279.741
Total Adjustments	20.794	24.860	-99.600	-	-99.600
• Congressional General Reductions	-3.000	-5.140			
• Congressional Directed Reductions	0.000	0.000			
• Congressional Rescissions	0.000	0.000			
• Congressional Adds	0.000	30.000			
• Congressional Directed Transfers	0.000	0.000			
• Reprogrammings	29.994	0.000			
• SBIR/STTR Transfer	-6.200	0.000			
• TotalOtherAdjustments	-	-	-99.600	-	-99.600

Congressional Add Details ($ in Millions, and Includes General Reductions)	FY 2018	FY 2019
Project: AIR-01: *ADVANCED AEROSPACE SYSTEMS*		
Congressional Add: *Hypersonics Weapons Programs Development and Transition*	-	30.000
Congressional Add Subtotals for Project: AIR-01	-	30.000
Congressional Add Totals for all Projects	-	30.000

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Change Summary Explanation

FY 2018: Increase reflects reprogrammings, offset by Congressional reduction and SBIR/STTR transfer.

FY 2019: Increase reflects Congressional adjustments, including a $20 million above threshold reprogramming for the Tactical Boost Glide program.

FY 2020: Decrease reflects rephasing of several Advanced Aerospace Systems programs.

C. Accomplishments/Planned Programs ($ in Millions)	FY 2018	FY 2019	FY 2020
Title: Hypersonic Air-breathing Weapon Concept (HAWC)	30.000	14.300	10.000

Description: The Hypersonic Air-breathing Weapon Concept (HAWC) program is a Joint DARPA / Air Force effort that will develop and demonstrate technologies for an effective and affordable air-launched hypersonic cruise missile. These technologies include advanced air vehicle configurations capable of efficient hypersonic flight, hydrocarbon scramjet-powered propulsion to enable sustained hypersonic cruise, thermal management approaches designed for high-temperature cruise, and affordable system designs and manufacturing approaches. This is a joint program with the Air Force, and HAWC technologies are planned for transition to the Air Force after flight testing is complete.

FY 2019 Plans:
- Continue software-in-the-loop testing for the demonstration vehicle.
- Continue hardware-in-the-loop testing for the demonstration vehicle.
- Complete flight certification reviews with the test range.
- Begin full-scale thermal-structural testing.
- Complete flight test planning for the demonstration system.
- Continue procurement of test assets and test support equipment.
- Begin assembly, integration, and test of demonstration vehicle.
- Conduct range safety analysis.
- Conduct mission readiness review.

FY 2020 Plans:
- Complete software-in-the-loop testing for the demonstration vehicle.
- Complete hardware-in-the-loop testing for the demonstration vehicle.
- Conduct first flight.
- Conduct interim flight test data analysis.
- Complete flight tests.
- Conduct final flight data review.
- Conduct final program reviews.

FY 2019 to FY 2020 Increase/Decrease Statement:

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C. Accomplishments/Planned Programs ($ in Millions)	FY 2018	FY 2019	FY 2020
The FY 2020 decrease reflects the completion of vehicle fabrication and initial testing and transition to final flight testing.			
Title: Tactical Boost Glide	68.126	147.000	162.000
Description: The Tactical Boost Glide (TBG) program is a Joint DARPA / Air Force effort that will develop and demonstrate technologies to enable air-launched tactical range hypersonic boost glide systems, including flight demonstration of a vehicle that is traceable to an operationally relevant weapon that can be launched from current platforms. The program will also consider traceability, compatibility, and integration with the Navy Vertical Launch System (VLS). The metrics associated with this objective include total range, time of flight, payload, accuracy, and impact velocity. The program will address the system and technology issues required to enable development of a hypersonic boost glide system considering (1) vehicle concepts possessing the required aerodynamic and aero-thermal performance, controllability and robustness for a wide operational envelope, (2) the system attributes and subsystems required to be effective in relevant operational environments, and (3) approaches to reducing cost and improving affordability for both the demonstration system and future operational systems. TBG capabilities are planned for transition to the Air Force and the Navy. ***FY 2019 Plans:*** - Continue procurement of hardware for demonstration vehicles. - Complete Assembly, Integration, and Test (AI&T) of Static Test Article (STA). - Complete aeroshell thermo-structural testing. - Continue risk reduction and qualification testing. - Complete test readiness review (TRR) for first flight. - Continue AI&T of remaining test articles. - Continue detailed flight test and range safety planning, coordination, and documentation. - Update Technology Maturity Plans (TMPs) and Risk Management Plans (RMPs). - Plan and conduct additional aerodynamic and aero-thermodynamic risk reduction testing. - Plan and conduct additional material and thermo-structural risk reduction testing. - Plan and conduct additional materials arc-jet testing. - Update aerodynamic and materials databases based on risk reduction test analysis. - Plan additional flight tests for expanded risk reduction. - Procure hardware for additional tests and begin AI&T of test articles. - Implement acquisition approach for second TBG performer to evolve an All-Up Round (AUR) design to a critical design level of maturity. - Plan and conduct second TBG performer aerodynamic and aero-thermodynamic risk reduction testing, including air vehicle and all-up round (AUR) subsonic, transonic, and hypersonic performance and control tests.			

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C. Accomplishments/Planned Programs ($ in Millions)	FY 2018	FY 2019	FY 2020
- Plan and conduct second TBG performer material and thermo-structural risk reduction testing, including seals characterization, and engineering environmental and static loads testing. - Update second TBG performer aerodynamics and materials databases based on risk reduction test analysis. - Conduct second TBG performer demonstration system solid rocket motor static fire test. - Develop preliminary requirements for a Navy variant AUR. - Conduct trade studies and assess booster and Vertical Launch System (VLS) integration development needs for a Navy variant AUR. - Begin Navy variant test planning. - Plan and conduct Navy variant risk reduction testing. - Conduct Navy variant AUR Conceptual Design Review. ***FY 2020 Plans:*** - Complete AI&T of Engineering Development Unit (EDU) and two flight test vehicles. - Conduct TRRs for two flights, conduct flight tests, and complete post-flight analysis. - Continue AI&T and conduct TRR of third flight test vehicle. - Continue additional aerodynamic and aero-thermodynamic risk reduction testing. - Continue additional material and thermo-structural risk reduction testing. - Continue additional materials arc-jet testing. - Continue detailed planning of additional flight tests for expanded risk reduction. - Continue procurement of hardware for additional tests and continue AI&T of test articles. - Complete second TBG performer's engineering component testing and design verification testing. - Continue second TBG performer's material and thermo-structural risk reduction testing, including carbon-carbon model validation structural test, and full-scale hot structure test. - Complete fabrication and integration and begin test of second TBG performer's inert operating missiles including ground testing and captive carriage testing. - Complete second performer's subsystem and system-level critical design reviews. - Continue Navy variant risk reduction testing. - Continue detailed Navy variant test planning. - Conduct Navy variant demonstration article Preliminary Design Review(s). ***FY 2019 to FY 2020 Increase/Decrease Statement:*** The FY 2020 increase reflects additional funds for increased risk reduction, Navy variant development, and second performer.			
Title: Advanced Full Range Engine (AFRE)	35.000	51.288	40.741

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C. Accomplishments/Planned Programs ($ in Millions)	FY 2018	FY 2019	FY 2020
Description: The Advanced Full Range Engine (AFRE) program will establish the feasibility of hypersonic aircraft propulsion through a two-pronged approach. AFRE will demonstrate turbine to Dual Mode Ramjet (DMRJ) transition of a Turbine-Based Combined Cycle (TBCC) propulsion system utilizing an off-the-shelf turbine engine. Large scale components of this complex propulsion system will be developed and demonstrated independently, followed by a full-scale freejet TBCC propulsion system mode transition ground test. Accomplishing these objectives will enable future hypersonic systems resulting in transformational changes in long range strike, high speed Intelligence, Surveillance and Reconnaissance (ISR) and Two-Stage-To-Orbit (TSTO) operations. The anticipated transition partner for this effort is the Air Force. ***FY 2019 Plans:*** - Complete manufacturing of full scale combustor and prepare for ground test. - Complete manufacturing and ground demonstrate full scale turbine/common nozzle with water injection. - Complete manufacturing and test of common inlet aerodynamic model. - Complete integrated system (TBCC) design (preliminary and critical design). - Complete manufacturing of full-scale common inlet. ***FY 2020 Plans:*** - Complete full-scale combustor (DMRJ) ground test demonstration. - Complete full-scale inlet test. - Complete component (inlet, combustor, turbine, and nozzle) post-test inspection and refurbishment. - Complete integrated TBCC system assembly, installation and initiate ground test. ***FY 2019 to FY 2020 Increase/Decrease Statement:*** The FY 2020 decrease reflects completion of design and fabrication and transition to testing.			
Title: Advanced Aerospace System Concepts	3.000	3.000	3.000
Description: Studies conducted under this program examine and evaluate emerging aerospace technologies and system concepts for applicability to military use. 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 aerospace 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 prototype development programs or refocus ongoing work. Topics of consideration include: methods of defeating enemy anti-aircraft attacks; munition technologies to increase precision, range, endurance, and lethality of weapons for a variety of mission sets; novel launch systems; air vehicle control, power, propulsion, materials, and architectures; and payload and cargo handling systems.			

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C. Accomplishments/Planned Programs ($ in Millions)	FY 2018	FY 2019	FY 2020
FY 2019 Plans: - Perform ground and flight experiments to characterize boundary layer transition physics. - Initiate studies of novel concepts. - Perform technology risk assessments to identify critical enabling technologies. ***FY 2020 Plans:*** - Conduct proof-of-concept demonstrations to verify technology feasibility. - Perform initial development of novel aircraft configurations.			
Title: Operational Fires	-	40.000	50.000
Description: The goal of the Operational Fires (OpFires) program is to develop and demonstrate a novel ground-launched system enabling advanced tactical weapons to penetrate modern enemy air defenses and rapidly and precisely engage critical time sensitive targets. This program seeks to develop an advanced booster capable of delivering a variety of payloads at a variety of ranges. Additional considerations include the need for compatible mobile ground launch platforms enabling integration with existing ground forces and infrastructure, and specific system attributes required for rapid deployment and redeployment. The OpFires program will conduct a series of subsystem tests designed to evaluate component design and system compatibility, and culminate in integrated end-to-end flight tests. OpFires will leverage and integrate ongoing investments in hypersonics to achieve these objectives. The transition partner is the Army. In FY18, this program was funded from PE 0602702E, Project TT-04. ***FY 2019 Plans:*** - Complete ground launch platform Systems Requirements Review (SRR) and Conceptual Design Review (CoDR). - Complete booster propulsion system Preliminary Design Review (PDR). - Conduct early propulsion system risk reduction testing. - Complete payload trade studies. - Begin Operational Fires integrated system trade studies. - Complete military utility assessment and wargames. - Begin development of technology maturation plans and risk management plans (TMPs and RMPs). - Begin flight test and range safety planning, coordination, and documentation. ***FY 2020 Plans:*** - Complete propulsion system Critical Design Review (CDR). - Complete integrated weapon System Requirements Review (SRR). - Perform extinguishable propellant formulation and characterization testing (strand tests, 12" motor). - Evaluate combustion stability in 1000 lb hybrid motor. - Develop integrated weapon system technology maturation plan and initial flight test plan.			

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C. Accomplishments/Planned Programs ($ in Millions)	FY 2018	FY 2019	FY 2020
- Complete Operational Fires integrated system trade studies. ***FY 2019 to FY 2020 Increase/Decrease Statement:*** The FY2020 increase reflects completion of integrated trade studies and initiation of propellant formulation and testing.			
Title: Air-Ground Autonomous VEhicles (AGAVE) ***Description:*** The Air-Ground Autonomous VEhicles (AGAVE) program will explore the seams between air and ground vehicles. New approaches are required to address one of the most symmetric of all warfighting domains-ground combat. The program will seek to provide improved mobility solutions for supporting combat operations that place unmanned assets forward to explore and inform troops prior to entering an area, or to provide continued perimeter and overhead surveillance during operations. Technologies will be explored to allow increased levels of autonomy, improved operating ranges, improved mobility through complex 3-dimensional battlespaces, and integration of the requirements for both ground and air mobility in complex urban warfare settings. Reduced manning requirements will be a part of the design space evaluation, with unmanned vehicles operating in a supporting role instead of a traditional supported role. Novel approaches to launch and recovery that reduce the need for highly trained personnel dedicated to monitoring unmanned vehicles will be explored. Problems that cross all domains, such as high energy density power supplies, navigation through uncertain and changing environments, and supervisory autonomy of vehicles will be addressed. Novel networking approaches will also be explored to close the seams between ground and air unmanned vehicles and to improve confidence in identifying risks associated with both natural hazards and enemy actions prior to ground personnel entering an area. Cueing from other assets and long range, long duration autonomous assets will be included in the overall tradespace explored. ***FY 2020 Plans:*** - Refine design space and develop system requirements. - Initiate studies in the areas of autonomy, mobility, and energy to define technology development areas. - Develop concepts of operations and system architecture. ***FY 2019 to FY 2020 Increase/Decrease Statement:*** The FY 2020 increase reflects program initiation.	-	-	14.000
Title: Aircraft and Vehicle IntegrAted Team (AVIATE) ***Description:*** The Aircraft and Vehicle IntegrAted Team (AVIATE) program will study use of an Unmanned Aerial System (UAS) that is an integrated subsystem of a ground vehicle with features to autonomously land, attach, stow, detach, and take-off from its parent ground vehicle while it is on the move to enable on-demand capabilities and drastically improved protection. Ground vehicles could perform traditional UAS missions such as intelligence, surveillance and reconnaissance (ISR) and fires support, as well as unique missions such as electronic attack, sensor emplacement, infrastructure attack, and active protection without having	-	5.875	-

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C. Accomplishments/Planned Programs ($ in Millions)	FY 2018	FY 2019	FY 2020
to rely on brigade and theater level assets. This effort will explore design interfaces between the air and ground vehicle, attributes to allow for launch and recovery on the move, and design considerations to enable operations in contested environments. ***FY 2019 Plans:*** - Explore airframe design concepts of flight demonstration vehicle. ***FY 2019 to FY 2020 Increase/Decrease Statement:*** The FY 2020 decrease reflects completion of studies and concepts.			
Title: Collaborative Operations in Denied Environment (CODE) ***Description:*** The goal of the Collaborative Operations in Denied Environment (CODE) program is to enhance mission performance, reduce cost, confound adversaries, and reduce reliance on space assets for navigation and communication by distributing mission functions such as sensing, communication, precision navigation, kinetic, and non-kinetic effects to small platforms and increasing their level of autonomy. Collaboration of multiple assets offers new possibilities to conduct military missions using smaller air platforms to enhance survivability, reduce overall acquisition cost, create new effects, increase communications range and robustness in denied environments, increase search area, increase areas held at risk, reduce target prosecution reaction time, and provide multi-mission capabilities by combinations of assets. This effort will specifically focus on developing and demonstrating approaches that will expand the mission capabilities of legacy air assets through autonomy and collaborative behaviors, within a standard based open architecture. Potential transition partners include the Air Force, Army, and Navy. ***FY 2019 Plans:*** - Complete integration of the full suite of CODE algorithms and Units of Portability (UoPs). - Demonstrate the ability of a single commander to plan and execute a complex end-to-end scenario. - Perform capstone demonstration involving six live and multiple virtual aircraft executing a complex end-to-end mission scenario with multiple contingency events and limited advanced knowledge of red team positions and tactics. - Complete independent, fully-informed modeling, simulation, and analysis effort to validate final CODE software builds. - Produce final CODE software package with complete software development kit and simulation environment to facilitate technology transfer. ***FY 2019 to FY 2020 Increase/Decrease Statement:*** The FY 2020 decrease reflects program completion.	30.074	11.000	-
Title: Vertical Take-Off and Landing (VTOL) Technology Demonstrator ***Description:*** The Vertical Take-Off and Landing (VTOL) Technology Demonstrator program sought to demonstrate revolutionary improvements in (heavier than air) VTOL air vehicle capabilities and efficiencies through the development of subsystem and	5.000	-	-

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C. Accomplishments/Planned Programs ($ in Millions)	FY 2018	FY 2019	FY 2020
component technologies, aircraft configurations and system integration. A strong emphasis was placed on the development of elegant, multi-functional subsystem technologies that demonstrated net improvements in aircraft efficiencies enabling new and vastly improved operational capabilities.			
Title: Tactically Exploited Reconnaissance Node (TERN) ***Description:*** The Tactically Exploited Reconnaissance Node (TERN) program, a joint effort with the Office of Naval Research, developed a systems approach for, and perform technical demonstration of, a Medium-Altitude, Long-Endurance Unmanned Aerial Vehicle (MALE UAV) capability from smaller ships. The program developed the technology for launch and recovery of large unmanned aircraft capable of providing persistent 24/7 Intelligence, Surveillance, and Reconnaissance (ISR) and strike capabilities at long radius orbits. TERN enabled novel operational concepts including maritime surveillance and responsive, persistent deep overland ISR and strike, without requirement for forward basing. Application of TERN technologies and operational concepts enabled a novel and cost efficient approach for multiple mission sets. DARPA transitioned the TERN program to the Office of Naval Research for continued development in Q4 FY 2018.	5.000	-	-
Accomplishments/Planned Programs Subtotals	176.200	272.463	279.741

	FY 2018	FY 2019
Congressional Add: Hypersonics Weapons Programs Development and Transition	-	30.000
FY 2019 Plans: - TBG: Conduct risk reduction efforts on additional leading edge materials and additional coating systems. - TBG: Conduct instrumentation development for the leading edge. - TBG: Fabricate and test additional aeroshell. - HAWC: Perform risk reduction efforts and initiate ground testing of the demonstration system. - HAWC: Conduct additional inlet cover ejection test. - HAWC: Complete additional high temperature instrumentation.		
Congressional Adds Subtotals	-	30.000

D. Other Program Funding Summary ($ in Millions)

N/A

Remarks

E. Acquisition Strategy

N/A

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F. Performance Metrics

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