Exhibit R-2, RDT&E Budget Item Justification: PB 2021 Office of the Secretary Of Defense	Date: February 2020
Appropriation/Budget Activity 0400: *Research, Development, Test & Evaluation, Defense-Wide* / BA 3: *Advanced Technology Development (ATD)*	**R-1 Program Element (Number/Name)** PE 0603941D8Z / *Test and Evaluation/Science and Technology*

COST ($ in Millions)	Prior Years	FY 2019	FY 2020	FY 2021 Base	FY 2021 OCO	FY 2021 Total	FY 2022	FY 2023	FY 2024	FY 2025	Cost To Complete	Total Cost
Total Program Element	628.934	114.559	191.574	187.065	-	187.065	139.577	140.124	129.410	131.996	Continuing	Continuing
091: *High Speed Systems Test*	194.311	33.355	112.776	74.435	-	74.435	55.665	48.438	42.736	43.590	Continuing	Continuing
092: *Spectrum Efficient Technology*	55.894	10.682	9.340	9.725	-	9.725	9.880	10.330	10.486	10.696	Continuing	Continuing
093: *Electronic Warfare Test*	85.364	12.478	12.808	45.980	-	45.980	15.675	20.452	14.318	14.604	Continuing	Continuing
094: *Advanced Instrumentation Systems Technology*	58.970	11.517	10.583	11.034	-	11.034	11.213	11.760	12.007	12.247	Continuing	Continuing
095: *Directed Energy Test*	59.282	8.654	11.032	10.096	-	10.096	10.572	10.932	11.057	11.278	Continuing	Continuing
096: *C4I & Software Intensive Systems Test*	107.237	12.381	11.297	11.977	-	11.977	12.131	12.637	12.763	13.018	Continuing	Continuing
097: *Autonomy and Artificial Intelligence Test*	40.518	14.490	11.050	10.648	-	10.648	11.090	11.641	11.873	12.110	Continuing	Continuing
098: *Cyberspace Test*	27.358	11.002	12.688	13.170	-	13.170	13.351	13.934	14.170	14.453	Continuing	Continuing

Note

Starting in FY 2020, Project 097 title will change FROM "Unmanned and Autonomous Systems Test" TO "Autonomy and Artificial Intelligence Test" to more accurately define and describe project workload in terms of the National Defense Strategy and the Under Secretary of Defense (Research and Engineering) prioritization of Artificial Intelligence and machine learning.

A. Mission Description and Budget Item Justification

The Test and Evaluation/Science and Technology (T&E/S&T) Program seeks out and develops test technologies to keep pace with evolving weapons technologies. Aligned with the National Defense Strategy, this program is critical to ensure that the Department of Defense (DoD) has the ability to adequately test the advanced systems that will be fielded in the future, building a more lethal force. To meet this objective, the T&E/S&T Program performs the following activities:

- Exploits new technologies and processes to meet important test and evaluation (T&E) requirements.
- Expedites the transition of new technologies from the laboratory environment to the T&E community.
- Leverages industry advances in equipment, modeling and simulation, and networking to support T&E.

Additionally, the T&E/S&T Program examines emerging T&E requirements resulting from Joint Service initiatives to identify T&E technology needs and develop a long-range roadmap for technology insertion. The program leverages and employs applicable applied research efforts from the highly developed technology base in DoD laboratories and test centers, other Government agencies, and industry to accelerate development of new test capabilities. The program outreaches and engages academia to address test technology challenges in DoD testing, advancing Science, Technology, Engineering and Mathematics (STEM) initiatives at Historically Black Colleges and Universities (HBCU) and other minority serving institutions. This program provides travel funds for T&E/S&T program oversight, special studies, analyses,

and strategic planning related to test capabilities and infrastructure. The T&E/S&T Program aligns with the science and technology (S&T) Communities of Interest (COI) to prepare the T&E community to test warfighting capabilities that emerge from priority S&T investments. The T&E/S&T Program is funded within the Advanced Technology Development Budget Activity because it develops and demonstrates high payoff technologies for current and future DoD test capabilities.

B. Program Change Summary ($ in Millions)	FY 2019	FY 2020	FY 2021 Base	FY 2021 OCO	FY 2021 Total
Previous President's Budget	117.389	175.574	154.520	-	154.520
Current President's Budget	114.559	191.574	187.065	-	187.065
Total Adjustments	-2.830	16.000	32.545	-	32.545
• Congressional General Reductions	-	-			
• Congressional Directed Reductions	-	-			
• Congressional Rescissions	-	-			
• Congressional Adds	-	16.000			
• Congressional Directed Transfers	-	-			
• Reprogrammings	-	-			
• SBIR/STTR Transfer	-2.810	-			
• Other Adjustments	-0.020	-	-	-	-
• Economic Assumptions	-	-	-0.155	-	-0.155
• DoD Increase for 5GAT	-	-	32.700	-	32.700

Change Summary Explanation

The FY 2020 Congressional add of $16.000 million is for program increase. The FY 2021 base increase of $32.700 million is for testing in support of the Fifth Generation Aerial Target (5GAT).

Exhibit R-2A, RDT&E Project Justification: PB 2021 Office of the Secretary Of Defense			Date: February 2020
Appropriation/Budget Activity 0400 / 3	R-1 Program Element (Number/Name) PE 0603941D8Z / *Test and Evaluation/ Science and Technology*	Project (Number/Name) 091 / *High Speed Systems Test*	

COST ($ in Millions)	Prior Years	FY 2019	FY 2020	FY 2021 Base	FY 2021 OCO	FY 2021 Total	FY 2022	FY 2023	FY 2024	FY 2025	Cost To Complete	Total Cost
091: *High Speed Systems Test*	194.311	33.355	112.776	74.435	-	74.435	55.665	48.438	42.736	43.590	Continuing	Continuing

A. Mission Description and Budget Item Justification

High-speed/hypersonic weapons are being developed to ensure the continued military superiority and strike capability of the United States including freedom of movement and freedom of action in areas protected by anti-access/area denial defenses. Current weapon system demonstrations and technology development programs include high-speed and hypersonic air-breathing missiles, maneuvering reentry and boost-glide weapons, hypersonic gun-launched projectiles, and air-breathing space access vehicles. These systems require development of conventional and high-speed turbine, ramjet, scramjet, and combined cycle engines; high temperature materials; thermal protection systems (TPS); and thermal management systems. The High Speed Systems Test (HSST) project addresses test technology needs including propulsion, aerodynamic and aerothermal testing, so the test community has the technology to support the required test scenarios for concepts under development in the S&T community. The technology developments within the HSST project align with the Department of Defense (DoD) S&T priority investments. As such, the HSST project is developing, validating and transitioning advanced T&E technologies for ground test, open-air range flight test, and advanced computational tools, along with instrumentation and diagnostics systems for use in both ground tests and flight tests of high speed systems.

The HSST project develops technologies to enable robust, accurate, and timely T&E of these future weapon systems. DoD acquisition regulations require weapon systems to undergo a thorough T&E process to detect deficiencies early and to ensure system suitability and survivability. However, the extreme environments in which these weapons operate preclude accurate determination of their performance and operability with today's T&E assets. Current national test capabilities have deficiencies in data accuracy, flight condition replication and simulation, test methods, productivity, modeling and simulation (M&S) fidelity, and range safety.

The HSST mission is to address these national test capability gaps by providing test technology solutions that will enable high-speed and hypersonic weapon systems to be successfully developed through accurate, robust, and efficient T&E.

B. Accomplishments/Planned Programs ($ in Millions)	FY 2019	FY 2020	FY 2021
Title: High Speed Systems Test	33.355	112.776	74.435
Description: The HSST project continued to advance ground and flight test technologies, techniques, instrumentation, and modeling and simulation capabilities required for the development of high speed air-breathing propulsion and boost-glide weapons. The HSST project continued progress toward addressing the two most significant technology shortfalls in current hypersonic aero propulsion ground test capabilities: clean air heat addition (i.e. non-vitiated air) and variable Mach number test capability. Current production ground test facilities create the high temperature propulsion system inlet conditions necessary for air-breathing scramjet engine testing by burning fuel in the facility airflow supplied to the engine inlet for operation. As demonstrated by a previous HSST test, the resulting vitiated air has different gas properties than clean air found in the atmosphere and thus is not representative of what the vehicle would experience during flight. This significantly affects the engine's performance and operability in the test environment resulting in erroneous flight performance predictions. In addition to the ability to test in clean air, a variable Mach number capability is required to "fly the mission" and determine the critical transient operability effects throughout the flight envelope. Incorporation of component technologies, previously developed by the T&E/S&T			

Exhibit R-2A, RDT&E Project Justification: PB 2021 Office of the Secretary Of Defense		Date: February 2020
Appropriation/Budget Activity 0400 / 3	**R-1 Program Element (Number/Name)** PE 0603941D8Z / *Test and Evaluation/ Science and Technology*	**Project (Number/Name)** 091 / *High Speed Systems Test*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2019	FY 2020	FY 2021
program, were integrated into a small-scale, clean air, true temperature, and variable Mach number aero propulsion test facility, called the Hypersonic Aerothermal and Propulsion Clean Air Testbed (HAPCAT). Completion of this facility will demonstrate that the component technologies and their integration have reached Technology Readiness Level (TRL) 6, provide an on-going test asset to the DoD, and reduce risk for construction of a full-scale facility. The Regenerative Storage Heater (RSH), was demonstrated at flight representative temperatures, allowing non-vitiated air up to Mach 7.5 conditions to be supplied. Final design, fabrication, and installation of the air delivery system (ADS) was completed, which will permit uniform flow into the test cabin with variable pressure and temperature from multiple sources, including the RSH. The facility initiated checkout runs to validate its operation to support DoD weapon systems. The design for a free-jet, variable Mach nozzle (VMN) for use in HAPCAT was continued. Such a capability will permit much more accurate simulation of transient operations along a flight trajectory in a free-jet configuration. The design of the VMN will also serve as a risk-reduction effort for a larger-scale VMN for use in the future full-scale facility. Efforts continued on the installation of a variable Mach number direct-connect nozzle for hypersonic ground test facilities that will provide flight-equivalent Mach numbers between 4 and 6 at true temperatures. The nozzle utilizes a metallic flexible wall to vary the Mach number while withstanding the high temperatures. It will be integrated into the HAPCAT facility upon completion for checkout. The development of a high-pressure tunable-diode laser absorption spectroscopy (TDLAS) continued for eventual integration into HAPCAT to provide accurate air temperature measurements at high temperatures and pressures, which will be used for facility control and determination of facility conditions. The TDLAS system will have uses in other facilities as well for temperature measurements. The arc heater flow quality aerothermal test technology development progressed toward independently-powered spin-coils to control the physical characteristics of the spinning arc column, its attachment location and duration on electrode surfaces within the arc heater. The effort investigated two different spin-coil designs, one of which was validated for use in the mid-pressure arc heater facility. This effort will improve the service life of the electrodes and improve nozzle flow quality. The HSST project continued research that will provide better prediction and determination of boundary layer growth and transition effects upon hypersonic vehicle performance. Understanding and predicting boundary layer transition represents a critical shortfall in the hypersonic community, as it affects the thermal loads, stability and control, and overall performance of a vehicle. Test data from a seven degree cone model were evaluated to assess test techniques and boundary layer transition measurement capabilities between various facilities. Analysis of tests of a boost-glide vehicle were completed in a quiet wind tunnel environment and a traditional, “noisy” wind tunnel environment, providing insight into the effects of flow field disturbances on boundary layer transition continued. Facility flow field characterizations were conducted at the Purdue quiet tunnel and the Large Energy National Shock (LENS) facilities at Calspan University at Buffalo Research Center (CUBRC), enabling more effective comparisons between all the facilities and informing test customers of intrinsic flow features in each facility. The characterizations will also provide insight to			

Exhibit R-2A, RDT&E Project Justification: PB 2021 Office of the Secretary Of Defense		Date: February 2020
Appropriation/Budget Activity 0400 / 3	**R-1 Program Element (Number/Name)** PE 0603941D8Z / *Test and Evaluation/ Science and Technology*	**Project (Number/Name)** 091 / *High Speed Systems Test*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2019	FY 2020	FY 2021
boundary layer transition studies in these facilities. The HSST project also conducted testing of a boost-glide vehicle, resulting in critical findings to support future flight tests of the vehicle. The HSST project continued the design and development of a SkyRange capability to support hypersonic flight testing. This capability aims to provide a more agile, flexible, and cost-effective method for providing support to hypersonic flight tests in the areas of telemetry, atmospheric sensing, optical imaging, flight safety, and other fields to aid in the development of hypersonic vehicles. The capability will reduce the requirement and high-costs of the “string of pearls” collection of air, sea, and land resources used for hypersonic flight tests. Several different technologies within the HSST project will be integrated as part of the SkyRange. Development of an airborne version of the already completed ground LIDAR system continued with the design and testing of hardware components for the in-flight demonstration of the system in preparation for implementation on an un-crewed vehicle. Design for integration of the system on-board an unmanned Global Hawk also continued. Progress continued on a high fidelity automated airborne reconfigurable tracking system which seeks to provide high resolution imaging of hypersonic vehicles in flight. The final design was completed including concepts for integration onto a Global Hawk aircraft. Design for integration of the system on-board an unmanned Global Hawk also continued. This technology will be integrated as part of a SkyRange capability as well. The development and improvement of a telemetry capability integrated with a High Altitude, Long Endurance Un-crewed Aerial System (HALE UAS) for a technical demonstration continued. An iterative development process is ongoing and the latest version of the system was integrated onto a Global Hawk and ground tested. In preparation for long range flight tests, multiple Range Hawks were deployed to Hawaii to exercise CONOPS for multi-aircraft mission support. ***FY 2020 Plans:*** The HSST project will continue developments to improve hypersonic ground and flight test capabilities to levels required for acquisition programs. Development and characterization of the variable-Mach number free-jet nozzle and integration into the HAPCAT facility will continue. Progress will be made in the development of test techniques to determine the combined aerodynamic and aerothermal effects on sensor and seeker performance. Improvements to Thermal Protection System (TPS) test capabilities will be made by developing new test technologies that enable the testing of larger test articles (3x) with more complex geometries for longer test durations. Enhancements to TPS test facilities will also be initiated enabling the simulation of flight trajectories on the ground to better characterize TPS performance in support of hypersonic vehicle design optimization for range, survivability and payload. Development will be initiated to increase the capacity of TPS test facilities to support the increasing demand of hypersonic TPS test needs. Current arc heater test facility availability is a critical-path, schedule bottleneck for hypersonic programs; Improved TPS test capabilities will increase throughput of hypersonic test programs developing TPS. Flight test infrastructure improvements will continue to enable better data collection including high resolution optics, atmospheric measurements, and terminal scoring capability. Investments to improve flight test infrastructure will be initiated to			

Exhibit R-2A, RDT&E Project Justification: PB 2021 Office of the Secretary Of Defense		Date: February 2020
Appropriation/Budget Activity 0400 / 3	**R-1 Program Element (Number/Name)** PE 0603941D8Z / *Test and Evaluation/ Science and Technology*	**Project (Number/Name)** 091 / *High Speed Systems Test*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2019	FY 2020	FY 2021
increase the op tempo of tests and improve data quality in support of hypersonic flight tests. More agile flight tests assets will be developed reducing schedule inflexibility, improving data collection, improving terminal scoring capability, and adding additional instrumentation platforms. Data limitations associated with inflexible test instrumentation assets increases uncertainty & risk in system performance, requiring more test flights to mitigate. Conduct facility flow field characterizations at the Large Energy National Shock (LENS) facilities at Calspan University at Buffalo Research Center (CUBRC), enabling more effective comparisons between similar test facilities and informing test customers of intrinsic flow features in each facility. The characterizations will also provide insight to boundary layer transition studies in the facility. Conduct technology development for a new test capability at LENS to perform long duration aero-optic and ablation testing of interceptors at flight velocities and conditions. The new test capability will enable the ground testing of missile defense, hypersonic, and reentry systems at flight matched conditions for mission relevant test durations. ***FY 2021 Plans:*** Continue development of improved TPS test facilities increasing TPS test throughput and capacity. New TPS test facility development to include the support of multiple classified programs concurrently will continue along with additional test control cells for independent operations between different arc heaters. New test article preparation areas will reduce test set-up time and increases throughput. Improvements to flight test infrastructure increasing op tempo and data quality will continue to include the continued development of in-flight imaging systems. Continued development of airborne instrumentation capable of reducing atmospheric conditions data uncertainty, critical to assess system design (lift vs. drag), will continue. The development of more agile flight test assets will also continue. Development of airborne assets as flight test instrumentation platforms reduces schedule inflexibility compared to the limited operational tempo of ships & barges. Better data collection to include high resolution optics, improved atmospheric measurements, and terminal area scoring in the Broad Ocean Area (BOA) for end game targeting will continue. Efforts will continue to investigate new flight test techniques, develop new ground test instrumentation, improve and validate CFD codes, and transition HSST technologies to the hypersonic community. ***FY 2020 to FY 2021 Increase/Decrease Statement:*** Program Adjustments			
Accomplishments/Planned Programs Subtotals	33.355	112.776	74.435

C. Other Program Funding Summary ($ in Millions)

N/A

Remarks

Exhibit R-2A, RDT&E Project Justification: PB 2021 Office of the Secretary Of Defense		Date: February 2020
Appropriation/Budget Activity 0400 / 3	**R-1 Program Element (Number/Name)** PE 0603941D8Z / *Test and Evaluation/ Science and Technology*	**Project (Number/Name)** 091 / *High Speed Systems Test*

D. Acquisition Strategy

N/A

Exhibit R-2A, RDT&E Project Justification: PB 2021 Office of the Secretary Of Defense			Date: February 2020
Appropriation/Budget Activity 0400 / 3	R-1 Program Element (Number/Name) PE 0603941D8Z / *Test and Evaluation/ Science and Technology*	Project (Number/Name) 092 / *Spectrum Efficient Technology*	

COST ($ in Millions)	Prior Years	FY 2019	FY 2020	FY 2021 Base	FY 2021 OCO	FY 2021 Total	FY 2022	FY 2023	FY 2024	FY 2025	Cost To Complete	Total Cost
092: *Spectrum Efficient Technology*	55.894	10.682	9.340	9.725	-	9.725	9.880	10.330	10.486	10.696	Continuing	Continuing

A. Mission Description and Budget Item Justification

Weapon systems have become increasingly complex in recent years, resulting in the need for significantly more data to be passed among these systems as well as between the systems and our test infrastructure. A vast amount of data must be collected, transmitted, and analyzed, which requires a large amount of radio frequency (RF) spectrum resources. However, the amount of RF spectrum designated to support test and evaluation (T&E) is decreasing, most notably due to reallocation of spectrum for commercial use. The combination of decreasing RF spectrum and increasing data requirements results in an urgent need to develop test technologies that maximize the use of spectrum resources for Department of Defense (DoD) T&E operations.

The L- and S- Band frequencies are the traditional spectrum allotted for military T&E use. The explosive need for spectrum in the commercial sector has resulted in reallocation of portions of these bands to industry. To compensate, DoD is now authorized to use the C-Band spectrum which offers numerous benefits, including the potential for a large increase in available bandwidth, but the C-Band spectrum comes with technical challenges and regulatory constraints. Most notably, our current test infrastructure for telemetry is not designed to accommodate C-Band and the band is heavily shared for alternate uses. Technologies are required to implement innovative techniques that efficiently facilitate our use of C-Band without a major overhaul to our national test infrastructure. For instance, commercial telemetry transmitters operate in C-Band but do not have the form factor (size, weight and power) nor ruggedized packaging to survive airborne test applications.

Traditional telemetry applications employ streaming telemetry where data is moved one-way from the instrumented system under test to our test range infrastructure. Modern network based telemetry and cellular based telemetry capabilities enable more robust, efficient bidirectional transfer of data. The DoD strategy is to create technologies for implementing a telemetry capability in C-Band, using the legacy L- and S-Bands for both streaming and networked telemetry, and researching the feasibility of using higher frequency bands to augment telemetry operations.

The Spectrum Efficient Technology (SET) project is developing test technologies that enable more efficient use of legacy telemetry bands and expansion into non-traditional areas of the RF and optical spectra at DoD test ranges. The technology development efforts within the SET project have been prioritized to align with Department of Defense guidance on science and technology priority investments. As such, the SET project is focusing on growing data requirements of warfighting systems and the limited availability of spectrum for testing. The SET project is structured to develop test technologies to advance range communications, networked and cellular based telemetry capabilities, and enhanced management of spectrum at DoD test ranges.

B. Accomplishments/Planned Programs ($ in Millions)	FY 2019	FY 2020	FY 2021
Title: Spectrum Efficient Technology	10.682	9.340	9.725
Description: The SET project risk reduced a ruggedized Ethernet switch for airborne systems in support of the Central Test and Evaluation Investment Program (CTEIP) networked telemetry projects. The ruggedized Ethernet switch addressed CTEIP requirements to fully instrument test aircraft with network enable instrumentation packages to support bi-directional telemetry. The ruggedized switch provides the Ethernet backbone on the aircraft which supports the transport of packetized telemetry data from the onboard instrumentation systems to the telemetry transceiver which transmits the data to the control room.			

Exhibit R-2A, RDT&E Project Justification: PB 2021 Office of the Secretary Of Defense		Date: February 2020
Appropriation/Budget Activity 0400 / 3	**R-1 Program Element (Number/Name)** PE 0603941D8Z / *Test and Evaluation/ Science and Technology*	**Project (Number/Name)** 092 / *Spectrum Efficient Technology*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2019	FY 2020	FY 2021
The SET project successfully demonstrated a software tool capable of accurately estimating current and future spectrum needs. The tool accounted for actual versus scheduled utilization of the spectrum and quantified the cost and schedule implications of the loss of needed spectrum. The spectrum efficient metrics tool provides spectrum managers a planning tool and also provides justification data needed to retain spectrum. The SET project also developed an optimized frequency planning tool supporting frequency re-use planning algorithms for telemetry networks and legacy telemetry systems. This planning tool provides next generation spectrum planning tools allowing for dynamic frequency re-allocation. The SET project completed risk reduction on a networked data recorder and data transmission scheme in support of CTEIP networked telemetry projects. The networked data recorder addressed CTEIP requirements for data recording and parametric extraction during flight testing. The networked data recorder was used as the primary data recorder during CTEIP flight tests. The data transmission scheme is designed to minimize the amount and type of data transmitted over the telemetry network, reducing the amount of bandwidth consumed during a test event. This technology enables more efficient use of the RF spectrum by reducing the amount of data transmitted by only transmitting data parameters when changes occur. ***FY 2020 Plans:*** The SET project will continue to investigate multi-band transceivers operating in the L/S/C-Band spectrum employing multiple advanced modulation schemes showing the ability to change both the frequency and modulation scheme of the telemetry system in near real time based on telemetry link performance and environmental conditions. This technology will determine the performance of the telemetry link and select the optimal modulation scheme based on current link conditions, accounting for issues such as multipath. The SET project will continue to develop technologies to address over-the-horizon telemetry requirements to support the testing of large footprint, long range missiles and hypersonic weapons. A phased array antenna suitable for mounting on a UAS will continue development and its antenna gain performance characterized in a high fidelity laboratory and open air environment. A modular digital beam-forming solution to control a phased array antenna and track multiple targets simultaneously will continue maturation. These technologies will significantly reduce the system complexity for an airborne phased array antenna, providing savings in terms of size, weight, and power consumption. ***FY 2021 Plans:*** The SET project will further advance development of technologies required for network and cellular based telemetry. Airborne phased array telemetry antenna technologies will continue to be matured. Technology enabling the compression of Pulse Code Modulation (PCM) data will transition to support aeronautical telemetry requirements at several test ranges. Efforts to develop spectrum management tools to optimize the use of available RF spectrum and accurately quantify RF spectrum usage on DoD test ranges will complete. Progress will be made on the development of techniques to assess the health and performance of			

Exhibit R-2A, RDT&E Project Justification: PB 2021 Office of the Secretary Of Defense		Date: February 2020
Appropriation/Budget Activity 0400 / 3	**R-1 Program Element (Number/Name)** PE 0603941D8Z / *Test and Evaluation/ Science and Technology*	**Project (Number/Name)** 092 / *Spectrum Efficient Technology*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2019	FY 2020	FY 2021
wireless ground based test support networks in real-time using unobtrusive and bandwidth efficient methods. The SET project will also continue to leverage cellular technologies to support aeronautical telemetry requirements. ***FY 2020 to FY 2021 Increase/Decrease Statement:*** Program Adjustments			
Accomplishments/Planned Programs Subtotals	10.682	9.340	9.725

C. Other Program Funding Summary ($ in Millions)

N/A

Remarks

D. Acquisition Strategy

N/A

Exhibit R-2A, RDT&E Project Justification: PB 2021 Office of the Secretary Of Defense			Date: February 2020
Appropriation/Budget Activity 0400 / 3	R-1 Program Element (Number/Name) PE 0603941D8Z / *Test and Evaluation/ Science and Technology*	Project (Number/Name) 093 / *Electronic Warfare Test*	

COST ($ in Millions)	Prior Years	FY 2019	FY 2020	FY 2021 Base	FY 2021 OCO	FY 2021 Total	FY 2022	FY 2023	FY 2024	FY 2025	Cost To Complete	Total Cost
093: *Electronic Warfare Test*	85.364	12.478	12.808	45.980	-	45.980	15.675	20.452	14.318	14.604	Continuing	Continuing

A. Mission Description and Budget Item Justification

In order to establish dominance in the modern battlespace, our offensive and defensive electronic warfare systems must be capable against advanced radio frequency (RF) directed threats and electro-optic (EO) guided threats, which include infrared (IR) guidance. Ensured dominance in these areas requires more robust test and evaluation (T&E) with technologies that are rapidly adaptable to changing threats.

Readily available, IR seeking, man-portable air defense systems (MANPADS) are difficult to detect and pose an imminent and lethal threat to military aircraft of all types. Our ability to counter such threats is essential to owning the battlespace in theater. Therefore, the ability to test missile warning systems (MWS), hostile fire indicator (HFI) systems, IR countermeasures (IRCM), and advanced threat sensors is critical to our national defense. Additionally, a new generation of enemy RF missile seekers is both currently fielded and in further development, requiring a correspondingly new generation of test technologies to test the latest countermeasures. The T&E community is required to test IRCM and RF countermeasure systems in a repeatable manner with ground-truth data before and after integration into warfighting systems. Without new test technologies, the Department of Defense (DoD) will be unable to perform adequate T&E of advanced warning and countermeasure systems.

The technology development efforts within the Electronic Warfare Test (EWT) project have been prioritized to align with DoD guidance on science and technology priority investments. As such, the EWT project is focusing on the test needs in both the EO, including IR, and the RF threat domains. Additionally, development of core test technologies in this area can be leveraged to meet other EO and RF test requirements, such as in fire control systems; intelligence, surveillance and reconnaissance (ISR) sensors, and weapon seekers.

The EWT project develops test technologies to stimulate IRCM and RF system sensors through the high-fidelity simulation of scenes viewed by the sensors. Stimulation can be as simple as testing to see if a system under test responds to an image or as complex as simulating complex battle space phenomena to measure the response of a system under test in a more relevant, cluttered scenario. Simulations and stimulations are used at open air ranges and in installed system test facilities (ISTF), and in hardware-in-the-loop (HWIL) test beds.

B. Accomplishments/Planned Programs ($ in Millions)	FY 2019	FY 2020	FY 2021
Title: Electronic Warfare Test	12.478	12.808	45.980
Description: The EWT project continued to develop high fidelity scene generation technology for both EO and RF environments. Work continued on the development of hardware and software that generates large number of independent radar targets in a high fidelity hardware-in-the-loop facility. This enabled chamber testing of radars in more dense target environments by generating large numbers of dissimilar false targets. Work continued on high temperature IR scene projectors. Work continued on increasing the efficiency of LED pixels for use in IR scene projectors. Work continued on development of interfaces for use of Active Electronically scanned arrays for open air range threat simulators.			
FY 2020 Plans: The EWT project will continue prior year efforts to improve the electronic warfare T&E infrastructure. The EWT project will continue the development of wideband, high power EW systems using solid state emitters. This technology enables high fidelity			

Exhibit R-2A, RDT&E Project Justification: PB 2021 Office of the Secretary Of Defense		Date: February 2020
Appropriation/Budget Activity 0400 / 3	**R-1 Program Element (Number/Name)** PE 0603941D8Z / *Test and Evaluation/ Science and Technology*	**Project (Number/Name)** 093 / *Electronic Warfare Test*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2019	FY 2020	FY 2021
threat simulation of next-generation surface-to-air missile systems on a variety of range systems. Technologies to support adaptive EW testing will continue to be investigated. EWT will consider new technologies for lasers or LEDS for open air range IRCM testing. EWT will continue investigating high speed techniques for converting terrain database images for IR scene generation. EWT will also look at surrogate missiles for IRCM open air range testing. EWT will also continue investigating an EW arena to address the “many on many” EW scenarios that need to be tested in a live/virtual/constructive environment. ***FY 2021 Plans:*** The EWT project will continue prior year efforts to improve the electronic warfare T&E infrastructure. Investigation of alternative technologies for IR scene projectors that reach higher apparent temperatures will continue. Progress will continue on the development of reconfigurable Active Electronically scanned arrays for open air range threat simulators. Design and develop an unmanned rapid prototype target to test sensors and DoD systems against 5th generation electronic warfare threats. The prototype target will enable the testing and assessment of advanced electronic attack measures. Initiate a flight test campaign with the unmanned prototype target to verify system performance and demonstrate 5th generation attributes. ***FY 2020 to FY 2021 Increase/Decrease Statement:*** FY 2021 increase to address 5th generation electronic warfare threats.			
Accomplishments/Planned Programs Subtotals	12.478	12.808	45.980

C. Other Program Funding Summary ($ in Millions)

N/A

Remarks

D. Acquisition Strategy

N/A

Exhibit R-2A, RDT&E Project Justification: PB 2021 Office of the Secretary Of Defense			Date: February 2020
Appropriation/Budget Activity 0400 / 3	R-1 Program Element (Number/Name) PE 0603941D8Z / *Test and Evaluation/ Science and Technology*	Project (Number/Name) 094 / *Advanced Instrumentation Systems Technology*	

COST ($ in Millions)	Prior Years	FY 2019	FY 2020	FY 2021 Base	FY 2021 OCO	FY 2021 Total	FY 2022	FY 2023	FY 2024	FY 2025	Cost To Complete	Total Cost
094: *Advanced Instrumentation Systems Technology*	58.970	11.517	10.583	11.034	-	11.034	11.213	11.760	12.007	12.247	Continuing	Continuing

A. Mission Description and Budget Item Justification

The Advanced Instrumentation Systems Technology (AIST) project addresses the test technology gaps resulting from emerging weapon systems that need to be tested at Department of Defense (DoD) open air ranges, undersea ranges, installed systems test facilities, hardware-in-the-loop laboratories, and measurement test facilities. Instrumentation requirements for systems under test are increasing exponentially for new weapons systems. Vehicle-borne and warfighter-wearable instrumentation packages are required. This instrumentation is for sensing and collecting critical performance data; determining accurate time, space, position information (TSPI)and attitude information; interfacing with command and control data links; monitoring and reporting system-wide communications; recording human operator physical and cognitive performance; and storing and transmitting data.

The technology development efforts within the AIST project have been prioritized to align with DoD guidance on science and technology (S&T) communities of interest (COIs). The AIST project is focused on supporting technology developments for advanced time, space, position information (TSPI) instrumentation (especially with limited or no availability of the Global Positioning System (GPS)), advanced sensors, advanced energy and power systems for instrumentation, non-intrusive instrumentation, mitigating range encroachment issues, and measuring warfighter physical and cognitive performance. The AIST project addresses requirements for miniaturized, non-intrusive instrumentation suites with increased survivability in harsh environments. Such instrumentation is an urgent need because minimal space is available to add instrumentation to new or existing weapon systems subsequent to their development; furthermore, additional weight and power from instrumentation can adversely affect weapon system signature and performance. Instrumentation for humans-in-the-loop, such as dismounted warfighters, must not adversely affect performance, induce artificiality in the test environment, nor create operational burden. New technologies can be exploited to integrate small, non-intrusive instrumentation into emerging platforms during design and development, and, in some cases, into existing platforms. This class of instrumentation will provide critical system performance data during operational test (OT) and continuous assessment throughout a system's lifecycle. Technology developed under AIST can also benefit training and combat missions by enabling a continual feedback loop between the developer, training staff, operators and commanders.

B. Accomplishments/Planned Programs ($ in Millions)	FY 2019	FY 2020	FY 2021
Title: Advanced Instrumentation Systems Technology	11.517	10.583	11.034
Description: Major thrusts included continuing efforts in advanced sensors, TSPI instrumentation, warfighter physical and cognitive assessment under various workloads and mitigation of test range encroachments. The AIST project transitioned a system to the U.S. Army's Test & Evaluation Command (ATEC) that measures and assesses warfighter cognitive performance under realistic conditions during a T&E event. A personnel tracking system using amplitude modulation (AM) band signals was developed and tested in a relevant environment before transition. The AIST project continued development of technology to evaluate back face deformation of body armor from a blunt trauma event, with final testing planned at Aberdeen Test Center's Light Armor Range Complex.			

Exhibit R-2A, RDT&E Project Justification: PB 2021 Office of the Secretary Of Defense		Date: February 2020
Appropriation/Budget Activity 0400 / 3	**R-1 Program Element (Number/Name)** PE 0603941D8Z / *Test and Evaluation/ Science and Technology*	**Project (Number/Name)** 094 / *Advanced Instrumentation Systems Technology*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2019	FY 2020	FY 2021
The AIST project continued an effort to develop a high fidelity model which takes into account the noisier acoustic properties of shallow water environments (120 feet to 900 feet) for littoral T&E. The model will support early evaluation of undersea test range technologies (e.g., hydrophone arrays, new communication signals/modulations, transducers, and portable instrumentation). ***FY 2020 Plans:*** The AIST project will initiate development of multi-disciplinary technologies addressing T&E requirements for countering small Unmanned Air Systems (UAS) and real-time casualty assessment (RTCA)of warfighter and weapons engagements; sensors to support advanced hypervelocity projectile testing; TSPI data fusion algorithms and technologies; high precision range radar technology to better address current and emerging requirements to track and measure the dynamics of multiple small and large closely spaced objects (e.g., dispensing of sub-munitions, debris, warhead particles, and swarms of independent autonomous airborne vehicles); energy and power for rapidly deployable sea ranges; advanced non-intrusive data management techniques; and mitigation technologies for monitoring effects from electromagnetic interference from solar power towers. The AIST project will complete fiber optic shape sensing technology that accurately provides dynamic measurements during the time history of back face deformation of body armor from a blunt trauma event. The AIST project will investigate technology development of passive imaging technology to derive size, shape, mass, drag coefficients, velocity and vectors for individual fragments during live warhead testing in support of hypersonic high speed test track testing and Broad Ocean Area (BOA) terminal scoring. This technology allows testers to quickly characterize the fragment characteristics and distribution from a munition explosion. ***FY 2021 Plans:*** The AIST project will continue development of: multi-disciplinary technologies addressing T&E requirements for countering small unmanned air systems (UAS) and real-time casualty assessment (RTCA) of warfighter and weapons engagements; sensors to support advanced hypervelocity projectile testing; TSPI data fusion algorithms and technologies; high precision range radar technology; improved energy and power density systems for T&E; advanced non-intrusive data management techniques; and mitigation technologies for monitoring effects from encroachment on test ranges. The AIST project will also continue the investigation and development of advanced instrumentation technologies to support lethality testing and end game scoring of hypersonic systems. ***FY 2020 to FY 2021 Increase/Decrease Statement:*** Program Adjustments			
Accomplishments/Planned Programs Subtotals	11.517	10.583	11.034

C. Other Program Funding Summary ($ in Millions)

N/A

Exhibit R-2A, RDT&E Project Justification: PB 2021 Office of the Secretary Of Defense		Date: February 2020
Appropriation/Budget Activity 0400 / 3	**R-1 Program Element (Number/Name)** PE 0603941D8Z / *Test and Evaluation/ Science and Technology*	**Project (Number/Name)** 094 / *Advanced Instrumentation Systems Technology*

C. Other Program Funding Summary ($ in Millions)

Remarks

D. Acquisition Strategy

N/A

Exhibit R-2A, RDT&E Project Justification: PB 2021 Office of the Secretary Of Defense			Date: February 2020
Appropriation/Budget Activity 0400 / 3	R-1 Program Element (Number/Name) PE 0603941D8Z / *Test and Evaluation/ Science and Technology*	Project (Number/Name) 095 / *Directed Energy Test*	

COST ($ in Millions)	Prior Years	FY 2019	FY 2020	FY 2021 Base	FY 2021 OCO	FY 2021 Total	FY 2022	FY 2023	FY 2024	FY 2025	Cost To Complete	Total Cost
095: *Directed Energy Test*	59.282	8.654	11.032	10.096	-	10.096	10.572	10.932	11.057	11.278	Continuing	Continuing

A. Mission Description and Budget Item Justification

The Department of Defense (DoD) is exploring the military utility, safety, and suitability of directed energy weapons. A robust test capability to assess directed energy weapons is essential to understanding their effectiveness and limitations, including determining their effectiveness in performing counter improvised explosive device (C-IED) operations. Such assessments will depend upon knowledge acquired through the test and evaluation (T&E) of directed energy technologies and testing of operational concepts. Directed energy weapon technologies, primarily consisting of high energy lasers (HEL) and high powered microwaves (HPM), are outpacing available test capabilities. Traditional test techniques for evaluating conventional munitions (with flight times ranging from seconds to minutes) are not sufficient for the T&E of directed energy weapons that place energy on target instantaneously. Consequently, new test technology solutions are needed to ensure that adequate developmental, live-fire, and operational test capabilities are available when directed energy programs are ready to test.

Directed energy system and component testing requires three principal assessments: (1) energy or power on target; (2) the effects on the target; and (3) the propagation of the directed energy to the target through the atmosphere. In addition, the vulnerabilities of DoD systems to directed energy threats are required to be characterized, such as those requirements captured in Military Standard (MIL-STD)-464C. Equally as important, current test capabilities do not provide the detailed data required to understand U.S. directed energy system performance and effects. The technology development efforts within the Directed Energy Test (DET) project have been prioritized to align with DoD guidance on science and technology priority investments. As such, the DET project is developing the technologies necessary for quantitative assessment of United States (U.S.) HEL and HPM performance, as well as the vulnerability of DoD weapon systems to enemy directed energy threats.

B. Accomplishments/Planned Programs ($ in Millions)	FY 2019	FY 2020	FY 2021
Title: Directed Energy Test	8.654	11.032	10.096
Description: The DET project continued efforts to measure HEL energy on small targets such as mortars. The effort designed a recoverable mortar prototype to address Army and Navy requirements and an Air Force requirement for a missile-mounted target board. The DET project continued efforts to develop M&S capability for assessing effects of threat HEL systems on blue aircraft. The DET project continued to mature a dense plasma focus technology to produce strategically relevant, ultra-short pulse neutron fluence levels for nuclear vulnerability testing. The DET project successfully demonstrated neutron production and dense plasma focus technology development continues to be optimized to support neutron production rates scalable to a test facility to be developed by the Central Test and Evaluation Investment Program (CTEIP). A larger chamber was integrated into the facility to test obtaining higher yields. The DET project initiated efforts to support testing of an HPM system integrated with a munition. The DET project initiated new developments in HPM envelope detection. A prototype vertical sensor net array was demonstrated with 4 prototype nodes. The prototype nodes achieved 'first light' at the High Energy Microwave Laboratory (HEML) facility at Kirtland AFB after being exposed to L-band radiation. This prototype sensor array provides rapid/ field expedient diagnostic of a High Power Microwave beam in the far field.			
FY 2020 Plans:			

Exhibit R-2A, RDT&E Project Justification: PB 2021 Office of the Secretary Of Defense		Date: February 2020
Appropriation/Budget Activity 0400 / 3	**R-1 Program Element (Number/Name)** PE 0603941D8Z / *Test and Evaluation/ Science and Technology*	**Project (Number/Name)** 095 / *Directed Energy Test*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2019	FY 2020	FY 2021
Investments in HEL test technologies will continue to assess the changes in HEL effects due to the shift of HELs to shorter wavelengths near one micron. These technology developments will include efforts to characterize the performance of HEL systems as they engage small targets such as enemy rockets, missiles, artillery, and unmanned aerial vehicles. DET will investigate technologies for assessing the aero-optical effects on HEL propagated from aircraft. DET will continue expansions of efforts to instrument UAVs and other targets with HEL target boards for open air range testing. In the HPM area, measuring the actual cause of HPM effects on electronics will be addressed by measurement of electrical currents within the wires and chips of the electronic targets. DET will continue to investigate new technologies to continue the development of sources for MIL-STD-464C testing. DET will invest in surrogate HPM sources for testing HPM lethality on threat representative targets. DET will also develop X-band sources for use in munitions seeker vulnerability testing. DET will also investigate instrumentation for assessing HPM effects on small UAVs. ***FY 2021 Plans:*** The DET project will continue developments in HEL test technologies and HPM test technologies to characterize the performance and effectiveness of HEL and HPM systems as they engage small targets, such as enemy rockets, missiles, artillery, and unmanned aerial vehicles, as well as electronic systems and other targets of interest. ***FY 2020 to FY 2021 Increase/Decrease Statement:*** Program Adjustments			
Accomplishments/Planned Programs Subtotals	8.654	11.032	10.096

C. Other Program Funding Summary ($ in Millions)

N/A

Remarks

D. Acquisition Strategy

N/A

Exhibit R-2A, RDT&E Project Justification: PB 2021 Office of the Secretary Of Defense			Date: February 2020
Appropriation/Budget Activity 0400 / 3	R-1 Program Element (Number/Name) PE 0603941D8Z / *Test and Evaluation/ Science and Technology*	Project (Number/Name) 096 / *C4I & Software Intensive Systems Test*	

COST ($ in Millions)	Prior Years	FY 2019	FY 2020	FY 2021 Base	FY 2021 OCO	FY 2021 Total	FY 2022	FY 2023	FY 2024	FY 2025	Cost To Complete	Total Cost
096: *C4I & Software Intensive Systems Test*	107.237	12.381	11.297	11.977	-	11.977	12.131	12.637	12.763	13.018	Continuing	Continuing

A. Mission Description and Budget Item Justification

The Command, Control, Communications, Computers, Intelligence (C4I) and Software Intensive Systems (SIS) (C4T) project addresses test technology gaps in the rapid advancement of C4T warfighting systems. The C4T technology gaps are driven by the more complex environments and distributed systems (e.g. Anti-Access Arial Denial (A2AD); Manned and Unmanned Systems (MUM-T)); big data and intelligence (e.g. Artificial General Intelligence (AGI) and Machine Learning Algorithms (MLA)); and more software intensive systems (e.g. F-35). The technology development efforts within the C4T project have been prioritized to align with DoD guidance on S&T Communities of Interest (CoIs). C4T is developing technologies, including leveraging advancements in machine learning, to analyze and evaluate the increasing mass of structured and unstructured data generated by C4I and SIS testing. The technologies are required when testing sensor platforms, command and control systems and weapon platforms that support the kill chain in a Joint operation. These systems must be evaluated for their ability to provide the accurate, timely transfer of data (e.g. target tracks, weapons allocation, mission tasking, and situational awareness) as the data passes among the Services and coalition participants.
The technologies within C4T will remove undesired distributed testing biases while improving test agility and the tester's ability to effectively support knowledge management, rapid analysis of "Big Data," and automated test reporting. The C4T project advances test automation features (test planning, test execution, Big Data collection, analysis, and visualization) that enable the virtual integration of Department of Defense (DoD) weapon laboratories and open air ranges. Using Modeling and Simulation (M&S) along with hardware-in-the-loop (HWIL) laboratories, the effectiveness of Joint missions can be assessed in terms of system-of-systems interoperability and effectiveness in executing Joint mission operations, including testing of weapons and C4I and SIS systems accessing and providing information.

B. Accomplishments/Planned Programs ($ in Millions)	FY 2019	FY 2020	FY 2021
Title: C4I and Software Intensive Systems Test	12.381	11.297	11.977
Description: The C4T project continued development of AI technologies in multiple areas of "Big Data" rapid analytics of large structured and unstructured datasets in support of F-35 Test and Evaluation (T&E). This includes the development of an analyst assisting Time Space Position Information (TSPI) tool. The TSPI tool is based on a learning system that combines the analysts' knowledge with the classification knowledge obtained from big data techniques and applies human-like reasoning to achieve an automated post mission processing tool. The C4T project continued development of M&S technologies to support real-time assessments of complex environments such as undersea environments. These technologies provided an acoustic propagation model, both narrow and broad band, of sufficient fidelity to test torpedo performance in various maritime tactical environments. The model included a real-time simulation/ emulation system for testing torpedo sonar systems in multiple bathometry, biological and threat environments. The C4T project completed development of technologies to provide a reliable, fast, and cost-effective approach that enables direct injection Live Virtual Constructive (LVC) testing of next generation weapon systems. The C4T project continued development of a configuration optimization of test support networks. Technologies included planning expeditionary tests, managing bandwidth			

Exhibit R-2A, RDT&E Project Justification: PB 2021 Office of the Secretary Of Defense		Date: February 2020
Appropriation/Budget Activity 0400 / 3	**R-1 Program Element (Number/Name)** PE 0603941D8Z / *Test and Evaluation/ Science and Technology*	**Project (Number/Name)** 096 / *C4I & Software Intensive Systems Test*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2019	FY 2020	FY 2021
and spectrum contention with a networked system under test, managing battery consumption, providing Real-Time Casualty Assessment (RTCA) data during live tests and providing continuous re-planning capability. These technologies will address deficiencies in Army Operational Test (OT) for network-enabled technologies. The C4T project initiated the development of deep neutral network technologies for real-time Automated Target Recognition (ATR) using real and synthetic data. These technologies are being developed to support Unmanned Aerial Vehicle (UAV) target recognition. ***FY 2020 Plans:*** The C4T project will continue to invest in developing C4I and SIS technologies to support complex and distributed environments assessing DoD platforms employing “Big Data” techniques with a specific focus on tactical systems and warfighter systems in a net-enabled, dynamic environment. Technology developments will focus on semantic analysis of large structured and unstructured data sets. These technology developments will include the ability to process unstructured test data into a structured format for analysis using D2D algorithms. Further work on the correlation and analysis of "Big Data" from multiple sources will continue. Development of techniques to automate the reuse of knowledge to enable continuous developmental testing throughout the lifecycle of weapon systems will continue. Additional investments will be targeted at assessing warfighter systems that in themselves implement D2D, big data, and deep learning technologies. C4T will continue to develop technologies that mitigate data biases introduced by the test infrastructure. Development will continue on LVC technologies for use by C4I systems to utilize a synthetic battlespace environment to augment the open-air range with vast simulated areas, frequency ranges, and transmitter entities for T&E in contested/dense communications environments. Multi-Level Security (MLS) and Cross Domain Solution (CDS) technologies will be investigated with the goals of improving the automation of preparing test data for analysis as well as facilitating automated sharing of information across all security enclaves. C4T will investigate M&S technologies to support emulation and stimulation of networks for conducting T&E. C4T will continue to develop representations of systems, communications and environments with the necessary fidelity and run-time performance crucial for the successful testing at HWIL laboratories, installed system test facilities, and open air ranges. Investments for new technologies addressing: testing warfighter systems employing agile communications, effectiveness evaluation in a mission context, analytics for database intensive warfighter systems, automated test planning, the design of experiments, machine cognitive analysis, and testing human-computer interactions. Further work targeted at technologies for analysis of large test databases for the F-35 will continue and become tailored for use by ranges supporting live testing for the aircraft. ***FY 2021 Plans:***			

Exhibit R-2A, RDT&E Project Justification: PB 2021 Office of the Secretary Of Defense		Date: February 2020
Appropriation/Budget Activity 0400 / 3	**R-1 Program Element (Number/Name)** PE 0603941D8Z / *Test and Evaluation/ Science and Technology*	**Project (Number/Name)** 096 / *C4I & Software Intensive Systems Test*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2019	FY 2020	FY 2021
The C4T project will investigate M&S technologies to support emulation and stimulation of networks for conducting T&E. The C4T project development will focus on the verification and validation (V&V) of the M&S test environment across battlespace environments in support of both Developmental Test (DT) and OT. The C4T project will continue to develop representations of systems, communications and environments with the necessary fidelity and run-time performance crucial for the successful testing at HWIL laboratories, installed system test facilities, and open air ranges. Continued work targeted at technologies for analysis of large test databases for the F-35 will continue and become tailored for use by ranges supporting live testing for the aircraft along with technologies to assist analysts with the reduction of large complex TSPI datasets. The C4T project will also focus on: testing warfighter systems employing agile communications, effectiveness evaluation in a mission context, analytics for database intensive warfighter systems, and automated test planning and assessments. ***FY 2020 to FY 2021 Increase/Decrease Statement:*** Program Adjustments			
Accomplishments/Planned Programs Subtotals	12.381	11.297	11.977

C. Other Program Funding Summary ($ in Millions)

N/A

Remarks

D. Acquisition Strategy

N/A

Exhibit R-2A, RDT&E Project Justification: PB 2021 Office of the Secretary Of Defense			Date: February 2020
Appropriation/Budget Activity 0400 / 3	R-1 Program Element (Number/Name) PE 0603941D8Z / *Test and Evaluation/ Science and Technology*	Project (Number/Name) 097 / *Autonomy and Artificial Intelligence Test*	

COST ($ in Millions)	Prior Years	FY 2019	FY 2020	FY 2021 Base	FY 2021 OCO	FY 2021 Total	FY 2022	FY 2023	FY 2024	FY 2025	Cost To Complete	Total Cost
097: *Autonomy and Artificial Intelligence Test*	40.518	14.490	11.050	10.648	-	10.648	11.090	11.641	11.873	12.110	Continuing	Continuing

Note

Starting in FY2020, Project 097 title will change FROM "Unmanned and Autonomous Systems Test" TO "Autonomy and Artificial Intelligence Test" to more accurately define and describe project workload in terms of the National Defense Strategy and the Under Secretary of Defense (Research and Engineering) prioritization of Artificial Intelligence and machine learning.

A. Mission Description and Budget Item Justification

Unmanned and autonomous systems support every domain of warfare -- operating in space, in air, on land, on the sea surface, undersea and in subterranean conditions to support a vast variety of missions. The emergence of Artificial Intelligence (AI) brings a host of revolutionary capabilities that will profoundly influence warfare. The UAST project addresses current and emerging challenges associated with the test and evaluation (T&E) of unmanned systems, particularly in testing autonomy, artificial intelligence, and machine learning. As such, the UAST project is developing test technologies to simulate, stimulate, instrument, measure, and assess an autonomous system's ability to perceive its environment, process information, adapt to dynamic conditions, make decisions, and effectively act on those decisions in the context of mission execution.

The UAST project will provide the test technologies to effectively measure performance and characterize risk, thereby increasing warfighter trust in autonomous systems and artificial intelligence tools. Current DoD test capabilities and methodologies are insufficient to address the testing of increasingly autonomous units operating in unstructured, dynamic, battlespace environments. Furthermore, advancements are being made in developing collaborating, system-of-autonomous-systems that will work in concert as a swarm or pack and in close proximity with humans. New test technologies are needed to stress the collective set of autonomous systems under realistic conditions, predict emergent behavior of autonomous systems, emulate the complex environment, and assess mission performance of these highly coupled and artificially intelligent systems.

B. Accomplishments/Planned Programs ($ in Millions)	FY 2019	FY 2020	FY 2021
Title: Autonomy and Artificial Intelligence Test	14.490	11.050	10.648
Description: The AAIT project continued test technology development supporting the near term challenges identified in the 2013–2038 DoD Unmanned Systems Integrated Roadmap, such as, integrating DoD unmanned systems within the National Airspace and safely operating unmanned aerial systems within the Major Range and Test Facility Bases (MRTFB). The AAIT project collaborated with the Autonomy Community of Interest (COI) Test and Evaluation, Verification and Validation (TEVV) Working Group to ensure that the AAIT project is investing in technologies relevant to the future of autonomous systems. The AAIT project explored technologies required for T&E of emerging UAS architectures, functional components, and interfaces. The AAIT project emphasized autonomy test technologies that can be integrated for use in a Test and Training Enabling Architecture (TENA) environment within the MRTFB. The AAIT project continued investments in robustness testing technology to detect and predict vulnerabilities and failures within UAS software. The AAIT project transitioned developments to automatically			

Exhibit R-2A, RDT&E Project Justification: PB 2021 Office of the Secretary Of Defense		Date: February 2020
Appropriation/Budget Activity 0400 / 3	**R-1 Program Element (Number/Name)** PE 0603941D8Z / *Test and Evaluation/ Science and Technology*	**Project (Number/Name)** 097 / *Autonomy and Artificial Intelligence Test*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2019	FY 2020	FY 2021

predict test vehicle collision potentials and cue test range controllers to take corrective action. These technologies prevent the test vehicle from violating flight envelopes, range boundaries, and warning areas. The AAIT project completed an effort to develop a software tool that will enable testers to monitor the internal autonomous processing states of a system under test without interfering with its operations or requiring modification to the system's software or hardware. The AAIT project completed efforts that rapidly identify challenging test scenarios for an undersea unmanned vehicle (UUV) under test. The effort identified performance boundaries for autonomy as they relate to the environment, mission, and vehicle state spaces; this technology transitioned to the Naval Undersea Warfare Center-Keyport.

The AAIT project continued development of technology to address the T&E of ground and air autonomy using optimization algorithms to rapidly generate salient test scenarios. Expansion to the ground domain continued with the integration of AAIT technology into the Autonomous Ground Resupply (AGR) autonomy within the Autonomous Navigation Virtual Environment Laboratory (ANVEL) simulation. The integrated autonomy simulation will be used to validate AAIT technologies in the ground domain. New architecture and state space designs better support multiple domains of autonomy testing. Unmanned Ground Vehicle and Undersea Vehicle domains test technology development will risk reduce CTEIP autonomous test capability development efforts.

FY 2020 Plans:

The AAIT project will continue to initiate and develop technologies to support autonomous system test planning, autonomous system test execution, and autonomous system performance assessment. Efforts within test planning will include predicting autonomous behavior for testing and assuring thorough testing of autonomous systems. Investments in test execution will include: enhancing safety of autonomous system testing; creating test environments that are complex, immersive, and reactive; and adapting ranges to cognitive, autonomous system testing. Developments under performance assessment will include: testing and evaluating UAS-to-UAS and human-to-UAS interactions and measuring autonomous system reliability.

The AAIT project will complete development of technologies that automatically learn conditions for activating vulnerabilities deep within an autonomous system, using machine learning and backward chaining techniques to determine system level inputs that induce failure.

FY 2021 Plans:

The AAIT project will continue to initiate and develop technologies to support autonomous system test planning, autonomous system test execution, and autonomous system performance assessment. Efforts within test planning and assessment will transition to multiple autonomy test capabilities under development in the Central Test & Evaluation Investment Program (CTEIP) and at DoD test ranges and laboratories.

FY 2020 to FY 2021 Increase/Decrease Statement:

Exhibit R-2A, RDT&E Project Justification: PB 2021 Office of the Secretary Of Defense		Date: February 2020
Appropriation/Budget Activity 0400 / 3	**R-1 Program Element (Number/Name)** PE 0603941D8Z / *Test and Evaluation/ Science and Technology*	**Project (Number/Name)** 097 / *Autonomy and Artificial Intelligence Test*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2019	FY 2020	FY 2021
Program Adjustments			
Accomplishments/Planned Programs Subtotals	14.490	11.050	10.648

C. Other Program Funding Summary ($ in Millions)

N/A

Remarks

D. Acquisition Strategy

N/A

Exhibit R-2A, RDT&E Project Justification: PB 2021 Office of the Secretary Of Defense			Date: February 2020
Appropriation/Budget Activity 0400 / 3	R-1 Program Element (Number/Name) PE 0603941D8Z / *Test and Evaluation/ Science and Technology*	Project (Number/Name) 098 / *Cyberspace Test*	

COST ($ in Millions)	Prior Years	FY 2019	FY 2020	FY 2021 Base	FY 2021 OCO	FY 2021 Total	FY 2022	FY 2023	FY 2024	FY 2025	Cost To Complete	Total Cost
098: *Cyberspace Test*	27.358	11.002	12.688	13.170	-	13.170	13.351	13.934	14.170	14.453	Continuing	Continuing

A. Mission Description and Budget Item Justification

The Department of Defense (DoD) ability to use cyberspace for rapid communication and information sharing in support of operations is a critical enabler of DoD military missions. Advancements in utilizing cyberspace are outpacing the technologies needed for test and evaluation (T&E). The Cyberspace Test Technology (CTT) project develops advanced technologies and methodologies to test and evaluate DoD capabilities and information networks to defend and conduct full-spectrum military operations across cyberspace. Current cyberspace T&E capabilities are insufficient to support the continual experimental, contractor, developmental, operational, and live-fire testing requirements of warfighter systems operating in cyberspace. Many of the test tools and infrastructure items required for systems in cyberspace will require advancement and maturation of nascent test technologies. The CTT project will address test technology shortfalls in cyberspace testing, including planning cyberspace tests, creating representative cyberspace threats and test environments, executing cyberspace tests, and performing cyberspace test analysis and evaluation.

B. Accomplishments/Planned Programs ($ in Millions)	FY 2019	FY 2020	FY 2021
Title: Cyberspace Test	11.002	12.688	13.170

Description: The CTT project continued development of technologies to detect, monitor, and analyze malware behavior during cyber-attacks in a virtualized T&E environment. The CTT project continued development of a capability to systematically verify (attest) that all persistent storage in an aircraft's avionics subsystems have not been altered. This technology development works to ensure that a weapon system has not been modified by malicious action or legitimate cyber T&E activities. The CTT project also continued development of an assisted cyber intelligence behavior testing technology that uncovers cyber vulnerabilities at machine speed and scale. This enables the evaluation of systems under test using automated means to find and fix vulnerabilities otherwise unknown to software developers and end users.

FY 2020 Plans:

The CTT project will pursue technology developments addressing needs for three domains – Cyber-Physical Systems, Tactical Edge Networks, and Enterprise Information Systems. In Cyber Physical Systems hypervisors/emulators for Kinetic Systems and Cyber Physical Networks will continue to be developed, instrumentation for cyberspace data collection, improved cyberspace analysis tools that show real time effects of cyberspace attacks on cyber-physical systems, and cyber Test Execution Tools. In the Tactical Edge networks domain we will continue the development of scalable cyberspace test environments, develop tools for mapping complex systems in test networks, and tools for visualization. In Enterprise Information Systems, we will develop emulated Cyberspace threats, develop tools for cyberspace threat attack control, develop tools for testing resiliency of infrastructure and systems, and develop artificial intelligent analysis for enterprise threat detection and mitigation.

FY 2021 Plans:

Exhibit R-2A, RDT&E Project Justification: PB 2021 Office of the Secretary Of Defense		Date: February 2020
Appropriation/Budget Activity 0400 / 3	**R-1 Program Element (Number/Name)** PE 0603941D8Z / *Test and Evaluation/ Science and Technology*	**Project (Number/Name)** 098 / *Cyberspace Test*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2019	FY 2020	FY 2021
The CTT project will continue to pursue technology developments addressing needs in Cyber-Physical Systems, in Tactical Edge Networks, and in Enterprise Information Systems. ***FY 2020 to FY 2021 Increase/Decrease Statement:*** Program Adjustments			
Accomplishments/Planned Programs Subtotals	11.002	12.688	13.170

C. Other Program Funding Summary ($ in Millions)

N/A

Remarks

D. Acquisition Strategy

N/A