Exhibit R-2, RDT&E Budget Item Justification: PB 2022 Office of the Secretary Of Defense	Date: May 2021
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 2020	FY 2021	FY 2022 Base	FY 2022 OCO	FY 2022 Total	FY 2023	FY 2024	FY 2025	FY 2026	Cost To Complete	Total Cost
Total Program Element	743.493	186.017	178.438	267.161	-	267.161	-	-	-	-	-	-
091: *High Speed Systems Test*	227.666	89.462	101.808	108.774	-	108.774	-	-	-	-	-	-
092: *Spectrum Efficient Technology*	66.576	11.720	9.725	9.376	-	9.376	-	-	-	-	-	-
093: *Electronic Warfare Test*	97.842	16.750	9.980	90.171	-	90.171	-	-	-	-	-	-
094: *Advanced Instrumentation Systems Technology*	70.487	16.814	11.034	11.209	-	11.209	-	-	-	-	-	-
095: *Directed Energy Test*	67.936	15.001	10.096	10.568	-	10.568	-	-	-	-	-	-
096: *C4I & Software Intensive Systems Test*	119.618	10.128	11.977	12.128	-	12.128	-	-	-	-	-	-
097: *Autonomy and Artificial Intelligence Test*	55.008	11.141	10.648	11.087	-	11.087	-	-	-	-	-	-
098: *Cyberspace Test*	38.360	15.001	13.170	13.348	-	13.348	-	-	-	-	-	-
099: *Space Test*	0.000	0.000	0.000	0.500	-	0.500	-	-	-	-	-	-

Note

Starting in FY 2020, Project 097 title changed 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 2020	FY 2021	FY 2022 Base	FY 2022 OCO	FY 2022 Total
Previous President's Budget	191.574	187.065	139.577	-	139.577
Current President's Budget	186.017	178.438	267.161	-	267.161
Total Adjustments	-5.557	-8.627	127.584	-	127.584
• Congressional General Reductions	-	-			
• Congressional Directed Reductions	-	-			
• Congressional Rescissions	-	-8.500			
• Congressional Adds	-	-			
• Congressional Directed Transfers	-	-			
• Reprogrammings	-5.557	-			
• SBIR/STTR Transfer	-	-			
• DoD add for Long Range Fires Testing and Evaluation	-	-	56.300	-	56.300
• DoD add for Joint Electronic Warfareminance Modernization	-	-	74.500	-	74.500
• Program Adjustment	-	-0.127	-3.216	-	-3.216

Change Summary Explanation

The FY 2022 increase of $127.584 million is for testing in support of the Long Range Fires Testing and Evaluation and Joint Electronic Warfare Modernization.

Exhibit R-2A, RDT&E Project Justification: PB 2022 Office of the Secretary Of Defense			Date: May 2021
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 2020	FY 2021	FY 2022 Base	FY 2022 OCO	FY 2022 Total	FY 2023	FY 2024	FY 2025	FY 2026	Cost To Complete	Total Cost
091: *High Speed Systems Test*	227.666	89.462	101.808	108.774	-	108.774	-	-	-	-	-	-
Quantity of RDT&E Articles	-	-	-	-	-	-	-	-	-	-		

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 2020	FY 2021	FY 2022
Title: High Speed Systems Test	89.462	101.808	108.774
Description: The HSST project continued to advance ground and flight test technologies, techniques, instrumentation, and modeling and simulation capabilities required for the development of hypersonic weapon systems. In FY20, HSST focused primarily on two critical technology shortfalls for hypersonic test and evaluation: aerothermal and propulsion ground testing capabilities and advanced instrumentation to support hypersonic flight tests. Several other technology development efforts also progressed through the year. To address the technology shortfall involving aerothermal and propulsion testing, HSST is developing a new test facility that utilizes clean-air heat addition (non-vitiated air) and a variable Mach number (VMN) capability to provide the representative high-temperature conditions for characterizing weapon systems, including air-breathing propulsion capabilities. The clean-air heat addition is especially important to the characterization of air-breathing propulsion systems, as previous HSST efforts demonstrated			

Exhibit R-2A, RDT&E Project Justification: PB 2022 Office of the Secretary Of Defense		Date: May 2021
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 2020	FY 2021	FY 2022
that vitiated air provides different gas properties than clean air found in the atmosphere and thus is not representative of what the vehicle would experience in flight. This significantly affects the engine's performance and operability in the test environment and results in erroneous flight predictions. Additionally, characterization of advanced sensors for hypersonic systems also benefits from clean-air heat addition as it provides a more representative environment for the sensor to operate in. The variable Mach number capability provides a more representative trajectory simulation for the system under test, permitting more accurate predictions before conducting flight tests. The new test facility, called the Hypersonic Aerothermal and Propulsion Clean-Air Testbed (HAPCAT), was checked out for initial operation in FY20, including the integration of the critical subcomponents of the Regenerative Storage Heater (RSH) and the Air Delivery System (ADS). Initial checkouts were conducted at lower-hypersonic representative temperatures to demonstrate operation of the facility. Designs for advanced sensor tests were developed to support multiple sensor development efforts ongoing within hypersonic development programs. Additionally, a Preliminary Design Review was completed for the VMN capability. All of the efforts associated with HAPCAT also serve as pathfinders for the development of a larger-scale, more capable facility at AEDC. Upgrades and development efforts associated with arc heater testing were also completed in FY20. The arc heater flow quality aerothermal test technology development was completed, demonstrating novel designs for arc heater spin coil components that provide higher quality flow to test articles and increases the lifespan of electrodes required for arc heater operation. These will be used to support the Mid-Pressure Arc Heater capability being implemented at the AEDC arc heater facility. Additionally, HSST completed multiple efficiency upgrades to the AEDC arc heaters to increase capacity in response to significant test demand. Significant progress was achieved in the development of the SkyRange capability, an unmanned aerial vehicle-based range to support hypersonic flight tests and other missions for the Department of Defense. SkyRange will provide a more agile, flexible, and cost-effective method for providing support to hypersonic flight tests with increased data collection capabilities beyond the current state-of-the-art. It also addresses a critical capacity shortfall for supporting the number of hypersonic flight tests required, as a sufficient number of existing assets does not exist. RQ-4 Global Hawks and MQ-9 Reapers comprise the platforms used for SkyRange. SkyRange will augment existing air, sea, and land test support assets referred to as the "string of pearls," reducing the high costs associated with traditional flight test support. Novel sensors are being developed in the areas of telemetry capture and relay, multispectral imaging, atmospheric sensing, terminal scoring, and other areas to aid in the development of hypersonic systems. Several of these sensors are being developed through HSST for integration into the SkyRange capability. Description: The HSST project continued to advance ground and flight test technologies, techniques, instrumentation, and modeling and simulation capabilities required for the development of hypersonic weapon systems. In FY20, HSST focused			

Exhibit R-2A, RDT&E Project Justification: PB 2022 Office of the Secretary Of Defense		Date: May 2021
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 2020	FY 2021	FY 2022
primarily on two critical technology shortfalls for hypersonic test and evaluation: aerothermal and propulsion ground testing capabilities and advanced instrumentation to support hypersonic flight tests. Several other technology development efforts also progressed through the year. To address the technology shortfall involving aerothermal and propulsion testing, HSST is developing a new test facility that utilizes clean-air heat addition (non-vitiated air) and a variable Mach number (VMN) capability to provide the representative high-temperature conditions for characterizing weapon systems, including air-breathing propulsion capabilities. The clean-air heat addition is especially important to the characterization of air-breathing propulsion systems, as previous HSST efforts demonstrated that vitiated air provides different gas properties than clean air found in the atmosphere and thus is not representative of what the vehicle would experience in flight. This significantly affects the engine's performance and operability in the test environment and results in erroneous flight predictions. Additionally, characterization of advanced sensors for hypersonic systems also benefits from clean-air heat addition as it provides a more representative environment for the sensor to operate in. The variable Mach number capability provides a more representative trajectory simulation for the system under test, permitting more accurate predictions before conducting flight tests. The new test facility, called the Hypersonic Aerothermal and Propulsion Clean-Air Testbed (HAPCAT), was checked out for initial operation in FY20, including the integration of the critical subcomponents of the Regenerative Storage Heater (RSH) and the Air Delivery System (ADS).. Initial checkouts were conducted at lower-hypersonic representative temperatures to demonstrate operation of the facility. Designs for advanced sensor tests were developed to support multiple sensor development efforts ongoing within hypersonic development programs. Additionally, a Preliminary Design Review was completed for the VMN capability. All of the efforts associated with HAPCAT also serve as pathfinders for the development of a larger-scale, more capable facility at AEDC. Upgrades and development efforts associated with arc heater testing were also completed in FY20. The arc heater flow quality aerothermal test technology development was completed, demonstrating novel designs for arc heater spin coil components that provide higher quality flow to test articles and increases the lifespan of electrodes required for arc heater operation. These will be used to support the Mid-Pressure Arc Heater capability being implemented at the AEDC arc heater facility. Additionally, HSST completed multiple efficiency upgrades to the AEDC arc heaters to increase capacity in response to significant test demand. Significant progress was achieved in the development of the SkyRange capability, an unmanned aerial vehicle-based range to support hypersonic flight tests and other missions for the Department of Defense. SkyRange will provide a more agile, flexible, and cost-effective method for providing support to hypersonic flight tests with increased data collection capabilities beyond the current state-of-the-art. It also addresses a critical capacity shortfall for supporting the number of hypersonic flight tests required, as a sufficient number of existing assets does not exist. RQ-4 Global Hawks and MQ-9 Reapers comprise the platforms used for			

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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 2020	FY 2021	FY 2022
SkyRange. SkyRange will augment existing air, sea, and land test support assets referred to as the “string of pearls,” reducing the high costs associated with traditional flight test support. Novel sensors are being developed in the areas of telemetry capture and relay, multispectral imaging, atmospheric sensing, terminal scoring, and other areas to aid in the development of hypersonic systems. Several of these sensors are being developed through HSST for integration into the SkyRange capability. Achievements were made for both SkyRange aircraft platforms in FY20. Work continued on the modification of two RQ-4s to facilitate eventual sensor package integration as part of SkyRange. Upon completion, this will result in three operational RQ-4s for SkyRange. For the MQ-9s, six aircraft were acquired and stationed at the main operating base in California. These MQ-9s will be used for integrating various sensors, generally through the use of pylon-carried pods. The development, integration, and operation of a phased-array telemetry capability continued as part of SkyRange. Various checkouts of the telemetry system were performed while installed on an RQ-4 as part of the development of this capability to support hypersonic flight tests. Progress continued on the development of a high-fidelity automated and reconfigurable multispectral imaging tracking system for integration into an RQ-4 Global Hawk as part of the overall SkyRange capability. Design of the system was completed and fabrication and assembly progressed toward ground checkouts of the system. Development of an airborne variant of the High-Altitude LIDAR Atmospheric Sensing (HALAS) system continued, with a prototype version successfully installed on a Gulfstream G-IV business jet. Flight operations were conducted to acquire atmospheric data in an operational environment, and the data will be used to inform the design of the HALAS system for integration on an unmanned RQ-4 Global Hawk as part of the overall SkyRange capability. Development of a ground based multispectral thermal imaging prototype was completed to enable collection of thermal imagery in the terminal phase of a hypersonic flight test for thermal protection system evaluation. The system was deployed to the Kwajalein Atoll to support terminal phase data collection for a hypersonic flight test, and the prototype successfully acquired thermal imagery data that was subsequently provided to the weapon system program. Initial evaluation of the imagery indicated a successful deployment. Additional upgrades and technology development continued at the CUBRC hypersonic shock and expansion wind tunnels to support hypersonic ground testing. These included the design of fast-response force and moment balances for use in the CUBRC facilities, and multiple non-intrusive diagnostic systems for evaluation of hypersonic systems. In addition to these upgrades, a			

Exhibit R-2A, RDT&E Project Justification: PB 2022 Office of the Secretary Of Defense		Date: May 2021
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 2020	FY 2021	FY 2022
new effort was initiated to develop and demonstrate a new test facility that utilizes wave rotor technologies for extended run-times with representative conditions at hypersonic speeds. ***FY 2021 Plans:*** In FY21, HSST will continue to focus on critical hypersonic test and evaluation shortfalls to address the Department's push to develop hypersonic systems. This includes executing efforts that will have near-term benefits to current weapon programs as well as addressing longer-term technology development requirements to support next-generation weapon systems. HSST will continue the development of the HAPCAT facility to support aerothermal, propulsion, and seeker/sensor performance testing. Checkout testing will be conducted at the upper envelope of the facility to demonstrate full operation of the facility and validate the enabling technologies that are a part of HAPCAT. Multiple test techniques, including combined effects testing of advanced sensors and direct-connect scramjet testing, will be developed and initially demonstrated. This includes support test entries for multiple programs to characterize the performance of advanced sensors. Rapid development of the overall SkyRange capability will also continue. The telemetry system will be integrated, flown, and operated on an RQ-4, providing support to hypersonic flight tests as an auxiliary asset. The multispectral imaging system will also be completed, integrated, and operated on an RQ-4. The multispectral imaging system will also be used to support hypersonic flight tests and other targets of opportunity to demonstrate performance. For the MQ-9s, initial operations will begin, to include trade studies on various sensor suites to achieve the various mission sets the MQ-9s will support as part of SkyRange. Range surveillance and clearance capabilities will be demonstrated and support multiple test ranges. New technology development efforts to address terminal scoring, weather measurement, and telemetry collection will be initiated. Overall, the concepts of operation of SkyRange will be further developed through these activities for an eventual initial operating capability. For ground test facilities, upgrades at the CUBRC facilities will continue. Progress on the new wave rotor facility will progress. New diagnostic capabilities will be developed for use in the CUBRC facilities as well as other relevant hypersonic ground test facilities to improve testing and evaluation of hypersonic systems. This includes the development of a multispectral imaging capability for facility health monitoring and system under test evaluations. Additionally, the design of a next generation ground test facility to support future hypersonic weapon systems will be developed to inform near-term investments required to realize such a facility. ***FY 2022 Plans:*** HAPCAT will achieve full operational capability, providing support to hypersonic weapon system programs test capabilities for aerothermal, propulsion, and combined effects advanced sensor characterization. Other test techniques to support directed energy and other propulsion system characterizations will also be developed.			

Exhibit R-2A, RDT&E Project Justification: PB 2022 Office of the Secretary Of Defense		Date: May 2021
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 2020	FY 2021	FY 2022
SkyRange will demonstrate full operation using multiple aircraft platforms, including RQ-4s and MQ-9s. Support will be provided to hypersonic flight tests using the telemetry, multispectral imaging, and atmospheric sensing sensor packages. This involves the completion of the atmospheric sensing capability. Additionally, development of terminal scoring capabilities deployed from SkyRange assets will continue. The new wave rotor heater at CUBRC will be completed and begin supporting hypersonic development programs . Further technology upgrades to arc heaters will continue to address capacity and capability shortfalls. Other test and evaluation gaps associated with ground and flight test, modeling and simulation, and instrumentation will be addressed through new efforts. ***FY 2021 to FY 2022 Increase/Decrease Statement:*** FY 2022 increase supports full operational capability of current programs.			
Accomplishments/Planned Programs Subtotals	89.462	101.808	108.774

C. Other Program Funding Summary ($ in Millions)

N/A

Remarks

D. Acquisition Strategy

N/A

Exhibit R-2A, RDT&E Project Justification: PB 2022 Office of the Secretary Of Defense			Date: May 2021
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 2020	FY 2021	FY 2022 Base	FY 2022 OCO	FY 2022 Total	FY 2023	FY 2024	FY 2025	FY 2026	Cost To Complete	Total Cost
092: *Spectrum Efficient Technology*	66.576	11.720	9.725	9.376	-	9.376	-	-	-	-	-	-
Quantity of RDT&E Articles	-	-	-	-	-	-	-	-	-	-		

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 2020	FY 2021	FY 2022
Title: Spectrum Efficient Technology	11.720	9.725	9.376
Description: 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			

Exhibit R-2A, RDT&E Project Justification: PB 2022 Office of the Secretary Of Defense		Date: May 2021
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 2020	FY 2021	FY 2022
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 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 for a variety of unmanned aerial platforms. 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 wireless ground based test support networks in real-time using unobtrusive and bandwidth efficient methods. The SET project will initiate an effort to develop a ground based phased array antenna to support telemetry data requirements for large footprint test events such as DDG-1000. The SET project will initiate an effort to develop and mature phased array telemetry antenna technologies for manned aircraft to support Navy over the horizon telemetry requirements and reduce technical risk for a CTEIP effort to develop a next generation range support aircraft capability. The SET project will also continue to leverage cellular technologies to support aeronautical telemetry requirements. ***FY 2022 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 for both manned and unmanned platforms. Ground based phased array telemetry antenna technologies to support large footprint test events will continue to be matured. The SET project will also continue to leverage cellular technologies to support aeronautical telemetry requirements. The SET project will initiate an effort to develop a ruggedized cellular based telemetry transceiver with size, weight, and power suitable for integration into a fighter aircraft. ***FY 2021 to FY 2022 Increase/Decrease Statement:*** No significant program changes.			
Accomplishments/Planned Programs Subtotals	11.720	9.725	9.376

C. Other Program Funding Summary ($ in Millions)

N/A

Exhibit R-2A, RDT&E Project Justification: PB 2022 Office of the Secretary Of Defense		Date: May 2021
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*

C. Other Program Funding Summary ($ in Millions)

Remarks

D. Acquisition Strategy

N/A

Exhibit R-2A, RDT&E Project Justification: PB 2022 Office of the Secretary Of Defense			Date: May 2021
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 2020	FY 2021	FY 2022 Base	FY 2022 OCO	FY 2022 Total	FY 2023	FY 2024	FY 2025	FY 2026	Cost To Complete	Total Cost
093: *Electronic Warfare Test*	97.842	16.750	9.980	90.171	-	90.171	-	-	-	-	-	-
Quantity of RDT&E Articles	-	-	-	-	-	-	-	-	-	-		

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 Electronic Warfare Electronic attack and Electronic protect community is developing jammers and EP measures that are more sophisticated and take advantage of newer technology that allows adaptive waveforms and artificial intelligence and autonomy to respond to threats more rapidly and robustly. In addition, the testing of these systems in realistic many on many environments that are more threat representative requires new technology investment.

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 2020	FY 2021	FY 2022
Title: Electronic Warfare Test	16.750	9.980	90.171
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			

Exhibit R-2A, RDT&E Project Justification: PB 2022 Office of the Secretary Of Defense		Date: May 2021
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 2020	FY 2021	FY 2022
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 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. EWT will continue to invest in IR Scene generation at higher frame rates. Design and develop a test capability to represent 5th generation electronic warfare threats in live test environments. The test capability will be used to test sensors and DoD systems against 5th generation electronic warfare threats, to include the testing and assessment of advanced electronic attack measures. Initiate a test campaign with the test capability to verify system performance and to demonstrate the system's 5th generation attributes. The EWT project will continue development of digital RF memory for threat representation. Work on high power solid state RF sources will continue. The EWT project will initiate an advance spectrum monitoring project that uses passive RF sensing over large bandwidths and high data rates. ***FY 2022 Plans:*** The EWT project will continue investments in Digital RF memory for adaptive waveforms. The EWT project will invest in technologies related to Cyber and EW convergence. EWT project will invest in technologies related to Cognitive EW, Cognitive Radar, and EW sensors that feed Artificial Intelligence uses of EW data. ***FY 2021 to FY 2022 Increase/Decrease Statement:*** FY 2022 increase to invest in 5th generation electronic warfare threat technology.			
Accomplishments/Planned Programs Subtotals	16.750	9.980	90.171

C. Other Program Funding Summary ($ in Millions)

N/A

Remarks

D. Acquisition Strategy

N/A

Exhibit R-2A, RDT&E Project Justification: PB 2022 Office of the Secretary Of Defense			Date: May 2021
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 2020	FY 2021	FY 2022 Base	FY 2022 OCO	FY 2022 Total	FY 2023	FY 2024	FY 2025	FY 2026	Cost To Complete	Total Cost
094: *Advanced Instrumentation Systems Technology*	70.487	16.814	11.034	11.209	-	11.209	-	-	-	-	-	-
Quantity of RDT&E Articles	-	-	-	-	-	-	-	-	-	-		

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 assessed at Department of Defense (DoD) installed systems test facility and hardware-in-the-loop testing (ISTF/HITL) and open-air range (including tropospheric, land-based, open-ocean, and undersea ranges) test facilities. Instrumentation requirements for systems under test are increasing exponentially for new weapons systems. System-borne, warfighter-wearable, and remote sensing 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 developing technologies for advanced TSPI instrumentation (especially with limited or no availability of Global Positioning System (GPS) signals), 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 needs for instrumentation can adversely affect weapon system signature and performance. Instrumentation for humans-in-the-loop, especially dismounted warfighters, must not adversely affect performance, induce artificiality in the test environment, nor create any operational burdens. New technologies can be exploited to integrate small, non-intrusive instrumentation (micro-technology) 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 2020	FY 2021	FY 2022
Title: Advanced Instrumentation Systems Technology	16.814	11.034	11.209
Description: Major thrusts included initiating and continuing efforts in advanced sensors, and TSPI instrumentation. The AIST project initiated an effort to support testing of military aircraft using externally mounted sound pressure instrumentation to gather data for analysis in all weather conditions, to overcome current constraints to flight testing in dry environments. The AIST project initiated a portable technology development effort using acoustic signatures to measure weapon location and attitude to characterize high dynamic weapon end-game maneuvers, and to evaluate impact location & velocity of attacking projectiles and resolving (scoring) very large quantities of impacts occurring closely spaced in position and/or time.			

Exhibit R-2A, RDT&E Project Justification: PB 2022 Office of the Secretary Of Defense		Date: May 2021
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 2020	FY 2021	FY 2022
To assist in assessing blunt trauma events, the AIST project completed development of technology to evaluate back face deformation of body armor, with final testing conducted at Aberdeen Test Center's Light Armor Range Complex. The AIST project will complete an effort in developing a high fidelity model which takes into account the noisier acoustic properties of shallow water environments 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). The AIST project will complete an effort related to electro-releasable attachment technology development. This included the investigation of new adhesive formulations that employ an electrically-releasing tape to allow for the attachment of sensors to non-conductive, painted surfaces of aircraft and other combat vehicles and significantly reduce the time to restore the system under test to its operational configuration. Efforts improved adhesion strength and ease of use. This effort culminated in field testing (e.g., onboard M1-Abrams Tanks and F-15 Fighter Jets) at Aberdeen Test Center and Edwards Air Force Base, respectively. ***FY 2021 Plans:*** The AIST project will continue efforts initiated FY 2020; and plans to initiate the development of a prototype technology suite to determine an object's placement and attitude relative to its target at the time of impact and fuse initiation above water for highly dynamic weapons at sea, requiring that weapon position and attitude (6 Degrees of Freedom (6-DOF)) be measured during terminal approach. Measurement parameters must be captured at a sampling rate adequate to fully characterize highly dynamic end-game maneuvers, while minimizing any impact to the weapon system itself in any way so as to preserve the integrity of testing. Ongoing efforts will include enabling the development of the next generation highly dynamic GPS receiver and its application to weapons testing. ***FY 2022 Plans:*** The AIST project will complete the technology development of a portable end-game scoring system and continue developing a broad ocean area test technology suite. The AIST project will continue development of: multi-disciplinary technologies addressing T&E requirements for real-time casualty assessment (RTCA) of warfighter and weapon 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 2021 to FY 2022 Increase/Decrease Statement:*** No significant program changes.			
Accomplishments/Planned Programs Subtotals	16.814	11.034	11.209

C. Other Program Funding Summary ($ in Millions)

N/A

Exhibit R-2A, RDT&E Project Justification: PB 2022 Office of the Secretary Of Defense		Date: May 2021
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 2022 Office of the Secretary Of Defense			Date: May 2021
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 2020	FY 2021	FY 2022 Base	FY 2022 OCO	FY 2022 Total	FY 2023	FY 2024	FY 2025	FY 2026	Cost To Complete	Total Cost
095: *Directed Energy Test*	67.936	15.001	10.096	10.568	-	10.568	-	-	-	-	-	-
Quantity of RDT&E Articles	-	-	-	-	-	-	-	-	-	-		

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 and counter UAS 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 2020	FY 2021	FY 2022
Title: Directed Energy Test	15.001	10.096	10.568

Description: The DET project continued efforts to measure HEL energy on small targets such as mortars, rockets, artillery, and UAS. 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

Exhibit R-2A, RDT&E Project Justification: PB 2022 Office of the Secretary Of Defense		Date: May 2021
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 2020	FY 2021	FY 2022
Power Microwave beam in the far field. In 2020 DET demonstrated a neutron fluence that meets the entry criteria for the building of a larger reactor using DT fusion. DET developed HPM sensors that allow characterization of the beam profile of the HPM system. DET initiated HPM UAS targets for dynamic tests of HPM systems against threat relevant UAS targets. DET initiated an atmospheric modelling project that will correlate weather data to HEL propagation. ***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. This will include sensor and associated data collection systems that can survive an HPM environment. DET will continue atmospheric modelling work that will allow the development of HEL predictive atmospheric propagation. DET will continue developing wide band HPM sources for assessing the performance of US systems in a hostile HPM environment. DET will continue the development of software and measurements to assess the survivability of DoD aircraft against HEL threats. ***FY 2022 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 and expand into larger UAS classes. This will include sensor and associated data collection systems that can survive an HPM environment. DET will complete atmospheric modelling work that will allow the development of HEL predictive atmospheric propagation. DET will complete developing wide band HPM sources for assessing the performance of US systems in a hostile HPM environment. DET will continue the development of software and measurements to assess the survivability of DoD aircraft against HEL threats. DET will invest in aero-optics effects characterization tools. DET will invest in lower noise, broader band E-field measurement sensors for HPM characterization. ***FY 2021 to FY 2022 Increase/Decrease Statement:*** FY 2022 increase to support high priority counter UAS prototype developments as well as counter high speed cruise missile prototypes in support of MDA and USD R&E Programs.			
Accomplishments/Planned Programs Subtotals	15.001	10.096	10.568

C. Other Program Funding Summary ($ in Millions)

N/A

Remarks

Exhibit R-2A, RDT&E Project Justification: PB 2022 Office of the Secretary Of Defense		Date: May 2021
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*

D. Acquisition Strategy

N/A

Exhibit R-2A, RDT&E Project Justification: PB 2022 Office of the Secretary Of Defense			Date: May 2021
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 2020	FY 2021	FY 2022 Base	FY 2022 OCO	FY 2022 Total	FY 2023	FY 2024	FY 2025	FY 2026	Cost To Complete	Total Cost
096: *C4I & Software Intensive Systems Test*	119.618	10.128	11.977	12.128	-	12.128	-	-	-	-	-	-
Quantity of RDT&E Articles	-	-	-	-	-	-	-	-	-	-		

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) and the National Defense Strategy. 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 technologies for next generation resilient, survivable, federated networks and information ecosystems (information superiority) from the tactical level up to strategic planning; as well as 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 2020	FY 2021	FY 2022
Title: C4I and Software Intensive Systems Test	10.128	11.977	12.128
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 multi-variant time series Sensor Data Anomaly Detection (SDAD) tool. The SDAD tool is based on a learning system that combines the analysts' knowledge with the classification knowledge obtained from big data techniques to achieve an automated post mission processing tool enabling identification of unknown anomalies within the terabytes of sensor data collected for a given flight test. The C4T project continues development of M&S technologies to support real-time assessments of torpedo performance in complex undersea environments, specifically for shallow water (<50 meters). These technologies provide an acoustic propagation model for both narrow and broad band, of sufficient fidelity to be used for the next generation of torpedo development as well as testing torpedo performance in various maritime tactical environments that cannot be assessed with live in-water testing. The			

Exhibit R-2A, RDT&E Project Justification: PB 2022 Office of the Secretary Of Defense		Date: May 2021
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 2020	FY 2021	FY 2022
model includes a real-time simulation/emulation system for design and testing the next generation of 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 C4I and software intensive systems for joint mission effectiveness. The C4T project continued development of a network M&S to achieve configuration optimization of test support networks. Technologies included planning expeditionary tests, managing bandwidth and spectrum contention with a networked system under test, managing power consumption providing a 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 big data analytics (BDA) projects implementing artificial intelligence/ machine learning (AI/ML) techniques for multi-variant time series sensor datasets, unstructured dataset analytics (audio, video, and imagery), and advanced visualization of large T&E datasets. These technologies are being developed to support test and evaluation of future warfighter C4I and Software Intensive Systems (4th and 5th generation military platforms). ***FY 2021 Plans:*** The C4T project will develop test technologies to enable the next generation resilient, survivable, federated networks and information ecosystems (information superiority) from the tactical level up to strategic planning across three domains: BDA, Live and Simulated Environments, and Test Automation. Work targeted at BDA technologies will continue for analysis of large test databases for 4th and 5th generation military platforms (e.g. F-35) resulting in BDA tools tailored for use by ranges, with technologies to assist analysts with the reduction and complete analysis of large complex datasets. Increase the use of M&S for test planning to support emulation and stimulation of networks for conducting T&E as well as effectiveness testing of system performance (e.g. torpedoes). The C4T project 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 Operational Testing (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. Other areas of interest for the C4T project include: 5th generation aerial target and threat emulations, M&S for testing AI/ML decision engines validation techniques, emulate contested dense communication environments, and C4I and SW intensive systems joint mission thread test planning and evaluation through automated testing tool technologies. ***FY 2022 Plans:*** The C4T project will continue to advance test technology development to enable the next generation resilient, survivable, federated networks and information ecosystems (information superiority) from the tactical level up to strategic planning across three domains: BDA, Live and Simulated Environments, and Test Automation.			

Exhibit R-2A, RDT&E Project Justification: PB 2022 Office of the Secretary Of Defense		Date: May 2021
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 2020	FY 2021	FY 2022
C4T project will now focus on testing more advanced technologies to assess big data warfighter systems implementing advanced algorithms and computer architectures. C4T project additional focus to increase use of live and simulated test environments with test environment driven M&S validation techniques. C4T project additional focus to increase use of test automation utilizing virtualization and cloud environments. ***FY 2021 to FY 2022 Increase/Decrease Statement:*** FY 2022 increase to support advanced test technology development.			
Accomplishments/Planned Programs Subtotals	10.128	11.977	12.128

C. Other Program Funding Summary ($ in Millions)

N/A

Remarks

D. Acquisition Strategy

N/A

Exhibit R-2A, RDT&E Project Justification: PB 2022 Office of the Secretary Of Defense			Date: May 2021
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 2020	FY 2021	FY 2022 Base	FY 2022 OCO	FY 2022 Total	FY 2023	FY 2024	FY 2025	FY 2026	Cost To Complete	Total Cost
097: *Autonomy and Artificial Intelligence Test*	55.008	11.141	10.648	11.087	-	11.087	-	-	-	-	-	-
Quantity of RDT&E Articles	-	-	-	-	-	-	-	-	-	-		

Note

Starting in FY 2020, Project 097 title changed 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, and bring special challenges for testers of Artificial Intelligence systems. 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 AAIT 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 2020	FY 2021	FY 2022
Title: Autonomy and Artificial Intelligence Test	11.141	10.648	11.087
Description: The AAIT Project continued test technology development supporting the 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 seeks solutions for legacy topics (test planning, test execution, safety, and performance assessment) but has also expanded our interest to ensure			

Exhibit R-2A, RDT&E Project Justification: PB 2022 Office of the Secretary Of Defense		Date: May 2021
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 2020	FY 2021	FY 2022
solutions for Artificial Intelligence and Machine Learning systems, topics identified by the intelligence community, and any other topics that are priority for TRMC and OUSD(R&E). The AAIT project initiated the Assured Development and Operation of Autonomous Systems (ADAS) effort. ADAS addresses the unique challenges of Autonomy test & evaluation to provide enterprise solutions in support of future programs. ADAS address autonomy test and evaluation verification and validation (TEV&V) needs across the full life cycle of an autonomy program from warfighter need identification to concept development and deployment. ADAS is exploring opportunities that support the overarching Autonomy T&E vision & strategy with actionable activity in requirements elicitation and formal modeling, linking formal models to implementation, composition for assurance, human autonomy interaction, development security operations, and simulation based test, live virtual constructive test, and integrated autonomous systems test. 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 safety-related vulnerabilities and failures within UAS software. The AAIT project is risk reducing Autonomy, Integration, and Teaming (AIT) test capability development, by providing autonomy test tools to be demonstrated on the Airborne Collision Avoidance System (ACAS-Xu) on Triton, and to test the Guardian Ground Based Detect and Avoid software, which will allow it to achieve certification for use during live test (DO-278A/NAVAIR Cert). The same technologies are risk reducing Autonomous Systems Test Capability (ASTC) development. The AAIT project used DARPA Collaborative Operations in Denied Environments (CODE) as a test case for this robustness technology, identifying and reporting on safety vulnerabilities found deep within the software, further identifying the conditions required to trigger the safety defects. The AAIT Project completed development of technology to improve test planning for 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. The AAIT Project is initiated development of technology to create machine-learned, behavioral copies of autonomy software. This technology creates faster-than-real-time versions of a given autonomy that can then be tested in an accelerated timeline in a simulated environment, and can also be cloned to be tested in parallel-processing fashion. This technology will provide faster, better, and more statistically significant testing data for testers. ***FY 2021 Plans:***			

Exhibit R-2A, RDT&E Project Justification: PB 2022 Office of the Secretary Of Defense		Date: May 2021
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 2020	FY 2021	FY 2022
The AAIT project will continue to initiate and develop technologies to support test planning, test execution, and performance assessment of unmanned, autonomous, artificial intelligence, and machine learning systems. AAIT will continue ADAS development across the full spectrum of TEV&V needs. AAIT will continue to transition technologies to end users at the labs and ranges of the MRTFB. The AAIT Project will initiate efforts to address artificial intelligence topics related to the performance and vulnerabilities of image classifiers, improved safety of autonomous systems on live test ranges, and continuous validation of advanced learning-in-the-field artificial intelligence systems. ***FY 2022 Plans:*** The AAIT Project will continue to initiate and develop technologies to support test planning, test execution, and performance assessment of unmanned, autonomous, artificial intelligence, and machine learning systems. AAIT will continue ADAS development across the full spectrum of TEV&V needs. AAIT will continue to transition technologies to end users at the labs and ranges of the MRTFB. AAIT will continue to risk reduce test capability development. AAIT will investigate concepts to verify the autonomy design models against design requirements using formal methods, and a Test-Case Execution Environment based on AI-guided Testing, using machine-learning in the test planning process to make recommendations of test conditions for evaluation of machine learning image classifiers. ***FY 2021 to FY 2022 Increase/Decrease Statement:*** FY 2022 increase to support test technologies of unmanned and autonomous systems.			
Accomplishments/Planned Programs Subtotals	11.141	10.648	11.087

C. Other Program Funding Summary ($ in Millions)

N/A

Remarks

D. Acquisition Strategy

N/A

Exhibit R-2A, RDT&E Project Justification: PB 2022 Office of the Secretary Of Defense			Date: May 2021
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 2020	FY 2021	FY 2022 Base	FY 2022 OCO	FY 2022 Total	FY 2023	FY 2024	FY 2025	FY 2026	Cost To Complete	Total Cost
098: *Cyberspace Test*	38.360	15.001	13.170	13.348	-	13.348	-	-	-	-	-	-
Quantity of RDT&E Articles	-	-	-	-	-	-	-	-	-	-		

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 2020	FY 2021	FY 2022
Title: Cyberspace Test	15.001	13.170	13.348

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 2021 Plans:

The CTT project will continue to pursue technology developments addressing needs in Cyber-Physical Systems, in Tactical Edge Networks, and in Enterprise Information Systems. This includes the capacity to verify that an aircraft's avionics have not been altered from a cyber attack. CTT also plans to initiate an effort to test the behavior of malware. CTT will initiate an effort to fuzz up virtualized targets. CTT will initiate an effort to reverse engineer firmware.

FY 2022 Plans:

The CTT project will continue to pursue technology developments addressing needs in Cyber-Physical Systems, in Tactical Edge Networks, and in Enterprise Information Systems. This includes the capacity to verify that an aircraft's avionics have not been

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2020	FY 2021	FY 2022
altered from a cyber attack. CTT also plans to initiate an effort to test the behavior of malware. CTT will initiate an effort to fuzz up virtualized targets. CTT will initiate an effort to reverse engineer firmware. ***FY 2021 to FY 2022 Increase/Decrease Statement:*** FY 2022 increase to support technological developments within Cyber-Physical Systems, Tactical Edge Networks, and Enterprise Information Systems.			
Accomplishments/Planned Programs Subtotals	15.001	13.170	13.348

C. Other Program Funding Summary ($ in Millions)

N/A

Remarks

D. Acquisition Strategy

N/A

Exhibit R-2A, RDT&E Project Justification: PB 2022 Office of the Secretary Of Defense			Date: May 2021
Appropriation/Budget Activity 0400 / 3	R-1 Program Element (Number/Name) PE 0603941D8Z / *Test and Evaluation/Science and Technology*	Project (Number/Name) 099 / *Space Test*	

COST ($ in Millions)	Prior Years	FY 2020	FY 2021	FY 2022 Base	FY 2022 OCO	FY 2022 Total	FY 2023	FY 2024	FY 2025	FY 2026	Cost To Complete	Total Cost
099: *Space Test*	0.000	0.000	0.000	0.500	-	0.500	-	-	-	-	-	-
Quantity of RDT&E Articles	-	-	-	-	-	-	-	-	-	-		

A. Mission Description and Budget Item Justification

As a new start in FY 2022, the Space Test project mission is to address national test capability gaps by providing accurate, robust, and efficient T&E solutions to successfully develop, validate, and inform the employment of new space control systems. The space domain has become a competitive, congested, and contested environment dominated by global economics and key to national security. The Department of Defense (DoD) is prioritizing investments to maintain space superiority and increase resiliency of legacy space systems as well as new space control systems. Current developments focus on deploying capabilities and systems to deter aggression and maintain freedom of action in space for the US, allies, and partner nations. Current testing infrastructure and methodologies to assess space system resilience against emerging threats is limited. The Space Test project addresses test technology needs for adequate realism for space systems and aligns with the DoD S&T priority investments. The Space Test project is developing a strategic roadmap and investment strategy to establish live and virtual range environments, develop space and ground-based threat emulation capabilities. The Space Test project develops technologies to enable robust, accurate, and timely T&E of future space weapon systems, and to ensure system suitability and survivability. Current test resource capability and capacity preclude accurate determination of future space system lethality and survivability.

B. Accomplishments/Planned Programs ($ in Millions)	FY 2020	FY 2021	FY 2022
Title: Space Test	0.000	0.000	0.500
Description: The Space Test (ST) project is conducting a test infrastructure gap analysis on the needs of testing space systems and is developing a time-phased investment strategy based on those requirements. Work includes engaging the space test community on needs and gaps to ensure traceability of test technology development to strategic objectives. ***FY 2021 Plans:*** The Space Test project will continue the detailed gap analysis and development of a time-phased investment plan. ***FY 2022 Plans:*** Stand up a Space Test Project within the T&E/S&T Program to pursue technology developments addressing test needs in Space Systems across DoD and National Organizations. Execute Space T&E investment roadmap and time-phased investment strategy. ***FY 2021 to FY 2022 Increase/Decrease Statement:*** Increase supports Space Test as a new start in FY 2022.			
Accomplishments/Planned Programs Subtotals	0.000	0.000	0.500

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Appropriation/Budget Activity 0400 / 3	**R-1 Program Element (Number/Name)** PE 0603941D8Z / *Test and Evaluation/Science and Technology*	**Project (Number/Name)** 099 / *Space Test*

C. Other Program Funding Summary ($ in Millions)

N/A

Remarks

D. Acquisition Strategy

N/A