Exhibit R-2, RDT&E Budget Item Justification: PB 2017 Office of the Secretary Of Defense	Date: February 2016
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 2015	FY 2016	FY 2017 Base	FY 2017 OCO	FY 2017 Total	FY 2018	FY 2019	FY 2020	FY 2021	Cost To Complete	Total Cost
Total Program Element	261.981	79.073	91.425	87.135	-	87.135	89.586	97.056	98.323	100.276	Continuing	Continuing
1: *High Speed Systems Test*	53.610	23.105	25.419	16.903	-	16.903	12.544	13.900	14.112	14.238	Continuing	Continuing
2: *Spectrum Efficient Technology*	25.371	5.612	7.572	8.458	-	8.458	9.633	10.306	10.486	10.689	Continuing	Continuing
3: *Electronic Warfare Test*	49.309	7.540	10.432	12.003	-	12.003	12.947	14.310	14.129	14.410	Continuing	Continuing
4: *Advanced Instrumentation Systems Technology*	30.381	12.071	12.886	10.876	-	10.876	11.919	12.408	12.641	12.908	Continuing	Continuing
5: *Directed Energy Test*	30.762	5.805	6.526	7.350	-	7.350	8.236	8.548	8.696	8.865	Continuing	Continuing
6: *C4I & Software Intensive Systems Test*	51.866	14.448	15.328	13.384	-	13.384	12.722	10.774	10.941	11.160	Continuing	Continuing
7: *Unmanned and Autonomous System Test*	14.021	5.239	6.686	8.819	-	8.819	9.888	12.697	12.980	13.408	Continuing	Continuing
8: *Cyberspace Test*	6.661	5.253	6.576	9.342	-	9.342	11.697	14.113	14.338	14.598	Continuing	Continuing

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 stay in pace with evolving weapons technologies. 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. 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 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.

Exhibit R-2, RDT&E Budget Item Justification: PB 2017 Office of the Secretary Of Defense	Date: February 2016
Appropriation/Budget Activity 0400: *Research, Development, Test & Evaluation, Defense-Wide I* BA 3: *Advanced Technology Development (ATD)*	**R-1 Program Element (Number/Name)** PE 0603941D8Z *I Test and Evaluation/Science and Technology*

B. Program Change Summary ($ in Millions)	FY 2015	FY 2016	FY 2017 Base	FY 2017 OCO	FY 2017 Total
Previous President's Budget	81.033	82.589	85.514	-	85.514
Current President's Budget	79.073	91.425	87.135	-	87.135
Total Adjustments	-1.960	8.836	1.621	-	1.621
• Congressional General Reductions	-	-0.164			
• Congressional Directed Reductions	-	-			
• Congressional Rescissions	-	-			
• Congressional Adds	-	9.000			
• Congressional Directed Transfers	-	-			
• Reprogrammings	-0.032	-			
• SBIR/STTR Transfer	-1.928	-			
• Internal Adjustment	-	-	2.249	-	2.249
• Economic Assumption Reduction	-	-	-0.628	-	-0.628

Change Summary Explanation

• Efficiency Savings: Fiscal Guidance of baseline program adjusted to realign funds for higher priorities within DoD and to achieve departmental efficiencies.
• Economic Assumption Reduction

Exhibit R-2A, RDT&E Project Justification: PB 2017 Office of the Secretary Of Defense			Date: February 2016
Appropriation/Budget Activity 0400 / 3	R-1 Program Element (Number/Name) PE 0603941D8Z / *Test and Evaluation/ Science and Technology*	Project (Number/Name) 1 / *High Speed Systems Test*	

COST ($ in Millions)	Prior Years	FY 2015	FY 2016	FY 2017 Base	FY 2017 OCO	FY 2017 Total	FY 2018	FY 2019	FY 2020	FY 2021	Cost To Complete	Total Cost
1: *High Speed Systems Test*	53.610	23.105	25.419	16.903	-	16.903	12.544	13.900	14.112	14.238	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 science and technology (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 test and evaluation (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 2015	FY 2016	FY 2017
Title: High Speed Systems Test	23.105	25.419	16.903
FY 2015 Accomplishments: 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. Progress was made 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 an HSST FY 2011 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. Variable Mach number capability is required to "fly the mission"			

Exhibit R-2A, RDT&E Project Justification: PB 2017 Office of the Secretary Of Defense		Date: February 2016
Appropriation/Budget Activity 0400 / 3	**R-1 Program Element (Number/Name)** PE 0603941D8Z / *Test and Evaluation/ Science and Technology*	**Project (Number/Name)** 1 / *High Speed Systems Test*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2015	FY 2016	FY 2017
and determine the critical transient operability effects throughout the flight envelope. Incorporation of component technologies, previously developed by the T&E/S&T program, were initiated into a small-scale, clean air, true temperature, and variable Mach number (M4.5-7.5) aero propulsion test facility, called the Hypersonic Aeropropulsion Clean Air Testbed (HAPCAT). Completion of this facility will demonstrate that component technologies 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. Phase I of the facility development completed, including successful demonstrations of the capability of the clean air regenerative storage heater ability to conduct aeropropulsion and aerothermal tests in the future. During these demonstrations, all associated support systems, instrumentation, and controls required for facility operation functioned appropriately. Design efforts for the immediate follow-on phase neared completion, including the critical design of the air delivery system. Another FY 2015 effort examined the incorporation of advanced morphing ceramic components for hypersonic ground test facilities into the design of common facility nozzle and ducting hardware. This effort was conducted to achieve a variable Mach number capability and variable inlet distortion patterns representative of flight-like inlet systems. Test planning activities to validate direct-connect hardware designs were completed with testing to take place at the Air Force Research Lab (AFRL). This technology promises to provide a significant advantage over current rigid, stationary facility hardware by providing a “first-ever” realistic variable Mach flight distortion simulation test capability, while reducing costs and increasing productivity. Large-scale scramjet engine test techniques accomplishments included continued progress in determining the capability of existing ground test facilities and methodologies to evaluate and develop large-scale hypersonic propulsion systems. Testing of the semi-freejet test configuration utilizing an advanced hydrocarbon fueled missile scale scramjet continued. Semi-freejet thrust stand improvement options were assessed to improve data quality for comparison to freejet test results. Upon completion of the final semi-freejet test phase of the project, the resulting analysis comparing tests between the larger and smaller facilities will allow the optimized utilization of existing facilities and define the size and type of investments needed for future large-scale scramjet vehicle development and reduction of flight test and acquisition risks. Efforts to extend the Large Energy National Shock Tunnel II were initiated. The resulting additional capability will allow longer duration testing of hypersonic vehicles. Such testing will enable the full development of complex flow features affecting vehicle performance, the determination of control surface responsiveness and effectiveness, and the evaluation of the performance of aerodynamic features. The improvements will help fill a critical test capability gap and support future hypersonic vehicle programs. Designs for the extended facility were completed and approved, and long-lead items were delivered. The HSST project initiated the aerothermal test technology development of a Mid-Pressure Arc Heater Prototype. The prototype will upgrade an existing Huels arc heater with a segmented heater, creating a test envelope approximately three times larger than the current envelope. The prototype will provide extended test run time of up to 30 minutes, and a higher thermal load, representative of those experienced by a hypersonic vehicle TPS. Initial system design and component acquisition began, including the upgrade of the power and cooling support systems. A facility checkout matrix was defined to confirm that the various upgrades function as expected. The completed prototype will enable better evaluation of the performance of TPS materials, seeker windows, and other vehicle features subjected to high thermal loads. In a related effort, the arc heater flow quality			

Exhibit R-2A, RDT&E Project Justification: PB 2017 Office of the Secretary Of Defense		Date: February 2016
Appropriation/Budget Activity 0400 / 3	**R-1 Program Element (Number/Name)** PE 0603941D8Z / *Test and Evaluation/ Science and Technology*	**Project (Number/Name)** 1 / *High Speed Systems Test*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2015	FY 2016	FY 2017
aerothermal test technology development made significant progress toward independently-powered spin-coil technologies to control the physical characteristics of the spinning arc column and its attachment location and arc duration on electrode surfaces within the arc heater. This effort will improve the service life of the electrodes and improve hypersonic nozzle flow quality. Computational and numerical simulation models of magnetic field and arc column interactions with the air flow of an arc heater were developed as part of an arc rotation prediction database. The HSST project continued research in FY15 that will provide better prediction and determination of boundary layer growth and transition effects upon hypersonic vehicle performance. Understanding and predicting boundary layer transition (BLT) represents a critical shortfall in the hypersonic community, as it affects the thermal loads, stability and control, and overall performance of a vehicle. Multiple test articles representing different flight vehicle shapes were defined for use in the research, and primary test parameters were identified. Using this information, test plans were developed for various wind tunnel entries to study critical parameters affecting boundary layer stability and transition. Experimental results acquired through the BLT effort will be used to validate state of the art prediction tools and measurements of BLT mechanisms. Progress continued toward the development of a ground based, portable high altitude light detection and ranging (LIDAR) system to measure atmospheric conditions (density, temperature, pressure, wind speed/direction, oxygen and water content) along a hypersonic vehicle's flight path. This technology is a significant advancement over current technologies, improving the accuracy of determining high altitude atmospheric conditions. This atmospheric data is needed to assess the performance and operability of air-breathing missiles and boost-glide vehicles during development. An effort was initiated to evaluate the feasibility of using Un-crewed Aerial System (UAS) platforms to support hypersonic flight test. Telemetry, optical remote sensing, and instrumentation for LIDAR atmospheric measurements were analyzed to estimate the technical performance of each on a UAS platform. This effort will also determine the Concept of Operations (CONOPS) for a High Altitude, Long Endurance (HALE) UAS configured to support flight test of hypersonic vehicles. Lessons learned from the development of a real gas force measurement balance system were used to begin the design of an advanced version of the balance system with optimal load cell and accelerometer placement. The advanced balance will enable force and moment measurements in a one to two millisecond timeframe. Significant progress was made with non-intrusive flow measurement systems as well. Work to validate an optical measurement instrument utilizing mid-wave infrared (MWIR) spectral absorption to obtain scramjet exhaust gas temperature and chemical species was conducted in realistic, high-noise test facility environments. Checkout of a high temperature shear stress sensor was successfully conducted, and a full uncertainty analysis was performed using test data. The sensor was installed into a scramjet engine for additional operational testing. Work on the MWIR thermal imaging technique continued with using the technology to support a hypersonic glide vehicle test program. This technique will permit quantitative thermal imaging of hypersonic model surface flow for high enthalpies without the obscuring flow field emissivity effects that can shroud surface temperature imaging. Advances were achieved in the development of M&S tools. Beta testing by a broad spectrum of hypersonic community professionals was completed for the STABL-3D advanced three-dimensional boundary layer stability and transition analysis code. Predictions from the code compared very well with experimental data. The code enabled prediction and analysis of the			

Exhibit R-2A, RDT&E Project Justification: PB 2017 Office of the Secretary Of Defense		Date: February 2016
Appropriation/Budget Activity 0400 / 3	**R-1 Program Element (Number/Name)** PE 0603941D8Z / *Test and Evaluation/ Science and Technology*	**Project (Number/Name)** 1 / *High Speed Systems Test*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2015	FY 2016	FY 2017
characteristics and extent of boundary layer transition on the test article surface resulting from variations in nose bluntness, unit Reynolds number, and angle of attack. A hypersonic nozzle characteristics based grid generation code with a graphical user interface was completed and used to support the design of a hypersonic tunnel nozzle. Development continued on the improved Computed Tomography Method (CTM) algorithm capable of constructing more complex flow field patterns for optical absorption measurements of turbine and scramjet engine exhaust gas properties. Processing time for the CTM algorithm was reduced and the resolution of the two-dimensional spatial maps was improved. A transient thermal analysis software toolset was developed to support T&E of a hypersonic vehicle's TPS aerothermal and ablation response to high speed, high temperature flow in ground and flight test environments.			
FY 2016 Plans: New test technology efforts will be initiated addressing: test technologies, techniques, and methodologies to determine full-scale propulsion system performance and operability from subscale tests. New test technology efforts will additionally address technology for improved characterization of TPS ablation and weather effects and further development of M&S codes for accurate prediction of flow fields, boundary layer transition, and heat transfer in high-speed flow. Efforts will be initiated to develop new and more accurate instrumentation systems and advanced test technologies to meet needs in gas turbine engine and electromagnetic railgun testing. The HAPCAT project will continue to develop and demonstrate air delivery system technologies to provide uniform flow with variable pressure and temperature from multiple air sources through a nozzle up to Mach 7.5 conditions. The project activities will include initiation of Phase 2 to begin fabrication of the air delivery system and design of the variable Mach nozzle. Direct-connect hardware validation testing of a ceramic morphing direct connect facility nozzle and distortion generator suitable for missile-scale high speed ground test facilities will be completed. This effort will aid in demonstrating the ability to maintain well-conditioned flow while continuously varying the flight Mach number and inlet distortion levels. Upon completion of the Large Energy National Shock Tunnel II extension, facility performance of the tunnel will be evaluated to verify extended run times. A helium recovery system will also be implemented to enable the reuse of helium in the facility, reducing the cost of testing. Heater segments for the segmented Mid-Pressure Arc Heater Prototype will be developed, and operation of the segmented arc heater system will be validated. Improved arc jet facility spin coil power controls will be fabricated, and the spin coil system will be demonstrated proceeding toward the goal of improved T&E of maneuvering reentry and boost/glide vehicles. The BLT project will conduct testing in multiple tunnel facilities to provide a basis for comparative analysis in different test configurations, and to provide comprehensive code validation test cases regarding 3D boundary layer stability and transition. Testing and demonstration of high altitude LIDAR atmospheric sensing will be completed and the portable system will be transitioned to support test programs at multiple flight test ranges. Development of an airborne version of the LIDAR sensor will begin. A more advanced real gas force measurement balance system will be developed for use on a flight-representative model. The balance system will be calibrated, and a full uncertainty analysis will be performed. Optimization of the MWIR thermal imaging			

Exhibit R-2A, RDT&E Project Justification: PB 2017 Office of the Secretary Of Defense		Date: February 2016
Appropriation/Budget Activity 0400 / 3	**R-1 Program Element (Number/Name)** PE 0603941D8Z / *Test and Evaluation/ Science and Technology*	**Project (Number/Name)** 1 / *High Speed Systems Test*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2015	FY 2016	FY 2017
signal-to-noise ratio as a function of test enthalpy technique will be completed. Measurements of thermal emissions from the surface of typical boost-glide vehicles in an impulse test facility will be conducted to evaluate the effectiveness of different surface compositions and treatments and selected filter frequencies for thermal imaging. Verification and improvement of computational fluid dynamics (CFD) codes will continue, making use of the unique data sets obtained from the HSST scramjet engines tests and BLT experiments described above. A validated STABL-3D boundary layer transition prediction tool will be released allowing for application to complex, 3D boost-glide vehicle geometries. The transient thermal analysis software effort will complete integration of an aerothermal code and a structural heating code which will be demonstrated on a flight-representative geometry. The UAS based range effort will continue to assess the technical performance and CONOPS for a HALE UAS configured to support flight T&E of hypersonic vehicles. Efforts will focus on the development and integration of an airborne telemetry system onboard a UAS capable of collecting data from a hypersonic flight vehicle over the ocean areas. ***FY 2017 Plans:*** FY 2017 will see continued efforts to improve hypersonic ground and flight test capabilities to levels required for acquisition programs. Efforts will include demonstration of new flight test techniques, improvements in instrumentation, and continued improvement and validation of CFD codes. Progress will continue toward final integration and operation of the HAPCAT clean-air, variable Mach number aeropropulsion test facility, including completion of the variable Mach number nozzle design and preparations to demonstrate the capability to simultaneously vary stagnation pressure, temperature and Mach number from 4.5-7.5. The upgrades to the mid-pressure arc heater will be completed, enabling more representative thermal loads to be simulated during hypersonic testing. The MWIR thermal imaging project will establish the necessary technique and equipment required to perform thermal imaging of models in high-temperature, high-emissivity flows. Completion of BLT efforts will establish a new baseline protocol and recommendations for hypersonic aero performance predictions utilizing testing and M&S.			
Accomplishments/Planned Programs Subtotals	23.105	25.419	16.903

C. Other Program Funding Summary ($ in Millions)

N/A

Remarks

D. Acquisition Strategy

N/A

E. Performance Metrics

Percentage of T&E/S&T projects progressing satisfactorily toward technical, financial, schedule, and risk mitigation goals.

Exhibit R-2A, RDT&E Project Justification: PB 2017 Office of the Secretary Of Defense			Date: February 2016
Appropriation/Budget Activity 0400 / 3	R-1 Program Element (Number/Name) PE 0603941D8Z / *Test and Evaluation/ Science and Technology*	Project (Number/Name) 2 / *Spectrum Efficient Technology*	

COST ($ in Millions)	Prior Years	FY 2015	FY 2016	FY 2017 Base	FY 2017 OCO	FY 2017 Total	FY 2018	FY 2019	FY 2020	FY 2021	Cost To Complete	Total Cost
2: *Spectrum Efficient Technology*	25.371	5.612	7.572	8.458	-	8.458	9.633	10.306	10.486	10.689	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 frequency bands 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 a three-fold increase in available bandwidth, but C-Band comes with technical challenges and regulatory constraints. Most notably, our current test infrastructure for telemetry is not designed to accommodate C-Band. 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 and weight) 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 capabilities enable more robust, efficient bidirectional transfer of data. DoD's 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 telemetry capabilities, and enhanced management of spectrum at DoD test ranges.

B. Accomplishments/Planned Programs ($ in Millions)	FY 2015	FY 2016	FY 2017
Title: Spectrum Efficient Technology	5.612	7.572	8.458
FY 2015 Accomplishments: The SET project developed technologies to meet networked telemetry requirements and performed risk reduction for Central Test and Evaluation Investment Program (CTEIP) networked telemetry projects. A networked data recorder was developed to provide risk reduction in support of CTEIP developments and subsequently tested in the CTEIP networked telemetry integration laboratory. The networked data recorder was transitioned to address test range requirements for data recording and selectable parametric extraction from the recorder during developmental flight testing at the Air Force Test Center (AFTC), Edwards			

Exhibit R-2A, RDT&E Project Justification: PB 2017 Office of the Secretary Of Defense		Date: February 2016
Appropriation/Budget Activity 0400 / 3	**R-1 Program Element (Number/Name)** PE 0603941D8Z / *Test and Evaluation/ Science and Technology*	**Project (Number/Name)** 2 / *Spectrum Efficient Technology*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2015	FY 2016	FY 2017
AFB, CA. Development of a prototype non-blocking Ethernet switch for airborne platforms was demonstrated to support the deployment of a networked telemetry system. This technology will serve as the network backbone which will tie all onboard instrumentation together with the onboard test data transmitter. Technology enabling the real-time dynamic reconfiguration of transmitted test data over a telemetry network was further matured. Development of a multi-band transceiver operating in the L/ S/C-Band spectrum employing multiple advanced waveforms continued and key components including the transceiver multi-band RF front end were matured. Development of a telemetry transceiver capable of dynamically reconfiguring the data modulation scheme based on telemetry link conditions continued. Technology enabling more efficient handling of multiple priority test data and communications between the network router and telemetry transceiver was matured. The SET project developed technologies to address over-the-horizon telemetry requirements and performed risk reduction for a CTEIP telemetry improvement project supporting testing of large footprint weapons, such as long range missiles. An L/S/C-Band phased array antenna suitable for mounting on an aircraft was completed, demonstrated, and transitioned to support the development of a Navy range support aircraft to replace the legacy range aircraft. Development continued on modular digital beam-forming technologies to control a phased array antenna and track multiple targets simultaneously. This technology will significantly reduce the system complexity for an airborne phased array antenna, providing savings in terms of size, weight, power consumption, and airframe modifications on the test platform. The SET project investigated techniques to expand telemetry operations into non-traditional spectrum bands by characterizing multipath effects in a range of terrestrial and atmospheric environments. A technical investigation into the telemetry link performance of the C-Band versus S-Band spectrum for a missile test mission was completed and the performance results transitioned to the test ranges. The C-Band telemetry antenna technology developed under this effort was initially transitioned to Naval Air Warfare Center – Weapons Division at China Lake, CA and Pt. Mugu, CA; however, the technology is extensible, enabling its widespread use across the Major Range and Test Facility Base. Additionally, this antenna technology was used to support technical investigation of C-Band versus S-Band link performance at White Sands Missile Range, NM. The SET project completed the development of a three dimensional channel model tool for modeling and simulation of telemetry channels in various environments. This tool provides higher fidelity simulations for use in researching the effects of terrain, environments, and various other factors on telemetry channels. This tool was transitioned to the AFTC to support pretest analysis of mission flight profiles. Additionally, SET completed several technical investigations to expand telemetry operations into non-traditional spectrum bands. SET initiated an effort to investigate the use of the higher frequency Ka-Band and Ku-Band for telemetry links. This investigation determined the performance characteristics of the bands, determined the ideal operating frequencies for telemetry purposes, and identified technology gaps and components required to implement a robust telemetry capability. The SET project completed a technical investigation exploring the use of directional free space optical links for telemetry purposes, and identifying potential scenarios where optical telemetry links can be used to augment traditional RF telemetry links.			
FY 2016 Plans:			

Exhibit R-2A, RDT&E Project Justification: PB 2017 Office of the Secretary Of Defense		Date: February 2016
Appropriation/Budget Activity 0400 / 3	**R-1 Program Element (Number/Name)** PE 0603941D8Z / *Test and Evaluation/ Science and Technology*	**Project (Number/Name)** 2 / *Spectrum Efficient Technology*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2015	FY 2016	FY 2017
The SET project will further advance development of technologies required for network telemetry. Efforts to develop a multiband L/S/C-Band transceiver will continue. Technology enabling more efficient handling of priority test data and communication between the network router and telemetry transceiver will continue. Development of a telemetry transceiver capable of dynamically reconfiguring the data modulation scheme based on telemetry link conditions will continue. An effort to develop digital beam forming and steering technologies for an airborne phased array antenna will be completed, tested, and transitioned to CTEIP to support the development of an over-the-horizon telemetry capability. Additionally, SET will initiate efforts to develop phased array technology for use on the ground. The high directionality of phased array antenna technologies will enable spectrum spatial reuse techniques for more effective spectrum scheduling. The SET project will initiate an effort to develop a telemetry transmitter capable of operating in the 5925-6700 MHz, “Upper C-Band”. This portion of the RF spectrum is highly fragmented, typically in 1-2 MHz portions due to incumbent users such as satellite uplinks. This effort will leverage existing commercial technologies, such as Long Term Evolution-Advanced (LTE-A), a type of wireless technology that has taken hold throughout North America and is fast becoming a global standard. LTE-A will sum the interstitial portions of spectrum to form an aeronautical telemetry channel, which is typically 20 MHz in bandwidth. This technology will enable RF spectrum scheduling flexibility, expand telemetry operations in the C-Band, and increase the number of test missions a range can simultaneously support. ***FY 2017 Plans:*** The SET project will initiate development of radio technology that can utilize alternate spectrum in the upper frequency bands. These efforts will determine the feasibility of using the upper bands for use in telemetry. Efforts to develop phased array technology for use on the ground will be further matured. Technologies to sum non-contiguous RF spectrum in the upper C-Band will be matured. A telemetry transceiver capable of reconfiguring the data modulation scheme based on telemetry link conditions will be completed, demonstrated, and transitioned to support networked telemetry requirements. Efforts to develop spectrum management tools to optimize the use of available RF spectrum will continue. Additionally, the SET project will complete work to mature technologies in optimization and management of the telemetry networks through spectrum management tools.			
Accomplishments/Planned Programs Subtotals	5.612	7.572	8.458

C. Other Program Funding Summary ($ in Millions)

N/A

Remarks

D. Acquisition Strategy

N/A

Exhibit R-2A, RDT&E Project Justification: PB 2017 Office of the Secretary Of Defense		Date: February 2016
Appropriation/Budget Activity 0400 / 3	**R-1 Program Element (Number/Name)** PE 0603941D8Z / *Test and Evaluation/ Science and Technology*	**Project (Number/Name)** 2 / *Spectrum Efficient Technology*

E. Performance Metrics

Percentage of T&E/S&T projects progressing satisfactorily toward technical, financial, schedule, and risk mitigation goals.

Exhibit R-2A, RDT&E Project Justification: PB 2017 Office of the Secretary Of Defense			Date: February 2016
Appropriation/Budget Activity 0400 / 3	R-1 Program Element (Number/Name) PE 0603941D8Z / *Test and Evaluation/ Science and Technology*	Project (Number/Name) 3 / *Electronic Warfare Test*	

COST ($ in Millions)	Prior Years	FY 2015	FY 2016	FY 2017 Base	FY 2017 OCO	FY 2017 Total	FY 2018	FY 2019	FY 2020	FY 2021	Cost To Complete	Total Cost
3: *Electronic Warfare Test*	49.309	7.540	10.432	12.003	-	12.003	12.947	14.310	14.129	14.410	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 2015	FY 2016	FY 2017
Title: Electronic Warfare Test	7.540	10.432	12.003
FY 2015 Accomplishments: The EWT project continued efforts to develop a wide field of view (WFOV) infrared scene projector interface by using a dynamic IR optical coupler. The scene projector will be used for testing IRCM systems. Dynamic and static testing and signature collection was completed for the boost sustained motor of a surrogate missile system used for testing MANPADS IRCM systems. The EWT project continued development of a wideband multi-beam klystron to be used as a simulator for next-generation surface-to-air-missile systems. EWT developed and tested control hardware for a system to generate virtual radar targets using digital RF memory (DRFM) technology. Additionally, EWT continued development of a prototype real-time air-to-surface radar stimulator for testing of synthetic aperture radar surveillance, automatic target recognition, and bomb damage assessment modes. The EWT project continued an effort to develop a technology to produce high-fidelity electronic counter-countermeasures (ECCM) radar			

Exhibit R-2A, RDT&E Project Justification: PB 2017 Office of the Secretary Of Defense		Date: February 2016
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B. Accomplishments/Planned Programs ($ in Millions)	FY 2015	FY 2016	FY 2017
signal processing techniques that employ sophisticated waveforms with algorithms, such as adaptive filtering. The technology will improve testing against modern RF surface-to-air missile threats. EWT demonstrated a high temperature infrared scene projector that operates over the entire mid-wave infrared (MWIR) band. ***FY 2016 Plans:*** The EWT project will complete efforts to develop an IR scene projector using digital micromirrors with long wave IR and MWIR channels. EWT will complete efforts to develop a system for testing directed IRCM (DIRCM) systems in a high clutter environment; the system will additionally be used in common IRCM (CIRCM) testing. EWT will complete and demonstrate a two-color IR scene projector to test two-color, high spatial resolution MWIR sensors. Work on multi-static radar trackers for testing of HFI systems will complete with demonstration of this technology. Additionally, EWT will demonstrate a prototype of a reconfigurable threat signal processor allowing rapid configuration of threat radar test simulators. EWT will continue developing a wideband multi-beam klystron transmitter for high fidelity threat simulation of next generation RF surface-to-air missiles, completing the electron gun fabrication and the output cavity design, and demonstrating a laboratory breadboard system. Development of DRFM algorithms for generation of virtual radar targets will continue with completion of bench testing of hardware and software. Work will continue on using DRFMs to enable chamber testing of operational communications data between aircraft. An air-to-surface radar imaging stimulator will be demonstrated. A prototype MWIR scene projector with apparent temperatures in excess of 1500K will complete as well as a 1kHz, two-color scene generator. EWT will demonstrate a prototype wideband multi-beam klystron transmitter for high fidelity threat simulation of next generation RF surface-to-air missile radars. The EWT project will complete development of DRFM algorithms with bench testing of hardware and software for generation of virtual radar targets. EWT will complete development efforts using DRFMs to enable chamber testing of operational communications data between aircraft. ***FY 2017 Plans:*** The EWT project will invest in new technologies related to improving the electronic warfare T&E infrastructure. These new technologies will address the test infrastructure requirements to measure emerging weapon sensors and seekers, as well as to assess the performance of next generation IRCM and EW systems.			
Accomplishments/Planned Programs Subtotals	7.540	10.432	12.003

C. Other Program Funding Summary ($ in Millions)

N/A

Remarks

D. Acquisition Strategy

N/A

Exhibit R-2A, RDT&E Project Justification: PB 2017 Office of the Secretary Of Defense		Date: February 2016
Appropriation/Budget Activity 0400 / 3	**R-1 Program Element (Number/Name)** PE 0603941D8Z / *Test and Evaluation/ Science and Technology*	**Project (Number/Name)** 3 / *Electronic Warfare Test*

E. Performance Metrics

Percentage of T&E/S&T projects progressing satisfactorily toward technical, financial, schedule, and risk mitigation goals.

Exhibit R-2A, RDT&E Project Justification: PB 2017 Office of the Secretary Of Defense			Date: February 2016
Appropriation/Budget Activity 0400 / 3	R-1 Program Element (Number/Name) PE 0603941D8Z / *Test and Evaluation/ Science and Technology*	Project (Number/Name) 4 / *Advanced Instrumentation Systems Technology*	

COST ($ in Millions)	Prior Years	FY 2015	FY 2016	FY 2017 Base	FY 2017 OCO	FY 2017 Total	FY 2018	FY 2019	FY 2020	FY 2021	Cost To Complete	Total Cost
4: *Advanced Instrumentation Systems Technology*	30.381	12.071	12.886	10.876	-	10.876	11.919	12.408	12.641	12.908	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 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 test 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 2015	FY 2016	FY 2017
Title: Advanced Instrumentation Systems Technology	12.071	12.886	10.876

FY 2015 Accomplishments:

A continued major thrust included the development of test technologies to support collection of TSPI on warfighter systems (manned and unmanned), particularly in GPS-denied or degraded environments, such as in urban canyons and tunnels. This challenging T&E need cannot be met by a single technology solution. As such, the AIST project is pursuing multiple solutions; some are competing and some are complementary.

Efforts to develop technology to test systems that operate in a GPS-denied environment included an inertial tracking system that employs boot-mounted sensors for dismounted warfighters. The tracking system demonstrated the ability to geolocate, with sub-meter accuracy, a dismounted warfighter conducting activities over two hours of free movement. The AIST project continued to

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2015	FY 2016	FY 2017
develop a system to measure warfighter enclosed location (GPS-denied environment) at sub-meter accuracies using ambient amplitude modulation (AM) signals from radio stations or low cost supplementary AM transmitters at DoD test ranges where AM signals may be sparse. AM signal propagation during day and night was evaluated at an urban training range; data was collected at a variety of urban range structures observing centimeter accuracy within a concrete and steel structure. Efforts completed to develop technology that provides a seamless transition between outdoor and indoor environments to accurately track systems under test using modified GPS receivers, relayed GPS signals, and multi-lateration. Other filters and other sensors e.g., an inertial measurement unit (IMU) integrated into the system can potentially provide an overall TSPI solution with sub-meter accuracies. Efforts continued to develop technology to measure projectile position and attitude (six degrees of freedom) of high-velocity, spinning projectiles (at accuracies that significantly exceed the system under test guidance system). This technology will provide continuous estimation of the state description of a projectile through the duration of projectile flight via accurate and rapid RF range observations between the projectile and ground-based components. In support of other instrumentation solutions, an electro-releasable attachment technology development effort was completed. This included investigation of new adhesive technologies that employ an electrically releasing foil patch to allow attachment of sensors to non-conductive, painted surfaces of aircraft and other combat vehicles. Such technology significantly reduces the time to restore the system under test to its operational configuration. Development of the foil patch focused on an improved operating temperature range and adhesion strength for environmental testing (e.g., resistance to lightning strike) and end-to-end field testing. Final test data analysis completed and transition to DoD test ranges is ongoing. The AIST project completed development of a fiber-optic instrumentation suite to integrate into test projectiles for measurement of magnetic field strength in the harsh environment of an electromagnetic railgun (EMRG). Full-up testing with three EMRG shots at the Naval Surface Warfare Center-Dahlgren Division (NSWCDD) was conducted, achieving a significant benchmark by successfully measuring, for the first time, magnetic field strengths in an EMRG-launched projectile at 15-20 kG forces. Additional tests were completed at higher energy levels. The AIST project completed the development of algorithms and methods for automated detection and classification of marine mammal vocalizations collected by ocean floor range sensors (e.g., hydrophones) to allow the Navy to conduct critical test and evaluation (T&E) events without adversely impacting marine mammal populations. Testing has been successfully conducted at undersea ranges. A baseline classifier for six marine mammal species is currently running real-time, range-wide at the Atlantic Undersea Test and Evaluation Center, Pacific Range Missile Facility, and the Southern California Offshore Range. Additional classifiers were developed or improved and integrated into marine mammal monitoring nodes and transitioned to the Navy's major undersea ranges. Follow-on work is underway to implement software tools to perform automated aggregation, post-processing and a graphical user interface of detection/classification data generated by the marine mammal classification algorithms; this process currently requires experienced analysts to reduce the data. To support the needs of test ranges that conduct arena testing for weapon systems, AIST continued developing technology that uses passive imaging to characterize munition warhead fragment size, velocity, and distribution. This technology will significantly reduce set-up times and data analysis costs of current warhead arena test techniques. Advanced tracking algorithms were			

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2015	FY 2016	FY 2017

merged into a stereo tracker (Track3D) to derive dense, fragment field state vector estimates. Stereo imagery was collected during three live-fire arena test events; the 3-D visualization and track analysis software developed for the arena test data was demonstrated.

The AIST project continued to develop technology that accurately provides dynamic measurements of warfighter body posture, and head and weapon orientation using fiber optic shape sensing integrated into a body suit to be worn under the uniform. Initial testing of electronics performance indicates four orders of magnitude faster than anticipated. The functionality of the fiber sensor length, shape, and absolute and relative angular accuracy of the system was demonstrated and verified in the laboratory environment.

Development of technology to assess warfighter cognitive states continued, including development of an integrated dry electroencephalogram (EEG) and functional near infrared (fNIR) sensor system capable of simultaneous measurement of brain electrical activity and blood oxygen level; an unobtrusive headset for test subjects; mental workload assessment software; and verification of system functionality.

An effort continued to investigate means to mitigate the impacts of wind energy system interference on test range radars. AIST evaluated four mitigation approaches to minimize the effects of wind turbines with the goal of reducing their effects by 60-70dB. AIST initiated an effort to collect wind turbine data for use in further evaluating algorithms to mitigate the impact to range radars.

Efforts continued to assess and leverage microsystems technology under development at universities, the Defense Advanced Research Projects Agency (DARPA), and government laboratories. These efforts will provide significant advances to T&E of modern war fighting systems.

A new effort was started to develop technology that enables in-water vehicles to recognize their position relative to another platform in real time. This new capability will improve ship safety during tests and allow for more controlled two-body measurements. The AIST project developed hardware and software and successfully conducted preliminary testing at the Atlantic Undersea Test & Evaluation Center and planned additional tests. AIST began development of a model to assess potential impacts of Electromagnetic Interference (EMI) caused by power lines near DoD test ranges. Lastly, AIST began an effort to evaluate Body Armor Blunt Trauma using fiber optics to measure the dynamics of back face deformation of body armor at high repetition-rates.

FY 2016 Plans:

Major thrusts for FY 2016 include continuing efforts in advanced sensors, TSPI instrumentation, warfighter physical and cognitive assessment under various workloads and test range encroachment mitigation. Additionally, AIST will continue to pursue test technologies for non-intrusive, advanced data acquisition and transformation instrumentation that operates on reduced power along with the development of advanced power sources for test instrumentation.

The AIST project will complete development of a model to assess potential impacts of EMI caused by high voltage power lines near DoD test ranges; the development of an inertial tracking system with boot-mounted sensors for dismounted warfighters; the investigations and resulting recommendations to mitigate wind turbine effects on DoD test ranges; development of technology to

Exhibit R-2A, RDT&E Project Justification: PB 2017 Office of the Secretary Of Defense		Date: February 2016
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B. Accomplishments/Planned Programs ($ in Millions)	FY 2015	FY 2016	FY 2017
provide accurate, dynamic measurements to display posture, head orientation, and respective orientations of warfighters and their equipment; development of a projectile tracking system using accurate and rapid RF range observations between the projectile and ground components; and technology to achieve real-time undersea situational awareness of undersea vehicles relative to another. The AIST project will continue the development and testing of classifiers to identify specific sea mammals (e.g., various dolphin and whale species) found at undersea ranges and the automated processing and display of mammal detections; developing compressive sensing cameras to characterize blast fragments; the development of a tracking system using AM Band signals; and developing technology to evaluate Body Armor Blunt Trauma. ***FY 2017 Plans:*** The AIST project will initiate efforts to develop advanced TSPI technologies for non-intrusive applications using wireless systems and optical, infrared, and/or acoustic techniques. TSPI technologies will be further developed to support: data collection in GPS-denied environments, TSPI on high dynamic systems such as missiles and projectiles, Real Time Casualty Assessment and TSPI on non-cooperative undersea weapon systems. Advanced sensor initiatives for non-intrusive applications will include multimodal transducers, and self-registering/self-calibrating sensors. Sensing applications will include weapon system orientation, body armor blunt trauma evaluation, air launched stores separation, angle of incidence measurement, and non-destructive radiographic defect evaluation for warheads and other weapons structures. Advanced data transformation initiatives will develop technologies for adaptive computing, virtual/synthetic instrumentation, data compression, wireless on-board data transport and improved data storage density. Other areas of investigation will include advanced data management techniques and micro-miniaturization of electronic components for non-intrusive applications. AIST will continue to investigate technologies for mitigating range environmental encroachment issues such as electromagnetic and alternative energy interference with range tracking systems. Additional efforts will include human performance measurement and assessment, specifically human interaction with unmanned systems and the evaluation of the interaction of the warfighter and weapons/equipment and interactions between individual warfighters in team-based holistic assessments. The AIST project will complete technology to measure fragment characteristics from warhead testing; TSPI using distinctive near-field patterns from AM signals; and automated processing and displaying of marine mammal locations on DoD sea ranges.			
Accomplishments/Planned Programs Subtotals	12.071	12.886	10.876

C. Other Program Funding Summary ($ in Millions)

N/A

Remarks

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D. Acquisition Strategy

N/A

E. Performance Metrics

Percentage of T&E/S&T projects progressing satisfactorily toward technical, financial, schedule, and risk mitigation goals.

Exhibit R-2A, RDT&E Project Justification: PB 2017 Office of the Secretary Of Defense			Date: February 2016
Appropriation/Budget Activity 0400 / 3	R-1 Program Element (Number/Name) PE 0603941D8Z / *Test and Evaluation/ Science and Technology*	Project (Number/Name) 5 / *Directed Energy Test*	

COST ($ in Millions)	Prior Years	FY 2015	FY 2016	FY 2017 Base	FY 2017 OCO	FY 2017 Total	FY 2018	FY 2019	FY 2020	FY 2021	Cost To Complete	Total Cost
5: *Directed Energy Test*	30.762	5.805	6.526	7.350	-	7.350	8.236	8.548	8.696	8.865	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 2015	FY 2016	FY 2017
Title: Directed Energy Test	5.805	6.526	7.350

FY 2015 Accomplishments:

The DET project completed development of target board sensors to assess HEL energy on large targets. Similar work on HEL energy sensors for small targets such as mortars and rockets continued under two parallel efforts, with initiation of testing subsystems and materials for HEL survivability.

The DET project completed development of a prototype adaptive optics system designed to be readily adaptable to telescopes at DoD test facilities. The test technology will allow improved imaging of an HEL spot on a remote target. Regarding HEL atmospheric propagation, development of a light detection and ranging system (LIDAR) to measure atmospheric profiles along a slant path adjacent to the HEL beam propagation path was completed. This technology simultaneously measures profiles for three parameters: optical turbulence, water vapor content, and aerosol attenuation. Measuring these profiles will enable understanding of how atmospheric effects distort HEL beam propagation. A maritime version of this technology continued with completion of a critical design review. Fabrication and assembly of subsystems was initiated.

The DET project completed development of electric and magnetic field sensors in support of electromagnetic railgun (EMRG) T&E with development of new techniques to reduce noise on these measurements; these techniques increased the quality

Exhibit R-2A, RDT&E Project Justification: PB 2017 Office of the Secretary Of Defense		Date: February 2016
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B. Accomplishments/Planned Programs ($ in Millions)	FY 2015	FY 2016	FY 2017
of data obtained to benchmark railgun development codes. DET completed development of a prototype miniature differential current measurement system that measures the current at nodes in a target circuit, allowing analysis of HPM effects at the sub-component level. DET continued development of a proof-of-concept voltage probe with bandwidths up to 100 MHz, allowing non-intrusive voltage measurements in HPM engagements. These probes are also useful for C-IED applications. Maturation of the slab coupled optical sensors from lab devices to prototypes was completed and testing was conducted in a relevant environment. The DET project completed design of an advanced radome that will allow more reliable operation of the White Sands Missile Range (WSMR) HPM Wide Band Threat Source over all five bands of operation, enabling more robust, cost effective testing of U.S. systems against HPM threats. Development of a compact hard tube vircator (CHTV) to cover two frequency bands of interest continued. The CHTV development will result in an HPM source for testing in-chamber HPM effects, which at certain frequencies, represents a gap in current MIL-STD-464C testing. The DET project completed a study of options for technology replacement of the WSMR fast burst nuclear reactor for sources that simulate nuclear weapon prompt radiation output (neutron radiation) for survivability testing of U.S. systems. Development of an enhanced capacitor bank and tube prototype was initiated in support of an ultra-short neutron pulse test capability. The driver of this effort is to enable higher fluence to support nuclear vulnerability testing. ***FY 2016 Plans:*** Within the HEL area, efforts will focus on continuing technology developments for measuring energy on target and characterizing effects on small targets using onboard sensing. DET will continue efforts to characterize HEL beam propagation through the atmosphere including those in the maritime environment to support emerging needs of the Navy. Initiatives to achieve very small, non-intrusive current and voltage sensors to measure HPM effects inside a target will be continued. A small, minimally intrusive data acquisition device with a wide bandwidth to complement that of narrow bandwidth non-intrusive electric and magnetic field sensors will be completed. The effort to develop an HPM source for use in a chamber to address survivability of munitions in an HPM environment will be continued. The effort to develop an enhanced capacitor bank and ultra-short pulse neutron source to address nuclear vulnerability testing will be continued. ***FY 2017 Plans:*** Investments in HEL test technologies will be initiated to assess the changes in HEL effects due to the shift of HELs to shorter wavelengths near one micron. This includes efforts to characterize the performance of HEL systems as they test against small targets such as enemy rockets, missiles, artillery, and unmanned aerial vehicles.			

Exhibit R-2A, RDT&E Project Justification: PB 2017 Office of the Secretary Of Defense		Date: February 2016
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B. Accomplishments/Planned Programs ($ in Millions)	FY 2015	FY 2016	FY 2017
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 also look at new technologies to further address gaps in the availability of sources for MIL-STD-464C testing.			
Accomplishments/Planned Programs Subtotals	5.805	6.526	7.350

C. Other Program Funding Summary ($ in Millions)

N/A

Remarks

D. Acquisition Strategy

N/A

E. Performance Metrics

Percentage of T&E/S&T projects progressing satisfactorily toward technical, financial, schedule, and risk mitigation goals.

Exhibit R-2A, RDT&E Project Justification: PB 2017 Office of the Secretary Of Defense											Date: February 2016	
Appropriation/Budget Activity 0400 / 3					R-1 Program Element (Number/Name) PE 0603941D8Z / *Test and Evaluation/ Science and Technology*				Project (Number/Name) 6 / *C4I & Software Intensive Systems Test*			
COST ($ in Millions)	**Prior Years**	**FY 2015**	**FY 2016**	**FY 2017 Base**	**FY 2017 OCO**	**FY 2017 Total**	**FY 2018**	**FY 2019**	**FY 2020**	**FY 2021**	**Cost To Complete**	**Total Cost**
6: *C4I & Software Intensive Systems Test*	51.866	14.448	15.328	13.384	-	13.384	12.722	10.774	10.941	11.160	Continuing	Continuing

A. Mission Description and Budget Item Justification

This project was previously named Net-Centric Systems Test (NST); however, as the project evolved, it became necessary to broaden the scope to include important elements integral to net-centric operations. The new name i.e., Command, Control, Communications and Intelligence (C4I) & Software Intensive Systems Test (C4T) more accurately reflects the scope and content of this project. The C4T project is pursuing test technologies to emulate net-centric military operations in a system-of-systems test environment. This emulation supports analysis and evaluation of the increasing collection of structured and unstructured data generated by complex military test environments. The technology to conduct T&E on software intensive systems is 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 conduct rapid analysis of "Big Data" and automated test reporting. C4T 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 command and control systems accessing and providing information.

B. Accomplishments/Planned Programs ($ in Millions)	FY 2015	FY 2016	FY 2017
Title: C4I and Software Intensive Systems Test	14.448	15.328	13.384
FY 2015 Accomplishments: The C4T project included efforts that enabled the Test and Training Enabling Architecture (TENA) to utilize remote methods of authentication and privilege management to distributed users. The resulting technologies will support DoD remote authentication T&E needs and next generation multi-level security T&E capabilities. The C4T project developed technologies to support the testing of the cyber robustness of military tactical networks. Specifically the StealthNet project completed and will be utilized in distributed cyber testing of C4I devices across DOD Labs and ranges. The C4T project developed a distributed policy-based access control capability for the TENA middleware. This technology developed end user authentication; enforcement of the defined access control policy prior to joining the TENA execution; and the automatic distribution of the required certificates, keys, and login tokens. The C4T project began development of technologies that apply automated analysis of large net-centric systems data sets using cloud computing technologies. Development of technologies continued to provide an acoustic propagation model of sufficient fidelity to evaluate torpedo performance operating in a range of naval environments.			
FY 2016 Plans:			

Exhibit R-2A, RDT&E Project Justification: PB 2017 Office of the Secretary Of Defense		Date: February 2016
Appropriation/Budget Activity 0400 / 3	**R-1 Program Element (Number/Name)** PE 0603941D8Z / *Test and Evaluation/ Science and Technology*	**Project (Number/Name)** 6 / *C4I & Software Intensive Systems Test*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2015	FY 2016	FY 2017
Development will continue on technologies to support the use of TENA over a broad range of networks and to provide common interoperability test architecture. Moreover, C4T will investigate M&S technologies to support emulation and stimulation of networks for conducting T&E. 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 use by data-to-decision algorithms. Further work on the correlation and analysis of Big Data from multiple sources will continue. The C4T project will develop technologies that mitigate data biases introduced by the test infrastructure. 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. ***FY 2017 Plans:*** Work started in FY 2015 and FY 2016 will continue. The C4T project will invest in developing CDS/MLS and assessing DoD platforms employing Big Data techniques with specific focus on tactical fighters in a net-enabled agile environment. Developments will include verification and validation across integration and aggregation techniques for systems-of-systems evaluation as well as automating testing of warfighter software intensive systems using virtualized and cloud environments.			
Accomplishments/Planned Programs Subtotals	14.448	15.328	13.384

C. Other Program Funding Summary ($ in Millions)

N/A

Remarks

D. Acquisition Strategy

N/A

E. Performance Metrics

Percentage of T&E/S&T projects progressing satisfactorily toward technical, financial, schedule, and risk mitigation goals.

Exhibit R-2A, RDT&E Project Justification: PB 2017 Office of the Secretary Of Defense			Date: February 2016
Appropriation/Budget Activity 0400 / 3	R-1 Program Element (Number/Name) PE 0603941D8Z / *Test and Evaluation/ Science and Technology*	Project (Number/Name) 7 / *Unmanned and Autonomous System Test*	

COST ($ in Millions)	Prior Years	FY 2015	FY 2016	FY 2017 Base	FY 2017 OCO	FY 2017 Total	FY 2018	FY 2019	FY 2020	FY 2021	Cost To Complete	Total Cost
7: *Unmanned and Autonomous System Test*	14.021	5.239	6.686	8.819	-	8.819	9.888	12.697	12.980	13.408	Continuing	Continuing

A. Mission Description and Budget Item Justification

Unmanned and Autonomous Systems (UAS) support every domain of warfare. They operate 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 unmanned systems brings a host of revolutionary capabilities that will profoundly influence warfare. The Unmanned and Autonomous Systems Test (UAST) project addresses current and emerging challenges associated with the test and evaluation (T&E) of these critical warfighting capabilities. The technology developments within the UAST portfolio have been prioritized to align with Department of Defense (DoD) guidance on science and technology priority investments, particularly in assessing autonomy. 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. Current DoD test capabilities and methodologies are insufficient to address the testing of increasingly autonomous units and teams of unmanned systems 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 intelligent systems.

B. Accomplishments/Planned Programs ($ in Millions)	FY 2015	FY 2016	FY 2017
Title: Unmanned and Autonomous System Test	5.239	6.686	8.819
FY 2015 Accomplishments: The UAST project focused on predicting and assessing the autonomy functions of unmanned and autonomous systems through ongoing technology developments. Efforts continued to develop technology to virtualize test sites into ultra-high-fidelity, real-time simulators. The goal is to facilitate verification, assessment, and evaluation of UASs in a realistic, risk mitigated, highly measureable, statistically significant manner prior to field test. The UAST project built automated tools to test the robustness of black-box UASs in unexpected operating scenarios. The technology feeds inputs that trigger software anomalies to find vulnerabilities without costly field testing. The test technology was developed and implemented as a prototype to enable stress testing of black box system autonomy architectures, with a focus on UAS software and the interfaces of the core components without requiring source code. The approach is agnostic to the specific component interfaces. This technology provided testers with a perspective of system performance and a previously unavailable prediction of behavior. Work commenced to develop technology to rapidly develop test plans, assess regression testing, and characterize the biases from the test environment.			
FY 2016 Plans:			

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2015	FY 2016	FY 2017
Work on the stress testing tool will complete and the tool will transition to T&E activities. New efforts will focus on investing in test technologies 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 & Test Facility Bases (MRTFB). The UAST project will further explore test technologies to meet the challenges of testing autonomy by leveraging advances made in the standardization of UAS architectures, functional components, and interfaces. UAST will continue research in the area of autonomous system test planning to develop technologies which develop the most relevant test plans for maritime, air, and ground-based autonomous systems and enable testers to identify the degree of regression testing required for autonomous systems upon changes to the hardware and software. The UAST project will emphasize autonomy test technologies that can be integrated for use in a TENA environment within the MRTFB. UAST will initiate developments to automatically predict test vehicle collisions and cue test range controllers to take corrective action. This system will prevent the test vehicle from violating flight corridor, test range, and warning area boundaries. ***FY 2017 Plans:*** The UAST project will continue development of technology to support testing autonomous ground systems. Development will continue on technologies that predict test air vehicle collisions while preventing the test vehicle from violating flight corridor, test range, and warning area boundaries; these technologies will be made TENA compliant to facilitate transition across the MRTFB. The development of technology that rapidly develops test plans, assesses regression testing required, and characterizes the bias from the test environment and instrumentation will complete. Developments will be fully compliant with TENA and suitable for integration on the Joint Mission Environment Test Capability network. The UAST project will continue to develop test technologies that address mid-term UAS test challenges associated with autonomy and initiate efforts to explore the far term challenges of testing system intelligence. These efforts will include an examination of test technologies that measure the logical flow of sensing data, to perception, decisions, and action. Additionally, the UAST project will focus on enhancing the test environment to assess unmanned threat systems. The UAST project will invest in complementary tools to predict UAS behavior by monitoring how autonomous systems process data in response to environmental changes. The UAST project will investigate technologies for T&E of UAS-to-UAS and human-to-UAS interactions.			
Accomplishments/Planned Programs Subtotals	5.239	6.686	8.819

C. Other Program Funding Summary ($ in Millions)

N/A

Remarks

D. Acquisition Strategy

N/A

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E. Performance Metrics

Percentage of T&E/S&T projects progressing satisfactorily toward technical, financial, schedule, and risk mitigation goals.

Exhibit R-2A, RDT&E Project Justification: PB 2017 Office of the Secretary Of Defense			Date: February 2016
Appropriation/Budget Activity 0400 / 3	R-1 Program Element (Number/Name) PE 0603941D8Z / *Test and Evaluation/ Science and Technology*	Project (Number/Name) 8 / *Cyberspace Test*	

COST ($ in Millions)	Prior Years	FY 2015	FY 2016	FY 2017 Base	FY 2017 OCO	FY 2017 Total	FY 2018	FY 2019	FY 2020	FY 2021	Cost To Complete	Total Cost
8: *Cyberspace Test*	6.661	5.253	6.576	9.342	-	9.342	11.697	14.113	14.338	14.598	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 2015	FY 2016	FY 2017
Title: Cyberspace Test	5.253	6.576	9.342
FY 2015 Accomplishments: The CTT project continued development of automated threat intelligence processing, target folder generation, traffic generation agents, malicious website analysis and cloning, and threat actor motivation. The CTT project completed successful demonstration of a system for threat traffic generation and automated attack, as well as a prototype for instrumentation and data analytics. The CTT project also successfully demonstrated the execution framework, tools, and payloads for automated and verified sanitization processes on specialized information technology assets. The project completed system-level tests and demonstrated a sanitization concept for kinetic assets. This technology will eliminate traces of contaminating cyber-attacks between tests, an essential step in the cyberspace test execution process.			
FY 2016 Plans: The threat and sanitization technology work will finish and transition to cyber test organizations and future test infrastructure development activities. The threat effort will deliver cyberspace threat representation and instrumentation technologies required to assess cyberspace vulnerabilities and improve the agility of cyberspace test capabilities. The sanitization technology development will deliver test technologies to develop a reliable, fast, automated, and cost-effective sanitization approach. This will allow the rapid repurposing of equipment between different tests to meet the expanding requirements for cyber testing. The CTT project will continue to seek out new cyberspace test technology development efforts.			
FY 2017 Plans: The CTT project will pursue technology developments addressing needs to: provide automated cyberspace test planning, create representative cyberspace threats and test environments, execute cyberspace tests, and perform cyberspace test analysis and			

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2015	FY 2016	FY 2017
evaluation. These efforts will support defensive and offensive cyberspace weapon systems testing, as well as cyber resiliency testing of air, land, and sea-based weapon systems.			
Accomplishments/Planned Programs Subtotals	5.253	6.576	9.342

C. Other Program Funding Summary ($ in Millions)

N/A

Remarks

D. Acquisition Strategy

N/A

E. Performance Metrics

Percentage of T&E/S&T projects progressing satisfactorily toward technical, financial, schedule, and risk mitigation goals.

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