Test and Evaluation Resources

Public law requires DOT&E to assess the adequacy of operational and live fire testing conducted for programs under oversight, and to include comments and recommendations on resources and facilities available for OT&E and on levels of funding made available for OT&E activities. DOT&E monitors and reviews DOD and Service-level strategic plans, investment programs, and resource management decisions to ensure capabilities necessary for realistic operational tests are supported. This report highlights general areas of concern in testing current systems and discusses significant issues, DOT&E recommendations, and T&E resource and infrastructure needs to support operational and live fire testing. FY15 focus areas include:

- Army Support of OT&E
- Cybersecurity Red Team Personnel Shortfalls
- Cyber Threat Support to T&E
- High Altitude Electromagnetic Pulse (HEMP) Test Capability
- Joint Strike Fighter (JSF) Advanced Electronic Warfare (EW) Test Resources
- Point Mugu Sea Test Range (STR) Enhancements to Support OT&E of Air Warfare Programs
- EW for Land Combat
- Navy Advanced EW Test Resources and Environments
- Equipping Self-Defense Test Ship (SDTS) for Aegis Combat System, Air and Missile Defense Radar (AMDR) and Evolved SeaSparrow Missile (ESSM) Block 2 Operational Testing
- Multi-Stage Supersonic Targets (MSST)
- Fifth-Generation Aerial Target
- Warrior Injury Assessment Manikin (WIAMan)
- Torpedo Surrogates for Operational Testing of Anti-Submarine Warfare (ASW) Platforms and Systems
- Submarine Surrogates for Operational Testing of Lightweight and Heavyweight Torpedoes
- Signature Data Collection for Infrared (IR) Guided Surface to Air and Hostile Fire Threats to Support Model Development
- Threat Modeling and Simulation (M&S) to Support Aircraft Survivability Equipment (ASE) Testing
- Foreign Materiel Acquisition Support for T&E
- Tactical Engagement Simulation with Real Time Casualty Assessment (TES/RTCA)
- Testing in Urban Environments
- Biological Defense Testing at West Desert Test Center on Dugway Proving Ground, Utah
- Range Sustainability
- Continuing Radio Frequency Spectrum Concerns

Army Support of OT&E

In the 2014 Annual Report, DOT&E recommended that the Army restore the Operational Test Command (OTC) and Army Evaluation Center (AEC) budgets in order to maintain FY14 staffing levels, and ensure staffing levels of the Army T&E Executive are consistent with its mission. In a memorandum to the Secretary of the Army, dated November 12, 2014, DOT&E highlighted the importance of the office of the Army T&E Executive and recommended decisions to reduce staff be reversed. For FY16, the OTC budget has remained flat and the AEC budget has been reduced an additional 4 percent from FY15. Staffing levels at OTC have increased ~7 percent, and AEC staffing has decreased ~1 percent compared to FY14 levels.

During the DOT&E review of the Army's T&E budget and resources, the Army acknowledged that the current staffing levels may cause increased customer billing rates, the inability to conduct simultaneous operational test events, and longer timelines for the release of test reports. DOT&E is concerned that the reduced staffing equates to an inadequate number of experienced T&E staff needed to ensure efficient and timely preparation of TEMPs and test plans. Delays in test planning, execution, and reporting can result in delayed acquisition. The savings generated by further reducing the staff of OTC and AEC could be offset by cost penalties to acquisition programs that are proportional to their respective spend rates multiplied by the duration of delay. Other smaller but valuable programs may be delayed even longer, as priority will be given to the Major Defense Acquisition Programs.

DOT&E will continue to monitor the Army T&E workforce to ensure that it is able to support and not hinder the outcomes of the Army's acquisition programs.

Cybersecurity Red Team Personnel Shortfalls

The increasing demand for certified cyber red teams to support training, operations, and acquisition testing is placing considerable strain on this small professional community within the Department. This demand is driven by the growing desire for acquisition program managers to test their systems during development to discover and address cybersecurity vulnerabilities, the continuing need to perform threat-representative cybersecurity operational testing, and the cybersecurity training needs of the growing number of Cyber Mission Force personnel. The subset of red team personnel certified to operate on live networks are critical to conducting the operational testing and Combatant Command (CCMD) assessments described in the Cybersecurity section of this report. These highly qualified red teams are experiencing the highest

demand, and some of these teams have indicated to DOT&E that they will not be able to support all of the currently planned operational tests.

DOT&E has already seen instances in which tests were rescheduled or could not be performed as planned due to a lack of available cyber teams authorized to conduct cyber operations on live networks and enclaves. The high operational tempo of the red teams has reduced or eliminated opportunities for the teams to train, thereby eroding their ability to ensure their skill level is commensurate with advanced nation state cyber threats. The high operational tempo has also induced a number of experienced red team members to seek higher paying, lower demand jobs outside of the Department, further exacerbating the personnel shortfalls.

A number of initiatives would help address the increasing shortfall of cyber red team personnel:

- Creating pay and other incentives for cybersecurity personnel such as those afforded other highly-trained, critical DOD personnel (e.g. pilots)
- Creating a "Persistent Cyber Opposing Force (OPFOR)" composed of red team members from across the Services to provide efficient, flexible, and threat-realistic cyber effects
- Establishment of dedicated T&E cyber teams, core-funded, rather than program-funded, to preserve continuity of skills
- Creating and implementing "red team in a box" software which can automatically identify common cybersecurity vulnerabilities

Cyber Threat Support to T&E

DOT&E has recognized that the cyber threat has expanded into the wireless domain using radio frequency (RF) transmissions to deliver the threat effect to the intended victim. This new medium of delivery has expanded the testing required to define, analyze, and resolve U.S. weapon system vulnerabilities. The expansion of cyber threat delivery into the RF domain has created a much more diverse EW portfolio and has led the defense industry to begin recognizing the merging of cyber and EW into a much more diverse threat.

The $5.0 Million appropriations increase for Threat Resource Activities allowed DOT&E to expand its understanding of the "wireless" cyber threat and begin the process of defining, cataloging, and incorporating these threats into a classified, online Threat Database available to the Department in support of U.S. weapon system testing. This online tool defines the threat, provides the appropriate contact information for the responsible intelligence organization, and the status of available representations of that threat to include models and simulations, surrogates, and/or hardware/software representations.

DOT&E recognized that efficiencies in our operations could be gained by merging this cyber threat activity with ongoing cybersecurity activities supporting the CCMD and Service assessments as part of the Cybersecurity Assessment Program. DOT&E's Cyber Threat Folder developers, located within Defense Intelligence Agency (DIA), were transferred to the Threat Resource Activity to allow for continued residence in DIA Headquarters and direct access to all pertinent cyber threat data. These cyber threat analysts continue to support the CCMD Cybersecurity Assessment Program while also providing threat data for incorporation into DOT&E's online Threat Database. While working with the DOT&E analysts at DIA Headquarters, the Threat Resource Activity recognized there was a pressing need for the intelligence community and the users of cyber threat information to have a process for easily sharing Cyber Threat Folders. The Threat Resource Activity began the process of developing a Cyber Threat Folder repository that would allow intelligence organizations and the testing community to have access to Service and intelligence organization Cyber Threat Information. This is an ongoing activity that will be "Beta Tested" in FY16.

High Altitude Electromagnetic Pulse (HEMP) Test Capability

DDG 51 Ship Specification, Section 407 establishes requirements for DDG 51 Electromagnetic Pulse (EMP) Protection. Section 407 states that during the guarantee period of the ship, the Government will conduct a full ship EMP test to determine the performance of the ship's electronic systems under simulated EMP conditions.

The Navy currently does not have a capability to conduct a survivability assessment of a full ship to EMP effects. Current Navy practice is to conduct limited testing on ship systems and sub-systems, and then extrapolate these results to the entire ship. This test approach is not technically effective nor cost efficient since it is limited in scope, time consuming, and expensive due to the time required to complete testing a handful of spaces. More importantly, this testing methodology is not performed at sea in an operational mode and doesn't provide the data needed to adequately assess the full ship EMP survivability. Existing EMP modeling and simulation capabilities provide very limited information on ship survivability with significant uncertainties.

After a detailed assessment of current OSD nuclear range capabilities, the OSD Chemical Biological Radiological and Nuclear Survivability Oversight Group – Nuclear (CSOG-N) T&E Working Group Roadmap identified a full ship EMP Threat-Level Simulator (TLS) for warships as their most important T&E gap. Additionally, the Tri-Service Technical Working Group responsible for the development of MIL-STD-4023, HEMP Protection for Military Surface Ships, agreed that a full ship EMP TLS is required for warship EMP threat survivability assurance.

The Chief of Naval Research/Director, Innovation, Technology Requirements, and T&E (N84) has teamed with the Defense Threat Reduction Agency to establish a Ship EMP TLS Test Working Group to inform Navy leadership of the increasing criticality of this threat. The Defense Threat Reduction Agency determined that tests using a full ship EMP TLS is the best approach to demonstrate ship threat-level HEMP protection and mission assurance in accordance with standing Navy requirements. The costs to build a full ship EMP TLS capability are estimated to be $49 – 54 Million. Once operational, the costs to conduct the first nine tests are estimated at $17.5 – $18.6 Million. Full ship EMP TLS testing at sea

will support mission assurance by provide test data for HEMP modeling and realistic HEMP training scenarios for ship crews. At sea testing using this capability will demonstrate full ship EMP survivability and support the U.S. nuclear deterrent posture.

Joint Strike Fighter (JSF) Advanced EW Test Resources

Since February 2012, when DOT&E identified shortfalls in EW test resources, significant progress has been made in some instances, while progress is lacking in other areas. The EW assets being purchased are key to the development, testing, and timely fielding of numerous U.S. systems critical to operating successfully against threats that currently exist, are proliferating, or are undergoing an accelerating pace of significant upgrades. These systems include the JSF, F-22 Increment 3.2 A/B, B-2 Defensive Management System, Long-Range Strike Bomber, and the Next Generation Jammer for the EA-18G. The status of these EW upgrades is displayed in the Table immediately below.

Due to delays and inaction by the F-35 Joint Program Office, the situation at the JSF mission data file reprogramming lab has reached a critical, nearly unrecoverable point.

TABLE 1. RECOMMENDATIONS ON ELECTRONIC WARFARE TEST RESOURCES

DOT&E Recommendation	Current Status
Developing a combination of open- and closed-loop simulators in the numbers required for operationally realistic open-air range testing of JSF and other systems beginning in 2018.	Both the open- and closed-loop efforts are underway. The open-loop effort delivers nine systems between mid-2016 and mid-2017; and is planned to provide an additional 7, for a total of 16, in time to support F-35 IOT&E and other testing in 2018 and beyond. Delivery of the first two open-loop systems is expected by mid-2016. The closed-loop effort is also underway, but the mobile closed-loop systems required for operational testing are not scheduled to be available until mid- to late-2019, well after the planned F-35 IOT&E. The architecture of the open-loop systems will provide adequate test capabilities for F-35 Block 3F IOT&E, in lieu of closed-loop systems.
Upgrading the government anechoic chambers with adequate numbers of signal generators for realistic threat density.	Initial studies of materiel solutions to achieve realistic densities have begun: • The Navy chamber has procured initial test support equipment for direct injection capability and executed a limited F-35 EW test in September 2014. • The Air Force chamber has identified a path forward covering extensive upgrades through 2020. • The JSF program has yet to develop concrete plans to integrate chamber testing into the verification test strategy.
Upgrading the JSF mission data file reprogramming lab to include realistic threats in realistic numbers.	A JSF Program Office-sponsored study to determine upgrade requirements was completed in December 2014. It confirmed the shortfalls identified by DOT&E in February 2012, but also identified many other critical shortfalls preventing effective and efficient mission data file development and reprogramming. Unfortunately, inexplicable delays by the program since this study was completed have resulted in little to no progress in addressing these shortfalls. Also, the program plans to procure fewer signal generators than the study recommended, further jeopardizing the program's ability to generate effective mission data for IOT&E and Block 3F operations.
Providing Integrated Technical Evaluation and Analysis of Multiple Sources intelligence products needed to guide threat simulations.	Products have been completed and delivered, and are being used to support development of the open- and closed-loop threat radar simulators.

Point Mugu Sea Test Range (STR) Enhancements to Support OT&E of Air Warfare Programs

In 2015, the JSF Joint Operational Test Team (JOTT) determined that an ability to conduct operational test missions on the Point Mugu STR could considerably shorten the duration of F-35 IOT&E, the pace of which is currently constrained by the competition with other programs for a limited number of range periods available each week at the Air Force Western Test Range (WTR), in Nevada. Nearly all mission-level testing in IOT&E was originally scheduled to take place at the WTR.

The JOTT assessment concluded that the key to conducting F-35 IOT&E missions at STR was the timely completion and integration of the Air Warfare Battle Shaping (AWBS) system at the STR. AWBS is a variant of the Air-to-Air Range Instrumentation system at the WTR, where it is essential for scoring and post-mission reconstruction and analysis of OT&E missions. At the time of the assessment, the development and integration of AWBS at the STR was stalled due to a severe funding shortfall. In response to the JOTT assessment, DOT&E and USD(AT&L) together allocated $20 Million to fund the shortfall.

About the same time of the JOTT assessment and the DOT&E and USD(AT&L) decision to provide funding for AWBS at the STR, the JSF Program Office decided to discontinue the Lockheed Martin Verification Simulation (VSim), a high-fidelity manned simulation central to the program's operational test plans, and transfer responsibility for the program's manned simulator requirements to Naval Air Systems Command (NAVAIR). The JSF Program Office stopped work on the Lockheed Martin effort

due to severe cost overruns and their assessment that Lockheed Martin would be unable to deliver an adequate VSim capability in time for F-35 IOT&E.

DOT&E is convinced that NAVAIR will likewise be unable to deliver an adequate VSim capability in time for F-35 IOT&E, and that, in particular, NAVAIR will be unable to complete the project within the cost constraints imposed by the Program Office. At the same time, DOT&E recognized that additional infrastructure upgrades for the Point Mugu STR, in addition to the completion and integration of AWBS, would be required to make the STR a robust venue of F-35 operational testing. Specifically, DOT&E determined that the STR needed equipment and software for replicating the air surveillance and command and control infrastructures of a threat integrated air defense system.

Accordingly, DOT&E has recommended to the Secretary of Defense that a significant portion of the money currently allocated for VSim be reallocated to constructing the required integrated air defense system infrastructure at the STR. DOT&E recommendations include buying a variety of systems, a number of which are available off-the-shelf on the international defense market.

EW for Land Combat

Networked mission command systems that support the commander's mission execution across the Brigade Combat Team (BCT) are a cornerstone of the Army's modernization plan. These integrated network capabilities are distributed throughout a combat formation and its support elements, from the brigade command posts down to the individual dismounted Soldier. Commanders using tactical network systems have the unprecedented ability to transfer information such as voice, video, text, position location information, and high-resolution photographs throughout the BCT, and provide individual commanders access to information needed to complete their mission. The expanded use of radio frequency spectrum to support mission command systems with supporting data networks exposes the BCT to contemporary EW threat vectors available to a broad range of potential enemies. As the Army becomes more dependent on these sophisticated network technologies, it is critical that the developmental/operational test communities continue to identify and assess vulnerabilities of these systems. Decision makers must understand the inherent vulnerabilities, as well as the ways in which an enemy may choose to exploit and/or degrade the network.

During operational testing, threat EW is part of a broader capability set that is made available to the OPFOR commander. Ideally, the EW capabilities, tactics, techniques, and procedures employed by the OPFOR during test should represent those of our potential adversaries. At present, there are necessary and severe limitations placed on the location, frequency, time, and amount of power that may be emitted by the threat EW equipment, in order to avoid interference with commercial aircraft and the civilian populations adjacent to the test and training ranges. Realistic threat EW against communication satellites is not allowed during operational testing due to the potential of interfering with satellites supporting commercial and military operations. These limitations cause artificialities in the test environment and affect the OPFOR's ability to degrade the network and combine EW with other lethal attacks. DOT&E recommends that the Army continue to investigate potential technical and procedural solutions to the current limitations. These critical threat test capabilities are needed to support testing of Warfighter Information Network – Tactical Increment 2, Nett Warrior/Rifleman Radio, Mid-Tier Networking Vehicular Radio, Manpack Radio, and Joint Battle Command – Platform.

Navy Advanced EW Test Resources and Environments

Capability for Realistic Representation of Multiple Anti-Ship Cruise Missile (ASCM) Seekers for Surface EW Improvement Program (SEWIP) Operational Testing

This gap in test capability was initially identified in DOT&E's FY13 Annual Report as "Additional Electronic Warfare Simulator Units for Surface Electronic Warfare Improvement Program (SEWIP) Operational Testing." The Navy addressed it with development of a programmable seeker simulator that could represent different ASCM seekers by specifying the electronic waveform emission characteristics for one of several possible threats. However, the effective radiated power (ERP) was not among those characteristics, resulting in simulated attacks by ASCM representations displaying disparate levels of ERP that are unlikely to be encountered during a stream raid attack of two ASCMs (along the same bearing and elevation and within close proximity of one another). The programmable seeker simulator, termed the "Complex Arbitrary Waveform Synthesizer," needs to be modified such that its ERP more realistically represents the second ASCM of a dual ASCM stream raid.

The next SEWIP Block 2 OT&E is projected for FY19. This is to be followed by FOT&E on a Product Line Architecture compliant DDG 51 with Block 2 actually integrated with the Aegis Combat System. This integration was not part of the Block 2 IOT&E. Subsequent FOT&E would be with the DDG 1000 and CVN 78 combat systems. Estimated cost to add the ERP improvement is $5.0 Million.

Long-Term Improvement in Fidelity of ASCM Seeker/Autopilot Simulators for EW Testing

This gap in test capability was initially identified in DOT&E's FY13 Annual Report due to the continued reliance on manned aircraft for captive-carry of the ASCM seeker simulators. Such simulators will be unable to demonstrate a kinematic response to electronic attack by SEWIP Block 3 nor demonstrate the effect such kinematic responses will have on ships' hard-kill (e.g. missiles, guns) systems. Manned aircraft fly too high and too slowly for credible ASCM representation and are unable to represent ASCM maneuvers. Credible ASCM representation requires a vehicle that can fly at subsonic ASCM speeds and lower altitudes than the current Lear Jets; can home on a platform representing a SEWIP Block 3-mounted ship, using a threat-representative radar seeker and autopilot; and can respond realistically to Block 3 electronic jamming. An approach to satisfy this requirement is a recoverable, unmanned

aerial vehicle using embedded, miniaturized simulators that can maneuver at ASCM speeds and altitudes with encrypted telemetry to track seeker/autopilot responses to electronic attack. A human-controlled override capability would be required for safe operation. The remotely controlled Self-Defense Test Ship (SDTS) would tow a ship target for the unmanned aerial vehicles to home on. SEWIP Block 3 would be mounted on the SDTS along with hard-kill systems such that the integrated hard-kill/soft-kill (i.e. SEWIP Block 3) combat system capability could be demonstrated. Currently, such testing is at the discrete combat system element level, leaving integrated combat system capability unknown.

SEWIP Block 3 IOT&E is projected for FY19. FOT&E of Block 3 integrated with the DDG 1000 combat system, as well as FOT&E with the CVN 78 combat system, should occur subsequent to the IOT&E. The cost for development of these unmanned aerial vehicles (with simulators and telemetry) is estimated to be approximately $120.0 Million for development, testing, and acquisition. Estimated unit cost of each vehicle is not expected to exceed $15.0 Million.

Equipping Self-Defense Test Ship (SDTS) for Aegis Combat System, Air and Missile Defense Radar (AMDR) and Evolved SeaSparrow Missile (ESSM) Block 2 Operational Testing

The close-in ship self-defense battle space is complex and presents a number of challenges. For example, this environment requires:

- Weapon scheduling with very little time for engagement
- The necessity of the combat system and its sensors to deal with debris fields generated by successful engagements of individual ASCMs within a multi-ASCM raid
- Rapid multi-salvo kill assessments for multiple targets
- Transitions between ESSM guidance modes
- Conducting BMD and area air defense missions (i.e., integrated air and missile defense) while simultaneously conducting ship self-defense
- Contending with stream raids of multiple ASCMs attacking along the same bearing, in which directors illuminate multiple targets (especially true for maneuvering threats)
- Designating targets for destruction by the Close-In Weapons System

Multiple hard-kill weapons systems operate close-in, including the Standard Missile 2 (SM-2), the ESSM, and the CIWS. Soft-kill systems such as Nulka MK 53 decoy launching system also operate close-in. The short timelines required to conduct successful ship self-defense place great stress on combat system logic, combat system element synchronization, combat system integration, and end-to-end performance.

Navy range safety restrictions prohibit close-in testing on a manned ship because the targets and debris from successful intercepts will pose an unacceptable risk to the ship and personnel at the ranges where these self-defense engagements take place. These restrictions were imposed following a February 1983 incident on the USS Antrim (FFG 20), which was struck with a subsonic BQM-74 aerial target during a test of its self-defense weapon systems, killing a civilian instructor. The first unmanned, remotely controlled SDTS (the ex-Stoddard) was put into service that same year. A similar incident occurred in November 2013, where two sailors were injured when the same type of aerial target struck the USS Chancellorsville (CG 62) during what was considered to be a low-risk test of its combat system. This latest incident underscores the inherent dangers of testing with manned ships in the close-in battlespace.

While the investigation into the Chancellorsville incident has caused the Navy to rethink how they will employ subsonic and supersonic aerial targets near manned ships, the Navy has always considered supersonic ASCM targets a high risk to safety and will not permit flying them directly at a manned ship. The Navy has invested in a current at-sea, unmanned, remotely-controlled test asset (the SDTS) and is using it to overcome these safety restrictions. The Navy is accrediting a high-fidelity modeling and simulation (M&S) capability utilizing data from the SDTS, as well as data from manned ship testing, so that a full assessment of ship self-defense capabilities of non-Aegis ships can be completely and affordably conducted. While the Navy recognizes the capability as integral to the test programs for certain weapons systems (the Ship Self-Defense System, Rolling Airframe Missile Block 2, and ESSM Block 1) and ship classes (LPD 17, LHA 6, Littoral Combat Ship, LSD 41/49, DDG 1000, and CVN 78), it has not made a similar investment in an SDTS equipped with an Aegis Combat System, AMDR, and ESSM Block 2 for adequate operational testing of the DDG 51 Flight III Destroyer self-defense capabilities. The current SDTS lacks the appropriate sensors and other combat system elements to test these capabilities.

On September 10, 2014, DOT&E submitted a classified memorandum to the USD(AT&L) with a review of the Design of Experiments study by the Navy Program Executive Office for Integrated Warfare Systems, which attempted to provide a technical justification to show the test program did not require an SDTS to adequately assess the self-defense capability of the DDG 51 Flight III Class Destroyers. DOT&E found that the study presented a number of flawed justifications and failed to make a cogent argument for why an SDTS is not needed for operational testing.

On December 10, 2014, the Deputy Secretary of Defense issued a memorandum directing the Director, Cost Analysis/Program Evaluation (CAPE) to identify viable at-sea operational testing options that meet DOT&E adequacy requirements and recommend a course of action (with cost estimates, risks, and benefits) to satisfy testing of the AMDR, Aegis Combat System, and ESSM Block 2 in support of the DDG 51 Flight III Destroyer program. The CAPE study evaluated four options to deliver an at-sea test platform adequate for self-defense operational testing of the DDG 51 Flight III, AMDR, and ESSM Block 2 programs. Each option requires funding beginning in FY18 to ensure support of operational testing of these systems in FY22.

A decision on whether to fund the procurement of the needed equipment is pending.

DOT&E continues to recommend equipping an SDTS with capabilities to support Aegis Combat System, AMDR, and ESSM Block 2 OT&E to test ship self-defense systems' performance in the final seconds of the close-in battle and to acquire sufficient data to accredit ship self-defense performance M&S. The CAPE-estimated cost for development and acquisition of these capabilities over the Future Years Defense Program is approximately $350 Million. Of that, approximately half could be recouped after the test program completes by installing the hardware in a future DDG 51 Flight III Destroyer hull. The Navy previously agreed with this "re-use" approach in their December 2005 Air Warfare/Ship Self-Defense Test and Evaluation Strategy stating that "… upon completion of testing and when compatible with future test events, refurbish and return the test units to operational condition for re-use."

Multi-Stage Supersonic Targets (MSST)

The Navy initiated a $297 Million program in 2009 to develop and produce an adequate multi-stage supersonic target (MSST) required for adequate operational testing of Navy surface ship air defense systems. The MSST is critical to the DDG 1000 Destroyer, CVN 78 Aircraft Carrier, DDG 51 Flight III Destroyer, LHA(R), AMDR, Ship Self-Defense System, Rolling Airframe Missile Block 2, and ESSM Block 2 operational test programs. The MSST underwent a re-structure/re-baseline from 2013 – 2015 to address technical deficiencies as well as cost and schedule breaches, which would have postponed its initial operational capability (IOC) to 2020 and increased total program cost to $962 Million. Based on the re-structured/re-baselined MSST program's high cost and schedule delays as well as new intelligence reports, the Assistant Secretary of the Navy for Research, Development, and Acquisition in 2014 directed that alternatives be examined to test against these ASCM threats and subsequently terminated the MSST program. While the details of the final alternative are classified, DOT&E determined that it would be very costly (Navy estimates $739 Million), very difficult to implement, dependent on the results of highly segmented tests, and would suffer from severe artificialities that would hopelessly confound interpretation of test results. DOT&E informed the Navy that the proposed alternative was not adequate for operational testing and recommended that the Navy not pursue it.

The failure of the MSST program and the inadequate alternative proposal is perpetuating poor Fleet understanding of how well or how poorly their surface combatants will be able to defend themselves against MSST-like ASCM threats. The requirement for a viable, cost-effective, adequate MSST target for operational testing remains valid. Nonetheless, DOT&E agrees that terminating the failed MSST program was the correct decision.

Fifth-Generation Aerial Target

DOT&E initiated studies in 2006 on the design and fabrication of a dedicated fifth-generation aerial target to evaluate U.S. weapon systems effectiveness. The study team, comprised of Air Force and Navy experts, retired Skunk Works engineers, and industry, completed a preliminary design review for a government-owned design. DOT&E requested $27 Million in the FY17 program review to complete final design, tooling, and prototyping efforts. The prototyping effort will provide cost-informed, alternative design and manufacturing approaches for future air vehicle acquisition programs. This data can also be used to assist with future weapon system development decisions, T&E infrastructure planning/investment, and could support future analysis of alternative activities. The prototype design directly supports the U.S. Strategic Command, U.S. Pacific Command, and U. S. Northern Command's Defense Innovation Initiatives for persistent cooperative unmanned aerial systems engagement.

Warrior Injury Assessment Manikin (WIAMan)

In 2010, after the publication of the DOT&E survivability evaluation of the MRAP Family of Vehicles, the Secretary of Defense directed an evaluation of underbody blast (UBB) modeling and simulation (M&S) tools. This evaluation was to determine if an enhanced UBB M&S capability could identify potential vulnerabilities in ground combat vehicle designs while still in the early stages of development. The evaluation identified 10 major gaps preventing the development of a comprehensive, robust UBB M&S capability to accurately model the effects of UBB. The top three gaps were all associated with the shortcomings in available instrumentation and criteria to assess human injury in the UBB environment. The evaluation concluded that automotive crash test dummies used in LFT&E and the consequent injury criteria designed and developed for forces and accelerations in the horizontal plane as seen in automotive frontal impact-induced injuries were not adequate to assess the effects of the forces and accelerations in the vertical plane typically seen in combat-induced UBB events.

In 2010, DOT&E submitted an issue paper advocating the need to fund the identified gaps and shortcoming in current LFT&E practices. This led to the Warrior Injury Assessment Manikin (WIAMan) project with an $88 Million budget over the FY12-16 Future Years Defense Program. Under the WIAMan project, the Army initiated critical biomechanical research and the anthropomorphic test devices (ATD) development program to increase DOD's understanding of the cause and nature of injuries incurred in UBB combat events.

In 2013, the Army created a dedicated office (the WIAMan Engineering Office (WEO)) under the Army Research, Development, and Engineering Command (RDECOM) to manage the WIAMan project. In 2015, the office of the Assistant Secretary of the Army for Acquisition, Logistics, and Technology designated the WIAMan project as an Acquisition Category II acquisition program of record under the Program Executive Office for Simulation, Training, and Instrumentation (PEO STRI). PEO STRI and RDECOM finalized the WIAMan Test Capabilities Requirements Document and a formal Program Office Estimate for full funding of the program. The technical achievements made by the WEO and the concerted effort by the Army to create the foundation for a formal acquisition program

represent major steps forward for the WIAMan project, and the effort is poised to made additional progress in FY16 and beyond, assuming remaining funding is allocated to allow for its completion.

The Assistant Secretary of Defense (Health Affairs) has committed Science &Technology funding to the program post-Milestone B to ensure critical injury biomechanics research is completed, but this commitment has not been matched by a similar commitment from the Army to program for the ATD production and procurement. This led DOT&E to submit another issue paper for additional funding of $98 Million through FY21 that would enable the completion of research and development of injury criteria, predictive M&S, and development of the technical data package including two generations of prototype ATDs. The Army has still not provided funding past FY17 jeopardizing the continuity and completion of this project.

Some within the Army have questioned whether DOD still needs a combat-specific injury assessment capability but in the view of DOT&E, it is entirely appropriate for DOD, and in particular for the Army, to accord the same high priority to testing and verifying the protection provided to Soldiers by their combat vehicles that the commercial automotive industry accords to testing and verifying the protection provided to the U.S. public by their automobiles.

Torpedo Surrogates for Operational Testing of Anti-Submarine Warfare (ASW) Platforms and Systems

Operational testing of ASW platforms and related systems includes the ability to detect, evade, counter, and/or destroy an incoming threat torpedo. The determination of system or platform performance is critically dependent on a combination of the characteristics of the incoming torpedo (e.g., dynamics, noise, fusing, sensors, logic, etc.). Due to differences in technological approach and development, U.S. torpedoes are not representative in many of these torpedo characteristics for many highly proliferated torpedoes, particularly those employed in Anti-Surface Warfare by other nations. Operational testing that is limited to U.S. exercise torpedoes will not allow the identification of existing limitations of ASW systems and related systems against threat torpedoes and will result in uninformed decisions in the employment of these same systems in wartime. A January 9, 2013 DOT&E memorandum to the Assistant Secretary of the Navy for Research, Development, and Acquisition identifies specific threat torpedo attributes that the threat torpedo surrogate(s) must be evaluated against. A June 18, 2015 DOT&E memorandum to Assistant Secretary of the Navy for Research, Development, and Acquisition reiterated the need for representative threat torpedo surrogates in operational test and emphasized understanding threat torpedo behavior, including tactics and counter-measure logic, when evaluating adequacy of torpedo surrogates. The non-availability of threat-representative torpedo surrogates will prevent adequate operational testing for ASW platforms and related systems, as well as adversely affect tactics development and validation of these tactics within the fleet.

Naval Undersea Warfare Center (NUWC) Division Keyport commenced a study of threat torpedo surrogates in FY14. The $480,000 study is jointly funded by the Navy and DOT&E. The completed study, dated September 4, 2015, confirmed DOT&E concerns that current torpedo surrogates have significant gaps in threat representation for operational testing and provided recommendations for improving current threat torpedo emulation. However, the Navy has yet to provide its plan for adequate torpedo surrogates to effectively characterize system performance in future operational tests.

NUWC Division Keyport is pursuing a prototype technology development project that will deliver a threat-representative high-speed quiet propulsion system. The development of a propulsion system prototype is intended to overcome a critical gap identified in the torpedo threat surrogate capability gap analysis, discussed in the preceding paragraph. This effort is funded by DOT&E at approximately $1.0 Million with delivery scheduled in 4QFY16. The NUWC Division Keyport study and prototype development could support future development of a threat torpedo surrogate. Procurement of adequate threat torpedo surrogates, however, is dependent on future Navy decisions.

Submarine Surrogates for Operational Testing of Lightweight and Heavyweight Torpedoes

The Navy routinely conducts in-water operational testing of lightweight and heavyweight ASW torpedoes against manned U.S. Navy submarines. Although these exercise torpedoes do not contain explosive warheads, peacetime safety rules require that the weapons run above or below the target submarine with a significant depth stratum offset to avoid collision. While this procedure allows the torpedo to detect, verify, and initiate homing on the target, it does not support assessment of the complete homing and intercept sequence. One additional limitation is the fact that U.S. nuclear attack submarines may not appropriately emulate the active target strength (sonar cross-section) of smaller threats of interest, such as diesel-electric submarines. During the MK 50 lightweight torpedo operational test in May 1992, the Navy conducted some limited set-to-hit testing against manned submarines, which included impact against the target hull, but that practice has been discontinued.

In preparation for the 2004 MK 54 lightweight torpedo operational test, DOT&E supported the development and construction of the unmanned Weapon Set-to-Hit Torpedo Threat Target (WSTTT) using Resource Enhancement Project (REP) funding. The WSTTT was a full-sized steel mock-up of a small diesel-electric submarine, with an approximate program cost of $11 Million. As a moored stationary target, the WSTTT was limited in its ability to emulate an evading threat, but its use in the MK 54 operational test demonstrated the value of such a dedicated resource. Unfortunately, the Navy did not properly maintain the WSTTT and abandoned it on the bottom of the sea off the California coast in 2006. In subsequent years, the Navy was able to make some limited use of the WSTTT hulk as a bottomed target for torpedo testing.

In a separate effort, the Navy built the Mobile Anti-Submarine Training Target (MASTT), designed to serve as a full-sized threat surrogate for use in training by surface and air ASW forces. The Chief of Naval Operations initiated the program in 2010 with the goal of achieving operational capability by late 2011. After four years and an expenditure of approximately $15 Million, the Navy has yet to use the MASTT in training and seems to be on the brink of abandoning the asset. The Navy resisted design input from the operational test community and made it clear that the MASTT was not intended to support torpedo testing.

In support of a 2010 Urgent Operational Need Statement, the Navy funded the construction of the Steel Diesel-Electric Submarine (SSSK), a full-sized moored set-to-hit target consisting of an open steel framework with a series of corner reflectors to provide appropriate sonar highlights. Unfortunately, this surrogate does not, in fact, provide a realistic sonar signature. Nonetheless, the Navy used the SSSK as a target for the MK 54 torpedo in a 2011 Quick Reaction Assessment and 2013 FOT&E. As part of the Test and Evaluation Master Plan approval for the latter, DOT&E sent a memorandum indicating that the Navy must develop an appropriate mobile target to support future MK 54 testing.

Since early 2013, DOT&E has participated in a Navy working group attempting to define the requirements for a mobile set to hit torpedo target. The group has identified a spectrum of options and capabilities, ranging from a torpedo-sized vehicle towing a long acoustic array to a full-sized submarine surrogate. At the very least, the target is expected to be mobile, autonomous, and certified for lightweight torpedo set-to-hit scenarios. More advanced goals might include realistic active and passive sonar signatures to support ASW search and reactive capability to present a more realistically evasive target. Cost estimates range from under $10 Million for a towed target to over $30 Million for a full-sized submarine simulator.

Signature Data Collection for Infrared (IR) Guided Surface to Air and Hostile Fire Threats to Support Model Development

Threat M&S capabilities are essential for testing missile warning and countermeasure systems under development. However, models for IR guided surface to air and unguided threat weapons do not adequately represent the threat characteristics for testing modern missile warning systems and are deficient. To support threat model development, an integrated, transportable capability to measure and record high fidelity signature, Time Space Position Information, and related information for live fire testing of threat missile and hostile fire munitions (e.g., small arms and RPG) firings was ranked as a high priority need by the Infrared Countermeasures Test Resource Requirements Study (ITRRS) team and the Threat M&S Roadmap. Additionally, the Aircraft Survivability Equipment (ASE) Program Offices from each Service have endorsed this need for assessment of ground truth, anomaly resolution, and to enhance M&S capabilities for the development and T&E of aircraft self-defense systems.

DOT&E supports the use of common, authoritative threat M&S capabilities for ASE testing. For example, the DOT&E Center for Countermeasures serves as the executing activity for a Test Resources Management Center (TRMC) Central Test and Evaluation Investment Program (CTEIP) REP, known as Joint Standards Instrumentation Suite (JSIS). When available, the JSIS IOC will support Advanced Threat Warner and Department of the Navy (DoN) Large Aircraft Infrared Countermeasure (LAIRCM) operational testing. JSIS can be deployed to OCONUS static live fire venues where opportunities exist to measure and collect data for threat assets that are either not available, or of insufficient quantities domestically. JSIS data will support improvements to existing threat models and help create models of new threats. JSIS will provide a capability for use by each Service and support other operational testing needs.

However, the JSIS IOC capability only partially addresses the needs identified by the ITRRS team. For example, it will not provide the capability to measure missile attitude information for the entire missile flyout, nor will the JSIS IOC capability meet all needs related to signature collection fidelity (i.e., frame rates and resolution). Full operational capability is required to meet the needs of the Army's Common Infrared Countermeasures (CIRCM) program, Navy's Advanced Threat Warning, Air Forces' LAIRCM program, and Navy Research Laboratory's Distributed Aperture Infrared Countermeasure (DAIRCM) program. JSIS requires an additional investment of $25 Million to provide the full operational capability needed for Infrared Countermeasures (IRCM) T&E.

Threat Modeling and Simulation (M&S) to Support Aircraft Survivability Equipment (ASE) Testing

Acquiring actual threat systems for widespread testing may not be possible. To address this challenge, DOT&E has funded standard, authoritative threat M&S for systems T&E. In some cases, threat M&S used in T&E have not provided accurate representations, and different M&S instantiations of the same threats often produced different results. DOT&E's objective is to improve the fidelity and consistency of threat M&S at various T&E facilities while reducing overall test costs.

Throughout the T&E process, M&S representations of threat systems can be used when actual threat components are not available. M&S can provide a more complete testing capability than possible through open-air facilities alone. It supports testing when flight safety precludes live testing, such as missile launches against manned aircraft. Threat M&S may be used to extend the results of live missile test events across a broader range of test conditions, with different threats, ranges, altitudes, aspect angles, atmospheric conditions, and other environmental variables affecting weapon system performance.

DOT&E has a T&E Threat M&S Configuration Management System to implement controls and distribution management for threat M&S. This Configuration Management System ensures integrity and consistency of test results among various T&E M&S regimes. This system also provides mechanisms to identify and correct anomalies between a threat and its M&S representations. It assists in controlling model configuration changes, maintaining critical documentation such as interface

descriptions and validation documents, and sharing updated threat M&S with multiple T&E facilities. The T&E Threat M&S Configuration Control Board, comprised of representatives from the T&E community and intelligence organizations, prioritizes existing threat M&S developments and changes to ensure updates are provided efficiently to T&E user facilities. Requests for T&E threat M&S, anomaly reports, and change requests are managed by DOT&E.

During FY15, the T&E Threat Resource Activity provided standardized authoritative threat M&S to multiple T&E facilities operated by the Army, Navy, and Air Force in support of Aircraft Survivability Equipment (ASE) testing. DOT&E has engaged our closest allied nations in implementing the same authoritative threat M&S for allied T&E. This allows the U.S. and its allies to efficiently leverage each other's ranges and facilities.

DOT&E developed and updated a Threat M&S Roadmap for ASE T&E to provide a comprehensive plan for future threat M&S. A good example is JSIS, which will capture threat data from live test events. The Roadmap identifies projects to conduct systematic analyses of the JSIS data to feed the development of threat-representative M&S to support U.S. and allied missile warning and infrared countermeasure systems.

Foreign Materiel Acquisition Support for T&E

DOT&E is responsible for ensuring U.S. weapons systems are tested in realistic threat environments using actual threat systems to create these threat environments whenever possible and appropriate. DOT&E develops an annual prioritized list of threat requirements tied to upcoming testing of programs. This list is submitted it to the DIA Joint Foreign Materiel Program Office. These requirements are consolidated with Service needs and then processed through various Service and intelligence community collection activities. DOT&E coordinates with the Department of State to identify resource providers to increase opportunities to acquire foreign materiel for use in OT&E.

Foreign materiel requirements span all warfare areas, but DOT&E continues to place a priority on the acquisition of Man-Portable Air Defense Systems (MANPADS) to address significant threat shortfalls that affect testing for IRCM programs like CIRCM, LAIRCM, and DoN LAIRCM. In some programs, a large number of MANPADS are required for development of threat M&S, for use in hardware-in-the-loop laboratories, and for LFT&E, to present realistic threats to IRCM equipment. Using actual missiles and missile seekers aids evaluators in determining the effectiveness of IRCM equipment. This past year, several ongoing Foreign Material Acquisition efforts have led to new opportunities to acquire IRCM equipment.

When acquiring specific hardware is not possible, the acquisition of technical documentation may be possible. Evaluating technical documentation is valuable because it supports the development of specific threat simulators to be used at T&E ranges and facilities.

Due to the inherent challenge of developing reliable sources for foreign materiel, negotiating the acquisition of foreign materiel, and the difficulty of using annual appropriations for foreign materiel acquisitions, DOT&E supports the establishment of dedicated, non-expiring funding authority within the DOD Foreign Materiel Program to support foreign materiel acquisitions.

Tactical Engagement Simulation with Real Time Casualty Assessment (TES/RTCA)

Realistic operational environments and a well-equipped enemy intent on winning are fundamental to the adequate operational test of land and expeditionary combat systems. Force-on-force battles between tactical units represent the best method of creating a complex and evolving battlefield environment for test and training. Simulated force-on-force battles must contain realism to cause commanders and Soldiers to make tactical decisions and react to the real-time conditions on the battlefield. TES/RTCA systems integrate live, virtual, and constructive components to enable these simulated force-on-force battles, and provide a means for simulated engagements to have realistic outcomes based on the lethality and survivability characteristics of both the systems under test and the opposing threat systems. TES/RTCA systems must replicate the critical attributes of real-world combat environments such as direct and indirect fires, IEDs and mines, realistic battle damage, and casualties. TES/RTCA systems must record the time-space position information and firing, damage, and casualty data for all players in the test event as an integrated part of the test control and data collection architecture. Post-test playback of these data provides a critical evaluation tool to determine the combat system's capability to support Soldiers and Marines as they conduct combat missions.

DOT&E has recommended the Army Test and Evaluation Command (ATEC) and the Marine Corps Test and Evaluation Activity (MCOTEA) leverage existing TES/RTCA capabilities to support upcoming operational tests and make necessary investments to meet known capability shortfalls and future requirements. Shortfalls include the ability to seamlessly simulate indirect fire weapons, IEDs/mines, and air-to-ground/ground-to-air combat including manned and unmanned teaming. Future requirements include new and upgraded combat vehicles, expanded use of remote weapon stations, and evolving threat systems.

In FY15, the Army increased their planned funding for the Integrated Test Live, Virtual, and Constructive Environment (ITLE) project, which was created to address the known TES/RTCA capability shortfalls and future Army requirements. ITLE will adapt and integrate a number of currently disparate capabilities and take advantage of recent investments made by the Army training community. DOT&E is encouraged by the increase in dedicated TES/RTCA resources and the continued cooperation between the test and training communities in the Army. Beginning in FY16, ATEC is working to resolve issues with its airborne TES/RTCA capability in support of upcoming operational tests of the Apache, Gray Eagle, and Shadow manned/unmanned teaming capability. Funding for this upgrade was anticipated to be provided by the CTEIP REP, but was

diverted to other higher priority efforts. DOT&E continues to support CTEIP and ATEC funded efforts to provide this needed capability.

The Marine Corps' current force-on-force training system, the Instrumented Tactical Engagement Simulation System II, does not support combat vehicle engagements. MCOTEA had planned a substantial upgrade beginning in FY16 to support the upcoming operational testing of the Amphibious Combat Vehicle and Amphibious Assault Vehicle – Survivability Upgrade programs. Funding for this upgrade was anticipated to be provided by the CTEIP REP, but was diverted to other higher priority efforts. DOT&E continues to support CTEIP and MCOTEA funded efforts to provide this needed capability.

TES/RTCA capabilities are essential for realistic force-on-force testing of current and future land and expeditionary warfare systems; DOT&E requires these capabilities for systems such as Amphibious Combat Vehicle, Bradley and Abrams Upgrades, Armored Multi-purpose Vehicle, AH-64E Block III, Joint Light Tactical Vehicle, and Stryker Upgrades.

Testing in Urban Environments

Operations in urban environments present unique challenges to the military Services and their equipment. Degraded mobility, communications, and situational awareness; a large civilian presence; the risk of collateral damage; reduced stand-off distances; and unique threat profiles are some of the conditions present during urban operations. These challenges and a world population that is becoming increasingly urban, reinforce the requirement that systems conduct operational testing in realistic urban environments.

From 2009 to 2011, the Army conducted the Urban Environment Test Capability study that collected data on cities around the world and characterized aspects of urban environments important to military operations. The Urban Environment Test Capability final report was used to support a Test Capabilities Requirements Document for the Army led Joint Urban Test Capability (JUTC) project. The JUTC planned to build a reconfigurable urban area with modular structures from one to five stories tall on the White Sands Missile Range (WSMR), New Mexico. The JUTC began design and development efforts in 1QFY12, but was canceled in 2QFY15 due to programmatic delays, a de-scoping of the original requirement, and cost growth.

The result of the cancellation of JUTC is that the long-standing urban environment operational and developmental test capability shortfall has not been addressed. DOT&E recommends that the Army focus research funding on the fundamental engineering challenges of producing an affordable structure concept that could be applied not only at WSMR, but also on other test and training ranges where operational tests are conducted. The JUTC Test Capability Requirement should be revisited to capture current T&E requirements and future efforts should take into consideration the lessons learned from the failure of JUTC.

Biological Defense Testing at West Desert Test Center on Dugway Proving Ground

In late FY15, DOD suspended the production of and testing with biological select agents and toxins (BSAT) and derivatives of BSAT materials at Dugway Proving Ground pending an investigation and review of safety and surety protocols and procedures. The suspension has temporarily imposed limitations to DOD's ability to test and evaluate biological defense systems. As directed by Deputy Secretary of Defense, a Biosafety Task Force is reviewing all DOD activities engaged in handling BSAT and providing recommendations to ensure the safety and surety of DOD protocols and procedures. The West Desert Test Center Life Sciences Division will be required to implement improved biosafety and surety protocols and procedures before seeking Centers for Disease Control and Prevention certification to operate at Bio Surety Level Three to resume full test capabilities. West Desert Test Center has unique biological testing facilities that provide operationally realistic T&E of biological defense systems.

Range Sustainability

Adequate mission space to conduct operationally realistic testing on DOD's air-land-sea test and training ranges is a critical resource for developing weapons systems that are effective, reliable, and lethal. DOD test and training ranges face environmental and mission compatibility encroachment challenges that, if not resolved successfully, will adversely affect test capabilities. Accordingly, DOT&E continues efforts on behalf of the T&E community to assess, mitigate where possible, and resolve compatibility challenges so that DOD's mission space is preserved for operationally realistic testing.

DOT&E is focusing on improvements to compatibility evaluation processes, so that deficiencies can be addressed promptly, and with analytical rigor and documentation to support decision makers. The continuing major areas of concern for compatibility evaluations are:

- Wind energy and transmission line projects
- Outer Continental Shelf (OCS) oil and gas leasing
- Foreign investment
- Threatened and endangered species

Wind energy projects, can adversely affect testing capabilities by interfering with test range radars and datalinks. DOD receives, on average, 66 such projects a month for evaluation of risk to mission capabilities. A significant improvement in the DOD evaluation process in 2014 resulted in more timely and effective consideration of projects undergoing review. For example, where a wind turbine project was found to have the potential to seriously degrade radar cross section testing at the Naval Air Warfare Test Center, Patuxent River, Maryland, a timely DOD objection on the basis of Adverse Impact to National Security was filed with the Department of Transportation based on a

thorough evaluation by DOD, and the developer subsequently withdrew the application for the project.

There has been an increase of over 20 percent, between 2014 and 2015, in the number of transmission line projects referred to DOD for review for compatibility concerns. DOT&E actively participated in the review of these projects, and coordinated its evaluations with those of other DOD components. In the case of the SunZia transmission line project, DOT&E-led test-related reviews determined that the proposed line routing would impair networked missile intercept testing at WSMR. DOD reached an agreement with the Bureau of Land Management to bury portions of the transmission lines in areas most critical for missile intercept testing. Subsequently, DOT&E conducted a post-decision SunZia lessons learned study intended to help improve DOD evaluation processes, and to include more effective interaction with other federal agencies.

DOT&E continues to work with the office of the Assistant Secretary of Defense (Readiness) to coordinate the DOD response to the Bureau of Ocean Energy Management on proposed oil and gas lease plans for the OCS. Areas considered for such leases are often the same areas where DOD testing must be conducted. Continued use of these areas is critical so that test realism is achieved and public safety is preserved. Consequently, DOT&E is engaged in evaluating test capability risk from proposed leaseholds in the OCS and representing those risks in developing the Bureau of Ocean Energy Management 2017 to 2022 lease plan so that weapons system testing requirements are balanced with national energy needs.

Foreign investment in the United States near test ranges is a new concern due to possible security risks for foreign data collection. Recognizing this concern, DOD refers some 20 projects per month from the Congressional Committee on Foreign Investment in the United States to DOT&E for evaluation. An analysis methodology, developed by DOT&E, is being used to determine whether there are potential risks to test resources.

Species and habitat environmental concerns continue to be issues for test ranges. There are 145 candidate species now awaiting U.S. Fish and Wildlife Service listing determinations, including 25 species which could potentially impact military test and training. To ensure a balance of testing requirements with species protection, DOT&E monitors potential impacts to test ranges. In collaboration with other DOD and Federal Agencies, DOT&E continues to seek proactive solutions that will minimize negative impacts for use of range space.

DOT&E's range sustainability work also relies on outreach with regional partnerships to include the Southeast Regional Partnership for Planning and Sustainability, Western Regional Partnership, Land Trust Alliance, other Federal agencies, the Range Commanders Council, and Service Program Executive Offices. This outreach provides a mechanism for mutual understanding of DOD and external-to-DOD requirements in addressing range sustainability issues. This outreach enables DOD to educate external organizations on why resources are needed for test purposes, and at the same time gives DOD improved access to, and awareness into, external-to-DOD information and processes.

Continuing Radio Frequency Spectrum Concerns

Adequate frequency spectrum is a critical resource for testing. It is required to both upload and download test data between the article being tested to test instrumentation, and to control resources during test operations. At the World Radiocommunication Conference 2007 (WRC-07), the United States position was that there is a large and growing shortfall of global or regional Aeronautical Mobile Telemetry (AMT) allocations. With increasing data rates associated with the testing of new and emerging technologies, the United States believed that an additional 650 Megahertz (MHz) would be required for AMT.

Test range use of frequency spectrum continues to be challenged by pressures to repurpose spectrum to broadband wireless and to support emerging technologies such as small unmanned airborne systems. With domestic and international spectrum being repurposed for non-defense wireless transmission needs, DOT&E remains actively engaged with the DOD Chief Information Officer, Deputy Assistant Secretary of Defense (Developmental Test and Evaluation), and TRMC, to ensure that frequency spectrum allocations are sufficient for the conduct of test operations, and also that these operations use frequency efficiently. This spectrum efficiency goal is being actively pursued through the TRMC administered Science and Technology program and CTEIP.

DOT&E documented the pending loss of the 1,755 – 1,780 MHz band and compression into 1,780 – 1,850 MHz in its FY13 Annual Report. This loss occurred during the Advanced Wireless Services – 3 auction, which concluded January 29, 2015. The impacts to the Services' T&E infrastructure for transitioning AMT capabilities from this spectrum in the L-band are:

- Army T&E requires ~ $27.7 Million to retrofit Aerial Telemetry Systems at WSMR and to compress operations into the 1,780 – 1,850 MHz band. An additional $1.0 Million is required to replace point-to-point datalinks at Aberdeen Test Center, Aberdeen Proving Ground, Maryland. Testing of robotics will be relocating to 4 Gigahertz (C-band), which will require new equipment to be installed.
- Navy T&E requires ~ $108 Million to compress AMT operations into the 1,780 – 1,850 MHz band and to make smart investments in ground and airborne infrastructure to utilize C-band AMT frequencies where practicable. In accordance with the National Telecommunications and Information Administration, Federal Communications Commission (FCC) and Office of Management of Budget approved transition plan, the Navy will modify ground and airborne AMT systems, including incorporating more efficient telemetry modulation techniques, adding multi-band antennas, and installing interference-monitoring equipment. The Navy transition plan also accounts for Missile Defense Agency (MDA)

requirements. Timelines for transition range from 36 months (MDA) to 102 months, depending on the installation. To minimize impacts on operational military mission capabilities, the Navy will also purchase five mobile/transportable telemetry units to supplement capacity while AMT receiver sites are offline for modification.

- Air Force T&E requires ~ $348 Million to compress into the 1,780 – 1,850 MHz band. The funds are required to modify ground and airborne systems, including incorporating more efficient modulation techniques, adding multi-band antennas, and installing interference-monitoring equipment. Timelines for this transition range from 66 to 120 months, depending on the installation. To minimize impacts on operational military mission capabilities, the Air Force will also purchase six mobile/transportable telemetry units to supplement capacity while AMT receiver sites are offline for modification.

Table 2 illustrates the frequency bands used for T&E, and identifies resource deficiencies and their potential mitigations. As the table below points out, both the range's primary L- and S-bands have been identified for study to support the National Broadband plan, published in March 2010 whereby 500 MHz would be repurposed from federal and non-federal bands for broadband wireless use. The spectrum now allocated to test is used full time during the range day (i.e., from 6:00am to 6:00pm), and continued unimpeded use is critical to allow for collection of the increasing volume of test data (e.g., that of the F-35 JSF).

The test ranges' are currently working two problems in the primary band for telemetry, 1,435 – 1,525 MHz:

1. The first problem is the recently approved FCC rulemaking to allow sharing of the spectrum with wireless microphones used for major concerts and sports events. DOD has worked successfully with industry to adopt the use of agreements (such as not-to-interfere agreements) and electronic keys to coordinate band usage. However, the development of the electronic key technology has not been done and its reliability has not been demonstrated.
2. The second problem has greater potential impact to the test community and stems from proposed WRC repurposing of AMT allocated spectrum for worldwide wireless broadband use, which both Canada and Mexico support. The United States has notified its neighbors it intends to continue using the band for telemetry albeit in accordance with any protection agreements concluded with each neighbor. Due to the location of many of the test ranges in the Southwest continental United States and commercial aircraft manufacturers' testing proximate to the U.S. and Canadian border, repurposing of the 1,435 – 1,525 MHz spectrum for wireless broadband is of major concern due to its potential to interfere with AMT operations. Canada has engaged with DOD and the aircraft industry to define protection criteria for both U.S. and Canadian systems to take effect when Canada begins using the band for wireless broadband service. Mexico has also been approached to work mitigation strategies for the same reason.

The second most-used band for test range telemetry is the 2,360 – 2,390 MHz spectrum. Again the issue confronting the ranges is the potential interference with AMT operations from assignment of adjacent spectrum (2,345 – 2,360 MHz) to wireless broadband use. The vendor for operations in this spectrum has agreed to use of the International Telecommunications Union recommendation that prescribes out-of-band emissions protection for telemetry systems. DOD continues to work this issue with both the FCC and the vendor.

Frequency spectrum is a limited resource with many more demands than available supply. The DOD published its Electromagnetic Spectrum Strategy at the end of 2013, followed by the Roadmap and Action Plan that will guide the strategy implementation in 2015. A major element of the strategy is an emphasis on spectrum sharing vice spectrum reallocation, because both DOD and the private industry sector demands are growing at rapidly.

TABLE 2. FREQUENCY ALLOCATIONS USED FOR TESTING AND DOD RESOURCE ISSUES AND POTENTIAL MITIGATIONS				
Frequency	**Use**	**Users**	**Resource Issue and Potential Mitigation**	**Notes**
406.1 – 420 MHz	Land mobile radio	Test control and field operators		
1350 – 1390 MHz	Time, Space, Position Information	Critical to almost all open-air tests; range surveillance radar (Air Route Surveillance Radar-4)	Band is part of 1300-1400 MHz band under consideration for reallocation to broadband at WRC-15. US will declare a no-change position if it comes to fruition, but will need to constrain operations along boarders if Mexico and/or Canada adopt such a change.	Band is where position location systems (TSPI) operate. Used at most test ranges, some training ranges.
1435 – 1525 MHz	L-Band Telemetry - Primary Telemetry Band	SDB, UH1/AH, T-45, SH-60, VH-S, V-22, F-18, F-18E, F-22, F-35, B-2, F-16, B-1, B-2, B-52, Global Hawk	• Issue: Wireless microphone use. • Potential Mitigation: Alternate user coordination with assigned key codes for spectrum access in allotted time periods. • Issue: WRC assignment to worldwide wireless broadband use. • Potential Mitigation: Ongoing negotiations with Canada and Mexico.	Regardless of outcomes of Canada & Mexico negotiations, usage would still be constrained along borders.
1675 – 1710 MHz	Weather, including wind speed measurement	Critical to almost all open-air tests		
1755 – 1780 MHz	L-Band Telemetry	F/EA-18G, Aerostar, ASVS, SM-2, RAM, SSRT, Classified UAV (WSMR), ARAV, X-47, the only band for miss-distance indicators used to score missile shots	• Issue: Advanced Wireless Services – 3 auction completed. • Mitigation: Use compression and relocation to 4400 – 4940 MHz and 5091 – 5150 MHz with Spectrum.	Regardless of mitigation, loss of capacity cannot be mitigated over long term.
1780 – 1850 MHz	L-Band Telemetry	F/EA-18G, Aerostar, ASVS, SM-2, RAM, SSRT, Classified UAV (WSMR), ARAV, X-47, the only band for miss-distance indicators used to score missile shots		This spectrum may be auctioned over the next 10 years. DOD working towards sharing vice reallocation.
2200 – 2290 MHz	S-Band Telemetry	AIM-9X, AIM-120, JAASM, JDAM, WCMD, JSOW, SDB, Aerostar, ASVS, WSI, 6DOF, MDA, Patriot, SM-2, ATACMS, F-15, F-16, F-22, F-35, T-38, B-1, B-2, B-52, C-17, Global Hawk, X-51 Waverider	Band has been found to be exceptionally vulnerable to emissions from Long Term Evolution wireless broadband towers operating more than 50 MHz below the band edge. Mitigation is being worked.	
2360 – 2390 MHz	Upper S-Band Telemetry	F-18E/400, E2-D, P-8A, Exdrone, Silver Fox, THAAD, F-16, F-22, B-1, B-2, B-52, C-17, Global Hawk	• Issue: Wireless communications in 2345-2360 can interfere with operations in this band. • Potential Mitigation: Pending.	Working with industry to try to solve interference problems.
2390 – 2395 MHz	Upper S-Band Telemetry	F-18E/400, E2-D, P-8A, Exdrone, Silver Fox, THAAD, F-16, F-22, B-1, B-2, B-52, C-17, Global Hawk		Shared for additional Upper S-Band coverage.
2700 – 2900 MHz	Range surveillance radar	Critical to almost all open-air tests		
4400 – 4940 MHz	Range Telemetry	F-15SA, F-15 (pending), fixed point-to-point microwave, tactical radio, UAV, threat simulators		Band is just now coming into use.
5091 – 5150 MHz (Region 2: 5091 – 6700 MHz)	Range Telemetry	F-15SA		Shared with Federal Aviation Administration. Band is just now coming into use.