

Test and Evaluation Resources

DOT&E assesses the adequacy of test and evaluation (T&E) resources and facilities for operational and live fire testing and evaluation. DOT&E monitors and reviews DOD- and Service-level strategic plans, investment programs, and resource management decisions that affect realistic operational and live fire tests. This section discusses areas of concern in T&E infrastructure needed for adequate operational and live fire testing of current and future systems, the associated challenges, and makes recommendations. FY19 areas include:

- Modernizing T&E Infrastructure for National Defense Strategy (NDS) Technologies
- T&E Workforce for the NDS
- Directed-Energy Weapons T&E
- Nuclear Survivability Test Capability
- Range Modernization
- Threat Representation for OT&E of Space Systems
- Advanced Satellite Navigation Receiver (ASNR)
- Counter-Unmanned Aerial Systems (C-UAS) T&E
- Fifth-Generation Aerial Target (5GAT)
- Navy Aerial Targets and Payloads
- Naval Test Infrastructure Upgrades
- Submarine Target and Countermeasure Surrogates for Torpedo Testing
- Army Manning and Test Technologies for OT&E
- Electronic Warfare (EW) for Land Combat
- Tactical Engagement Simulation with Real Time Casualty Assessment (TES/RTCA)
- Threat Modeling and Simulation (M&S) for T&E
- Foreign Materiel Acquisition Support for T&E
- Earthquake Damage to T&E Infrastructure
- Range Capabilities and Sustainment

Modernizing T&E Infrastructure for NDS Technologies

The 2019 DOD Appropriations Act authorized \$150 Million to DOT&E for modernizing DOD T&E infrastructure in areas such as hypersonics, directed energy, augmented intelligence, machine learning, robotics, and cyberspace. DOT&E partnered with USD(R&E) to align T&E infrastructure investments with advanced technology roadmaps. DOT&E and the Test Resources Management Center (TRMC) developed an investment strategy and managed T&E infrastructure modernization program implementation. This investment supports T&E infrastructure capabilities in the following NDS advanced technology areas and will be transitioned to test ranges, the Services, and TRMC for sustainment as they are completed:

- Hypersonics (\$55 Million). Telemetry and optics instrumentation for unmanned aerial, atmospheric measurement capabilities, and capabilities supporting end-game scoring and weapons effects.
- Directed Energy (\$50 Million). High-Energy Laser (HEL) instrumentation and atmospheric characterization, HEL target and scoring boards, high-power microwave (HPM) diagnostics.
- Big Data Analytics (\$25 Million). Analytics to evaluate next-generation aircraft.
- Artificial Intelligence / Machine Learning (\$10 Million). Test tools to stress artificial intelligence data fusion algorithms.
- Autonomy / Robotics / Cyberspace (\$10 Million). Autonomous cyber threat emulation (“Red Team”) tools.

T&E Workforce for the NDS

The NDS and USD(R&E) modernization priorities focus on development of capabilities based on advanced technology areas such as hypersonics, directed energy, autonomy, artificial

intelligence, and technological innovations to computation, communications, navigation, and sensor capabilities based on quantum physics. Development and testing of systems using these technologies requires an adequately trained and qualified workforce in adequate numbers to develop and implement test strategies and provide the infrastructure to characterize their performance. For example, autonomous systems that rely on artificial intelligence and machine learning are being developed to provide new capabilities that span warfighting functions from intelligence analysis and mission sustainment to force protection and medical treatment of casualties. Autonomous systems are expected to team with human users and/or other autonomous systems, may learn and evolve over time, and potentially exhibit emergent behavior. Understanding the operational performance of autonomous capabilities will require a knowledgeable and multi-disciplinary T&E workforce. Testing autonomous systems requires development of testing methods, evaluation frameworks, and architectures, to include development of test beds, M&S capabilities, and test ranges to observe and analyze performance. The following are recommended to improve access to the highly skilled and talented human capital needed to test and evaluate advanced technology weapon systems:

- Incentivize development of the civilian T&E workforce through establishment of a T&E career path that includes education and training opportunities and rotational assignments.
- Provide professional pay for hiring civilians with special knowledge and skills in high demand.
- Establish/expand scholarships, internships, and fellowship programs to attract new talent to the defense T&E community.

- Expand use of expertise at Federally Funded Research and Development Centers, National Laboratories, University Associated Research Centers, and universities.

Directed-Energy Weapons T&E

Recent advancements in directed-energy weapons to include HEL and HPM warrant test infrastructure and evaluation methods advancement to adequately measure the capabilities and limitations of such systems in relevant operational environments. Damage mechanisms imposed by directed-energy weapons warrant unique T&E requirements that need to be advanced:

- A metrology equipment suite capable of measuring atmospheric reference data relevant to laser propagation and a tool to characterize the effects of atmospheric reference data on laser propagation due to turbulence, extinction, and thermal blooming.
- Reconfigurable, reusable, and/or expendable, instrumented threat surrogates capable of measuring incident laser irradiance in real-time (i.e., laser effects on targets).
- Instrumentation that can withstand expected irradiance levels and accurately measure downrange intensity whether on the ground or in the air (as HEL weapon systems become more powerful).
- M&S tools to estimate directed-energy weapons damage effects on various targets as well as collateral effects (due to laser reflections) so risk to operational T&E events and combat missions can be safely assessed.

In FY19, TRMC allocated funds for the development of HEL and HPM technologies for use on test ranges and in operational environments. The following technologies will aid in atmospheric measurement, system assessment, and safety measurements:

- Mobile High-Energy Laser Measurement (MHELM) to provide instrumentation for use on small unmanned aerial vehicles/targets, anti-ship cruise missiles, and high-speed platforms to diagnose/characterize the laser beam on target. This includes the development of a Laser Integrated Diagnostics System and HEL Target Board Suite to provide mobile diagnostics capability for characterization of HEL beams downrange. Both systems will enable open-air testing of HEL systems in relevant environments.
- Range safety hardware and software to allow for high fidelity measurements of HEL reflections off targets at various distances/angles to validate target reflection hazard predictions. Such hardware will provide range safety personnel as well as warfighters with the necessary tools/data to understand the implications of operating HELs.
- Various HPM technology to include a diagnostic suite/enhanced sensor array, beam evaluation tool/vertical sensor net array, tethered recorder/target, and HPM S-band source.

In FY19, the Center for Countermeasures worked with TRMC to develop the High-Energy Laser Remote Target Scoring (HRTS) system. HRTS is intended to track, image, and score engagement of a target that would not be recoverable. HRTS developmental efforts are ongoing, and its contract award is planned in FY20.

Nuclear Survivability Test Capability

While the Department is in the process of reconstituting the Large Blast Thermal Simulator and the Fast Burst Reactor, several nuclear survivability T&E infrastructure gaps remain. Each of the below capabilities has been identified by the Services and the Contamination Survivability Oversight Group for Nuclear as major T&E capability shortfalls. Continued development of the nuclear survivability T&E infrastructure will support mission assurance, the U.S. nuclear deterrent posture, and enhance national security. The DOD should continue with advancements to enable:

- Survivability assessments of a full ship at sea, in an operational mode, subjected to electromagnetic pulse (EMP) effects. Although the Navy is attempting to pursue full-ship EMP hardening T&E via Low-Level Continuous Wave Illumination coupled with M&S, this method will only provide limited information on ship survivability with significant uncertainties.
- Assessments of DOD systems in cold and warm X-ray environments generated by nuclear blasts. Improved T&E capabilities are needed to advance the understanding of cold (impulse effects) and warm (effects on electronics) X-ray environments on systems (particularly space systems) and improve M&S tools.
- Assessments of DOD systems exposed to radioactive dust suspension after a nuclear blast. The combined abrasive and chemical effects of such dust could cause damage to optical sensor windows, leading surface edges, and hot engine components. Improved test capabilities are needed to enable accurate assessment of the durability of U.S. military systems in such an environment.

Range Modernization

Existing laboratories and range systems do not reflect current or future threat laydowns, and must be upgraded for both flight test and training missions. Improvements include but are not limited to the following:

- Connecting U.S. test and training ranges via secure networks.
- Acquisition of additional high-fidelity, rapidly reprogrammable, open-air threat emulation systems.
- Upgrades to current high fidelity systems in order to provide greater flexibility to the ranges in support of the warfighter.

Updates to and full funding for open-air battle-shaping that would be used to provide real-time battle-shaping of open-air missions and collection of critical data that will be used to verify, validate, and accredit M&S capabilities.

Threat Representation for OT&E of Space Systems

U.S. adversaries are pursuing offensive space control capabilities to mitigate U.S. military space superiority. The Services test space systems against natural phenomena and space hazards, but do not have the infrastructure to test them against man-made threats. The DOD has invested little in the infrastructure needed for operational testing against known and emergent threats in the space domain.

To demonstrate DOD space system survivability against kinetic, directed-energy, and radio frequency (RF) threats, they must be tested against those threats. In March 2016 and again in September 2019, DOT&E issued guidance to the Services to identify gaps in their ability to emulate realistic space threats, and to program resources to mitigate those gaps. In FY19, the Air Force used some added congressional funding to improve testing against space threats. DOT&E estimates \$100 Million per year across the Future Year Defense Program is required to adequately test existing space programs against validated threats. Additional funding will be needed to test future space programs being considered for development.

Advanced Satellite Navigation Receiver (ASNR)

The DOT&E Test and Evaluation Threat Resource Activity (TETRA) project for the ASNR is intended to improve the accuracy of the Time Space Position Information (TSPI) instrumentation used to collect threat missile dynamics and performance data during flight tests. Accurate TSPI information is needed to support threat model design, and the development/improvement of U.S. countermeasure capabilities. Current TSPI instrumentation cannot capture all required data for system assessment, flight data analysis, and intelligence model design, and will start becoming obsolete within the next 3 years. The ASNR task needs continued funding for completion in order to provide the Intelligence Community (IC) and test community with the required TSPI accuracy, and to mitigate obsolescence concerns.

Counter-Unmanned Aerial Systems (C-UAS) T&E

The DOD has been developing an array of technologies to protect against UAS threats. Advancements in C-UAS test infrastructure, instrumentation, policy, and UAS targets are needed for adequate evaluation of C-UAS in contested environments.

- Comprehensive evaluation of C-UAS performance requires testing desert, coastal, urban, forested areas, and congested (e.g., cellular 4G and 5G) and contested RF environments.
- A standard set of operational protocols is necessary to consistently test and evaluate systems and compare system performance over time.
- Trained military operators are required for an operationally realistic assessment of effectiveness and suitability.
- Ranges need optical and RF tracking systems to enable the simultaneous tracking of multiple targets approaching on multiple threat axes.
- Validated target inventory will need to increase and reflect the evolving commercial market and advancements in threat capabilities.
- Standard diagnostics are needed to evaluate operational effectiveness for non-kinetic kill mechanisms (such as jamming), particularly if the kill mechanism prevents the threat mission without a recognizable catastrophic kill.
- Instrumentation is needed to quantify the significance of the effect on individual elements and potential interaction between elements within a swarm.
- Representative battle management C2 infrastructure needs to be present and included in testing.

Fifth-Generation Aerial Target (5GAT)

The 5GAT team – comprised of Air Force and Navy experts, retired Skunk Works engineers, and industry experts – completed the fully owned government design. This includes the aircraft outer mold line, internal structures, loads analysis, propulsion, and subsystems. The 5GAT effort is currently completing the first demonstration prototype, including flight propulsion, system integration, and flight simulation/verification activities. Flight testing of the first prototype is scheduled to begin in 2QFY20. The prototyping effort will provide cost-informed alternative design and manufacturing approaches for future air vehicle acquisition programs, and verified cost data for all-composite aircraft design/development and alternative tooling approaches. TRMC will begin managing 5GAT in FY20.

Navy Aerial Targets and Payloads

Improved aerial target capabilities are needed to emulate the threats for testing current and upcoming surface Navy combat systems, defensive missiles, and radars, including those of CVN 78 and DDG 51 Flight III.

- The BQM-74 and BQM-177 subsonic aerial targets are not able to emulate some important features of anti-ship missile radars.
- The GQM-163 supersonic aerial target does not have a payload to emulate the radar systems of modern supersonic anti-ship missiles. The increased tempo of Navy testing and System Ships Qualification Trials have exceeded the throughput capability of the GQM-163 target preparation and storage facilities.
- Threat surrogates for testing shipboard electronic attack or decoy systems currently do not emulate threat missile speeds, altitudes, maneuvers, autopilot logic, and electronic protection capabilities.
- The lack of a threat-representative multi-stage supersonic target limits the ability to assess the combat effectiveness of ship self-defense capabilities. The Navy is conducting an M&S study to determine what aspects of the threat are of greatest importance to the systems to be tested.
- A hypersonic threat missile surrogate is needed to assess combat system, radar, and missile performance against hypersonic threats, and to validate M&S.

Naval Test Infrastructure Upgrades

The seagoing, unmanned, remotely controlled self-defense test ship (SDTS) is integral to the test programs for certain weapons systems (the Ship Self-Defense System, Rolling Airframe Missile Block 2, and Evolved Sea Sparrow Missile (ESSM Block 2)), sensors (Enterprise Air Surveillance Radar (EASR)), and ship classes (LPD 17 Flight II, LHA 8, Littoral Combat Ship, LSD 41/49, DDG 1000, and CVN 78).

- DOT&E continues to recommend equipping the SDTS with capabilities to support testing and to validate ship self-defense M&S. In particular, an array of the EASR going on CVN 79, LPD 17 Flight II, and LHA 8 should be installed on the SDTS for use in testing these combat systems. The IOT&Es for these platforms are in the FY24-25 timeframe.

- To support adequate testing of ESSM Block 2 and Standard Missile-6, in the quantities required to be operationally realistic, range infrastructures need telemetry upgrades to support both the greater bandwidth that active missiles employ and the numbers of missiles fired to represent operationally realistic raid sizes.

Submarine Target and Countermeasure Surrogates for Torpedo Testing

The Navy completed an evaluation of set-to-hit target options in 2018 and determined the most cost effective and timely solution for a set-to-hit torpedo target is a certified U.S. attack submarine slated for inactivation. The Navy is currently completing analysis to determine set-to-hit certification criteria for potential submarine targets. The Navy plans to use a combination of existing surrogates, modified artificial targets, and manned submarines to support torpedo testing.

In FY09, DOT&E funded the development of the Submarine Launched Countermeasure Emulator (SLACE) to provide representation of threat countermeasures that have significantly different performance characteristics than U.S. countermeasures. Further enhancement of SLACE is required to provide characteristics of modern torpedo countermeasures. DOT&E supported the use of FY19 funding to include the development of a towed array and its integration into SLACE. This will enable SLACE to emulate modern torpedo countermeasures and better inform the capabilities of lightweight and heavyweight anti-submarine warfare torpedoes.

Army Manning and Test Technologies for OT&E

In FY18, the Army initiated modernization and acquisition reforms, established eight Cross-Functional Teams (CFTs), and activated the Army Futures Command to support rapid acquisition and fielding of new warfighting capabilities. To support the Army's Multi-Domain Operations 2028 concept the Army aligned the CFTs with its six modernization priorities: Long Range Precision Fires, Next Generation Combat Vehicles, Future Vertical Lift, Army Network, Air and Missile Defense Capabilities, and Soldier Lethality.

Beginning in FY14, DOT&E expressed concern about reductions in funding for personnel and test technology at the Army Operational Test Command (OTC). Adjusted for inflation, OTC experienced a 14 percent decrease in funding for personnel. Funding for OT technology has not been adequate to sustain legacy data collection instrumentation, C2 networks, and live/virtual/constructive simulation capabilities. DOT&E is concerned that OTC funding will not be sufficient to support the Army's aggressive modernization goals. The Army Test and Evaluation Command and OTC should work with the CFTs to evaluate the operational test technology needs associated with the Army's modernization priorities and increase OTC funding to match those needs.

Electronic Warfare (EW) for Land Combat

Threat EW environments are essential for operational testing of future Army network initiatives, Nett Warrior/Leader Radio, Manpack Radio, Mission Command Systems, Electronic Warfare Planning and Management Tool, and Assured Positioning, Navigation, and Timing. The Army must continue to enhance its suite of EW test equipment, support a technically competent and experienced T&E workforce, and develop innovative approaches to creating a realistic EW environment to support units operating in the contested electromagnetic environments described in the Multi-Domain Operations concept and the NDS.

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

Sustained investment and upgrades in TES/RTCA capabilities are necessary for testing systems such as Soldier Lethality efforts, Amphibious Combat Vehicle, Bradley and Abrams Upgrades, Armored Multi-Purpose Vehicle, AH-64E Block III, Mobile Protected Firepower, Stryker Upgrades, and Next Generation Combat Vehicle. TES/RTCA systems must record the time-space position information and firing, damage, and casualty data for all players and vehicles in the test event as an integrated part of the test control and data collection architecture. Timely updates to Instrumentable – Multiple Integrated Laser Engagement System (I-MILES) are needed to enable force-on-force testing for new and upgraded vehicles.

Beginning in FY20, the Army cut funding for the Integrated Live, Virtual, Constructive, Test, and Training Environment (ILTE) program that was to acquire the TES/RTCA upgrades. Cutting funding to ILTE is counter to the NDS strategy to “build a more lethal Force” and the Army modernization and readiness priorities.

Threat Modeling and Simulation (M&S) for T&E

The DOT&E TETRA team leads the Threat M&S Working Group Enterprise in the development of common, IC-endorsed threat models used in OT&E. TETRA promotes threat M&S development based on an enterprise management process that provides interoperability standards to facilitate data correlation with threat models across the T&E enterprise. TETRA is funded to develop, validate, and deliver at least 10 RF and 10 infrared high-priority threat models, Laboratory Intelligence Validated Emulators (LIVE), and software-in-the-loop, high-fidelity threat LIVE models. Additional funding will be required to fully develop required near-peer threat models for future battlefield environments. DOT&E recommends continued funding for development of required threat models in collaboration with the IC for systems under oversight.

Foreign Materiel Acquisition Support for T&E

Actual foreign materiel and the information gained through the exploitation of foreign materiel is critical to developing weapons

that work. DOT&E and TETRA develop an annual prioritized list of foreign materiel requirements that are submitted to the Joint Foreign Materiel Program Office (JFMPO) to inform DOD-wide materiel collection priorities. There is a need to identify and develop new sources and opportunities for acquiring foreign materiel. Foreign materiel acquisitions are often lengthy and unpredictable, making it difficult to identify appropriate year funding. DOT&E recommends a no-year or non-expiring funding line for foreign materiel acquisitions, funded at a level of \$10 Million per year for JFMPO.

Earthquake Damage to T&E Infrastructure

Naval Air Weapons Station, China Lake, California, endured magnitude 6.4 and 7.1 earthquakes in July 2019. The China Lake Ranges provide 25 percent of all DOD range capability for the mission areas that they support. The effect on the base was significant with repair and replacement costs for all facilities, instrumentation, and infrastructure currently estimated to be in excess of \$4 Billion.

- Hangar 2, which supports test customers, and Hangar 3, which supports VX-31 (F/A-18 and AV-8B test squadrons), were heavily damaged and require replacement. VX-31 resumed limited flight operations in late July. Due to hangar damage, VX-31 will continue to operate at 50 percent or less of normal capacity until an adequate number of temporary facilities are procured and operational. With these temporary facilities, capacity should approach approximately 70 percent.
- Range operations are operating at approximately 25 percent of capacity. Operations at 70 percent capacity are estimated to resume by July 2020. Test capacity will increase incrementally as power is restored and repairs are completed.
- The Ordnance T&E site suffered significant damage and is currently without power. The estimated date for power restoration is February 2020. Key facilities at this site include the Area R Test Range, Burro Canyon Test Range, CalTech Test Range, Skytop Rocket Motor Firing Bays, two Ordnance Radiographic Inspection Facilities, Ordnance Environmental Test Facilities, and the Ordnance T&E Support Facility.
- Key acquisition programs affected include F/A-18 family of systems, Air Force UAS programs, F-35, Tomahawk, AIM-9X, AV-8B, Army Deliberate Attack, and T&E support to Australian and UK armed forces.

The Navy continues to plan and implement repairs to restore critical capabilities.

Range Capabilities and Sustainment

DOT&E continues to monitor activities with the potential to limit the ability of the Department to fully use test and evaluation infrastructure. The following continue to be areas of particular concern:

Mission Space

Operational testing of hypersonic weapons, directed-energy systems, and autonomous and unmanned vehicles is either now underway or planned in the near future. Adequate operational testing will require long-range corridors that are in excess of currently available air, land, and sea space. The Department continues to be concerned about increased development in the eastern Gulf of Mexico, where the existing statutory moratorium on oil and gas development expires in 2022. The Department is also concerned about certain areas of the mid-Atlantic and off the coast of California, which are being considered for wind power development.

Frequency Spectrum

National spectrum policy supports turning over more spectrum resources to commercial users, at the same time telemetry data rates for weapon systems are increasing. The Department is conducting research and development to identify techniques to conserve spectrum and implement technologies that more efficiently utilize available spectrum. It is imperative that future spectrum sales be carefully structured to ensure no additional loss of capabilities and that adequate spectrum is available to satisfy current and future DOD testing requirements.

Threats to Range Instrumentation

Some of the current range instrumentation rely on obsolete technology and software, increasing the risk of exploitation of sensitive information generated by weapon system testing. Adequate funding for range instrumentation modernization is required so instrumentation can be upgraded or replaced to standards that incorporate cybersecurity as a key performance parameter.

Persistent Surveillance

Foreign intelligence services may be able to conduct surveillance of weapon systems under test or training by investing in U.S. entities. DOT&E monitors projects under review by the Committee on Foreign Investment in the United States, with the goal of identifying foreign investment proposals that pose a significant risk to test and training activities. The recently enacted Foreign Investment Risk Review Modernization Act of 2018 will, when fully implemented, expand the universe of transactions subject to review, thereby allowing greater scrutiny. Range operations may also be limited by space-borne surveillance platforms and by unmanned systems not controlled by the Department.

