Test and Evaluation Resources

Public law requires DOT&E to assess 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 so that capabilities necessary for realistic operational and live fire tests are supported. This report highlights areas of concern in testing current and future systems and discusses significant challenges, DOT&E recommendations, and T&E resource and infrastructure needs to support operational and live fire testing. FY18 focus areas include:

- Hurricane Damage to T&E Infrastructure
- Personnel and Capabilities to Support Cyber-related Operational Testing
- Threat Representation for OT&E of Space Systems
- Automated Ballistic Missile Flight Termination Systems
- Nuclear Survivability Test Capability
- Directed-Energy Weapons T&E
- Counter-Unmanned Aerial Systems T&E
- Advanced Electronic Warfare Test Resources for Air Warfare
- Range Enhancements to Support OT&E of Air Warfare Programs
- Fifth-Generation Aerial Target
- Aircraft Survivability Equipment Test Capability Gaps
- Navy Advanced Electronic Warfare Test Resources and Environments
- Ship Self-Defense Test Capabilities
- Multi-Stage Supersonic Targets
- Torpedo Surrogates for Operational Testing of Anti-Submarine Warfare Platforms and Systems
- Submarine Surrogates for Operational Testing of Lightweight and Heavyweight Torpedoes
- Army Support of OT&E
- Electronic Warfare for Land Combat
- Tactical Engagement Simulation with Real Time Casualty Assessment
- Test and Evaluation of Army Software-Defined Tactical Radios
- Warrior Injury Assessment Manikin
- Foreign Materiel Acquisition Support for T&E
- Range Sustainability

Hurricane Damage to T&E Infrastructure

Hurricane Michael significantly damaged the infrastructure at Tyndall AFB, Florida; Naval Surface Warfare Division (NSWC) Panama City Division (PCD); and the Gulf of Mexico (GOMEX) operating area when it made landfall in October 2018. The storm effect to the test infrastructure at Tyndall AFB included severe damage to the Air Force's primary/preferred BQM-167 aerial target launch site and primary QF-16 aerial target base and test control and range support structure. Two QF-16 unmanned aerial targets were damaged beyond repair. Range safety boat piers were damaged, and one of three range safety and subscale recovery boats was beached and needed recovery by the Navy. Damage to T&E infrastructure such as radar and telemetry antennas extended along the GOMEX coast as far as Eglin AFB.

The Air Force estimates that Tyndall AFB will be unavailable for target support from 6 months up to 3 years. Losses to T&E instrumentation such as telemetry and radar systems in the Florida pan handle are estimated at $65 Million. Although these capabilities exist at other ranges, their temporary unavailability at Tyndall AFB will cause inefficiencies in acquisition test programs requiring these test assets through the spring of 2019. Although a back-up capability resides at Holloman AFB, New Mexico, some maintenance and operational manpower augmentation from Tyndall's manpower pool are required. However, Tyndall manpower is limited while they salvage their personal property and homes which were heavily damaged or destroyed by Hurricane Michael. Additionally, increased testing at Holloman AFB will affect scheduling of airspace at White Sands Missile Range, New Mexico.

Hurricane Michael caused significant damage to the infrastructure and multiple research, test, and training facilities at NSWC PCD, limiting access to the base for several weeks. Recovery costs are estimated to be $238 Million. NSWC PCD was not fully staffed through October 2018 while personnel dealt with the hurricane damage to personal property. NSWC PCD testing for several mine countermeasures programs was delayed for more than 2 months due to this storm.

Earlier in 2018, Hurricane Florence downed trees that damaged fences and caused electric outages for the eastern shore towers at Aberdeen Test Center in Maryland used for range safety observations and noise management. Repairs were quickly implemented and did not impact testing. Repair costs were estimated at $2,500.

Personnel and Capabilities to Support Cyber-related Operational Testing

Well-qualified personnel and effective, up-to-date test capabilities are essential to planning and conducting adequate, operationally threat-representative cybersecurity testing. Currently, the DOD has had difficulty hiring and retaining cybersecurity

professionals, and lacks the resources to develop and field specialized, automated cybersecurity test tools. Meanwhile, the demand for cybersecurity testing continues to grow in both the government and private sectors. The Operational Test Agencies (OTAs) and cyber Red Teams currently do not have enough experienced cybersecurity professionals to accommodate the increasing number and complexity of test events projected in FY19 and beyond, and lack the funds and expertise to develop specialized cybersecurity test tools.

To address this problem, the DOD must overcome significant barriers:

- There is a global shortage of cyber expertise driving up the cost to hire well-qualified cyber people. A 2017 Global Information Security Workforce Study sponsored by the non-profit International Information System Security Certification Consortium forecasts 1.8 million unfilled cybersecurity positions globally by 2022. Currently, there are close to 300,000 unfilled positions in the United States alone. The OTAs have over 30 unfilled cybersecurity T&E billets, representing almost a fifth of the current OTA manning structure.
- Most cybersecurity positions within the Department are not compensated commensurate with the position's required experience and expertise. Further, it takes considerable time and specialized on-the-job training to develop a skilled workforce to perform cybersecurity testing of weapons systems. Once trained, the risk of losing experienced cybersecurity personnel to the private sector is high due to the compensation differences, creating an ongoing challenge to maintain and grow an experienced DOD cybersecurity workforce.
- The DOD reliance on software-intensive weapons systems creates a need to not only test traditional information technologies, but also other capabilities: vehicle and aircraft data buses, radar and acoustic systems, radio frequency (RF), wireless, and the datalinks that support DOD weapons systems. Cybersecurity testers in the DOD are handicapped by lack of expertise and developmental support to obtain test capabilities and tools to address these areas.

In order to obtain top-notch cyber talent, the Department should secure seed funding for a select group of Service academies, private companies, universities, and national laboratories to grow the DOD cybersecurity testing workforce and capabilities. Hiring more cyber experts will not be enough. The large and chronic lack of qualified cyber personnel means that there will never be enough cyber experts to adequately cyber-test all DOD networks and systems. The Department should focus some of the newly-acquired cyber expertise on the development of advanced, automated cybersecurity test tools to augment the skills of cyber testers and provide additional test capacity.

If implemented, these recommendations will enable more threat realistic cybersecurity assessments for critical networks and systems across the DOD. Doing so will permit the Department to more effectively conduct its missions in the cyber-contested environments of today and the future.

Threat Representation for OT&E of Space Systems

U.S. adversaries are actively pursuing offensive space control capabilities to diminish and overcome U.S. military space superiority. Although the Services normally test space systems against representative natural hazards and space phenomena, they have not adequately tested them against representative threats emulating the full spectrum of hostile environments. Within the T&E community, there are limited infrastructure, tools, and resources for realistic representation of the space threat.

Several DOD laboratories have threat-representative systems (e.g., laser, high-energy chambers, etc.); however, the Service OTAs and Program Offices have not made use of these assets. The Intelligence Community also has some space threat modeling tools that have not yet been utilized.

In a memorandum dated March 2016, DOT&E provided guidance to the Service acquisition officials and OTAs to improve their ability to identify and track space threat representation capabilities; identify space threat representation gaps, and request funding to fill those gaps; and to develop modeling and simulation (M&S) capabilities to support the assessment of space threats. To enable adequate testing using threat systems and threat surrogates against satellites for OT&E, the Services should fund pre-launch testing of either first articles or production-representative "test satellite" articles against all validated threats. Representative operational crews should operate satellites being threat tested for OT&E using the ground stations that control the satellites and capabilities intended for operational employment. Post-launch, the Services should fund threat-representative articles through the operational life of space systems to support ground testing and training against an evolving threat; system-of-systems assessments; ongoing tactics, techniques, and procedures (TTP) development; and exercises.

The OT&E of space systems must reflect all threats that U.S. space systems will face, and the Services should provide the additional resources required to ensure these threats are realistically represented and assessed during OT&E. Air Force Operational Test and Evaluation Center (AFOTEC) and the Air Force Space and Missile System Center Program Offices need to define their test resource requirements for contested space. Additionally, the DOD needs to prioritize space threat test resources in the budget cycle to support development of the necessary infrastructure for contested space and space-threat testing. Although the Air Force conducted analysis to determine threat test resource needs and submitted requirements for funding, the submission was not funded to support realistic operational testing.

Automated Ballistic Missile Flight Termination Systems

Locations for ballistic missile flight test are limited to test ranges using safety systems employing range-certified flight termination systems onboard the ballistic missiles. The operational realism and number of ballistic missiles involved in a single flight test is capped by the number of available safety systems. For example, the Missile Defense Agency's Flight Test, Integrated-03 (FTI-03) had to be reduced in content by 50 percent due to the

loss of a range safety ship that required unexpected mandatory maintenance.

Ballistic missile safety systems are typically labor- and resource-intensive. In addition to its flight termination system, each ballistic missile requires multiple sources of independent position and velocity data to be supplied in real-time to its dedicated safety system. Automated flight termination systems are already in use in some applications, but are not wide-spread across current DOD ranges that conduct ballistic missile flight testing. Expanded certification of Automated Ballistic Missile Flight Termination Systems for use on DOD ranges would provide significant resource efficiencies and test flexibility to the ballistic missile test community. However, the ranges must continue to maintain access to man-in-the-loop commanded flight termination systems until availability of automated solutions and entry cost for implementation is improved.

Nuclear Survivability Test Capability

Nuclear survivability T&E capabilities must enable adequate assessment of system performance in nuclear blast environments. While the Department has reconstituted some capabilities such as the Large Blast Thermal Simulator (to assess thermal shock and follow-on blast effects) and the Fast Burst Reactor (to generate neutron flux environments), several nuclear survivability T&E infrastructure gaps remain. The DOD should continue with the 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 enivornments generated by nuclear blasts. Improved T&E capabilities are needed to advance understanding of cold/warm X-ray environments on systems and improve M&S tools. In FY18, the Central Test and Evaluation Investment Program (CTEIP) sponsored the development of a design solution for X-Ray Simulators for Test and Evaluation of Nuclear Survivability (XSTENS). However, these X-ray simulators will not test cold X-ray system impulse effects.
- 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.

Development of the nuclear survivability T&E infrastructure will support mission assurance, the U.S. nuclear deterrent posture, and enhance national security. DOT&E supports ongoing efforts to address current nuclear survivability testing shortfalls.

Directed-Energy Weapons T&E

The recent advancements of directed-energy weapons (high-energy lasers and high-power microwaves) warrant commensurate advancements of the test infrastructure and evaluation methods to adequately measure the capabilities and limitations of such systems in relevant operational environments. Directed-energy weapons use a different damage mechanism (function of atmospheric conditions, dwell time, and power) than kinetic weapons (function of fragments/blast) presenting unique T&E challenges that need to be addressed.

The T&E infrastructure is currently not set up to fully assess changes in laser performance as a function of temperature, pressure, humidity, vibration, and other environmental and atmospheric conditions. To enable more adequate assessment of the lethality of directed-energy weapons across the spectrum of relevant operational conditions, the DOD needs to identify and construct a metrology equipment suite capable of measuring atmospheric reference data relevant to laser propagation. The DOD should then develop tools to allow for a more adequate characterization and linkage between the atmospheric reference data and effects on laser propagation due to turbulence, extinction, and thermal blooming. This T&E infrastructure enhancement will enable the development of a standard and consistent T&E protocol (with associated metrology data) to measure and predict laser propagation as a function of a spectrum of operationally relevant atmospheric conditions.

The DOD should also develop hardware-in-the-loop facilities to more efficiently assess laser effects on targets. This will require development of instrumented threat surrogates capable of measuring incident laser irradiance in real-time. These instrumented threat surrogates should be reconfigurable, reusable, and/or expendable. Programs such as the Big Area Target System and the Irradiance Collection and Reporting System are critical steps in the advancement of this T&E capability and require continued development and resourcing.

Future instrumented threat surrogates will also require calibration designed to support verification, validation, and accreditation of laser propagation M&S tools. Adequate M&S tools would enable the DOD to estimate directed-energy weapons damage effects on various targets. These capabilities would also enable the DOD to define the TTP needed not only to execute relevant operational T&E events but to plan future operations and missions with directed-energy weapons. Lastly, the M&S tools need to adequately capture collateral effects (due to laser reflections) so that risk to operational T&E events and combat missions can be safely assessed.

Counter-Unmanned Aerial Sysems

The DOD has been developing an array of technologies, both kinetic and non-kinetic, to counter unmanned aerial systems (UAS), a growing threat to U.S. warfighters, equipment, and facilities. A more adequate evaluation of counter-UAS (C-UAS)

capabilities, in a range of contested environments, requires advancements in C-UAS test infrastructure, instrumentation, and UAS targets.

- C-UAS need to be evaluated in an operationally relevant cellular environment that adequately represents the threat command and control (C2) system. This requires investment in the Advanced Cellular Communication Network (ACCN) test infrastructure equivalent to those deployed globally. Test ranges are in need of various software upgrades and firmware patches to existing cellular infrastructure as well as modernization of signal generation, monitoring, and instrumentation to address expanded 4G and new 5G communications standards.
- Current range infrastructure is short of GPS trackers as well as appropriate high-speed cameras, optical sensors, and radar systems to evaluate the variety of C-UAS under test. Ranges require expanded fiber-optic test networks to enable the extension of high-speed data acquisition systems.
- Ranges also need additional optical imaging and tracking systems to enable the simultaneous tracking of multiple targets.
- Relevant diagnostics need to be developed to support T&E lethality evaluation for non-kinetic kill mechanisms (such as jamming), particularly if the kill mechanism does not cause a recognizable, catastrophic kill. Mission kills (e.g., the threat has effectively been denied the ability to complete its mission due to sensor losses) can be difficult to detect with the current T&E infrastructure of ground sensors.
- As the swarm threat proliferates, additional investment will be required for instrumentation to quantify the significance of the effect on individual elements and potential interaction between elements within a swarm. Miniaturization of threat instrumentation to enhance test capability to meet future swarm test is an area that also requires investment.

Advanced Electronic Warfare (EW) Test Resources for Air Warfare

In February 2012, DOT&E identified significant shortfalls in EW test resources – in particular surface-to-air threat representation on the open-air ranges, which resulted in nearly $500 Million of funding for the Electronic Warfare Infrastructure Improvement Program (EWIIP). The intent of EWIIP was to buy ground radar emulators for the open-air ranges, provide corresponding upgrades to anechoic chambers and the Joint Strike Fighter (F-35) mission data file reprogramming lab, and provide intelligence products to support the development of the threat emulators.

Table 1 displays the status of various components of the EWIIP effort.

TABLE 1. RECOMMENDATIONS ON ELECTRONIC WARFARE TEST RESOURCES

DOT&E Recommendation	Current Status
Develop a combination of open- and closed-loop ground radar emulators in the numbers required for operationally realistic open-air range testing.	EWIIP has delivered open-loop systems, called Radar Signal Emulators (RSEs) that are currently undergoing integration into range infrastructure for use in OT&E. The EWIIP Closed-Loop PESA* Simulator (CLPS) systems are scheduled to deliver in the spring of 2020. *Passive Electronically-Scanned Array
Provide Integrated Technical Evaluation and Analysis of Multiple Sources intelligence products needed to guide threat simulations.	Products delivered and in use to support development of the open- and closed-loop threat radar emulators.

Range Enhancements to Support OT&E of Air Warfare Programs

In 2015 and 2016, DOT&E and USD(AT&L) allocated $22 Million to fund integration of the Air Warfare Battle Shaping (AWBS) system and Radar Signal Emulators (RSEs). AWBS is a variant of the Air-to-Air Range Instrumentation system used for scoring and post-mission reconstruction and analysis of OT&E missions. Use of RSEs with AWBS will provide operationally realistic scenarios and lessen some of the test and training requirements at other ranges. Additionally, conducting test trials at multiple range locations could shorten the duration of various tests. AWBS is projected to declare basic Initial Operational Capability (IOC) in early 2019, followed by full integration of the RSEs for use in test by late spring 2019.

Fifth-Generation Aerial Target (5GAT)

DOT&E has been investigating the means to develop a full-scale aerial target to represent the characteristics of fifth-generation threat aircraft in order to adequately assess the performance of current and future U.S. air defense weapon systems. The 5GAT study effort began in 2006 and examined the design and fabrication of a dedicated 5GAT. The 5GAT team – comprised of Air Force and Navy experts, retired Skunk Works engineers, and industry experts – completed the preliminary design in 2016. The fully owned Government design includes the aircraft outer mold line, internal structures, loads analysis, propulsion, and subsystems. The DOD provided additional funding in FY18-19 to complete the final design, tooling, fabrication, and flight tests (FY19), and to build a second prototype. The 5GAT effort is currently building the first demonstration prototype, including flight propulsion, system integration, and flight simulation/verification activities. The team built one full-scale, flight-representative wing that will be used for structural load tests and a system integration laboratory, as well as a full-scale test article for radar cross-section testing. 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, alternative tooling approaches, and innovative management applications. The 5GAT effort can also be used to assist with future weapon system design/development, planning and investment, and future analysis of alternative activities. It is also intended to demonstrate reduced signature, basic aerodynamic performance, alternative cost models for aircraft development, and provision for special mission systems.

Aircraft Survivability Equipment Test Capability Gaps

To support aircraft survivability equipment (ASE) testing for high-priority threats, DOT&E and TRMC updated the Infrared Countermeasure Test Resource Requirements Study (ITRRS), which identified shortfalls in infrared countermeasure (IRCM) testing and developed a prioritized IRCM investment roadmap of projects to mitigate current testing shortfalls. The ITTRS priorities include:

- Upgrades to both open-air test ranges and indoor test facilities needed to test the latest missile warning systems and IRCM
- Open-air test range improvements that include additional firing points for multi-threat environments and angular separation, upgrades to improve test efficiency, improved instrumentation, and jitter and atmospheric distortion measurement capability
- Upgrades to hardware-in-the-loop and installed system test facilities to better represent the latest threats in a simulated operational environment
- Expansion to heavily-utilized, hardware-in-the-loop, and installed system test facilities to better support program test schedules
- Increased dynamic range and fidelity for ground-based missile plume simulators to expand their testing envelopes
- Improved surrogate threat missiles to support open-air testing
- Increased cooperation among the military and intelligence agencies to collect more threat systems
- Threat system storage facilities to store actual threats as they become available
- Airborne signature measurement

A high ITRRS priority is the ability to measure threat signature data for the development or improvement of the threat models for IR-guided missiles and unguided hostile fire munitions used for the T&E of ASE. These signature models drive a large number of T&E simulation tools. The DOT&E Center for Countermeasures (the Center) is the executing activity for the Joint Standard Instrumentation Suite (JSIS) project. JSIS is an integrated suite of instrumentation designed to mitigate the threat signature data gap, as well as provide ground truth for live fire missile and hostile fire tests for IRCM system testing. A JSIS IOC supported two threat live fire events this fiscal year. JSIS Full Operational Capability (FOC) development will begin in FY19 and deliver additional capabilities for use as they become available. FOC is required to meet the needs of current and future missile warning systems.

In a complementary effort, DOT&E and TRMC drafted threat M&S capability investment roadmaps addressing M&S investment needs for both IR and RF threats, ensuring adequate evaluation of airborne combat systems. These roadmaps identified projects for new threat model development for current and emerging threats, updates to existing models, enhanced intelligence community threat assessments of current and emerging threats, and implementation of a threat M&S for the T&E enterprise management process. As a result of these roadmaps, funding was allocated to develop 10 IR and 10 RF high-priority threat models not currently available for T&E.

In addition to threat signature data, time, space, and position information (TSPI) is critical to understanding threat missile performance, building the threat fly out model, and evaluating system under test performance. The DOT&E T&E Threat Resource Activity (DOT&E/TETRA), with support of the Center, is leading the Advanced Satellite Navigation Receiver project in FY19 to equip small threat missiles with a telemetry pack that will provide accurate position information, guidance signals, and other advanced capabilities for testing ASE in live fire testing. The current capability is limited and parts obsolescence will halt future procurement by 2021. This new capability is intended to improve current and future threat fly out models and reduce test costs. Current funding is sufficient to begin the design work and reduce technical risk, but future funding will be necessary to complete the design and produce the first articles for evaluation.

Navy Advanced Electronic Warfare Test Resources and Environments

Improving Capability to Realistically Represent Multiple Anti-Ship Cruise Missile (ASCM) Seekers for Surface Electronic Warfare Improvement Program (SEWIP) Operational Testing

A gap in the ability to realistically represent multiple ASCM seekers during test was initially identified in this section of the DOT&E FY13 Annual Report. The Navy subsequently developed a programmable seeker simulator that could represent different ASCM seekers by specifying 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," should be modified such that its ERP more realistically represents the second ASCM of a dual ASCM stream raid.

The next SEWIP Block 2 FOT&E is projected for FY20 on a Product Line Architecture-compliant DDG 51 with Block 2 integrated with the Aegis Combat System. This integration was not part of the Block 2 IOT&E. Subsequent FOT&E is intended with the DDG 1000 destroyer and CVN 78 aircraft carrier combat systems.

Improving the Fidelity of ASCM Seeker/Autopilot Simulators for EW Testing

DOT&E initially identified a gap in the fidelity of ASCM seeker/autopilot simulators in the this section of the FY13 Annual Report. The gap arose because of continued reliance on manned aircraft for captive-carry of ASCM seeker simulators. This had only a limited effect on SEWIP Block 2 IOT&E, but will severely limit the adequacy of SEWIP Block 3 IOT&E. Captive-carried ASCM seeker surrogate limitations restrict their usefulness for SEWIP Block 3 operational tests. First, it is difficult to tell if the SEWIP Block 3 electronic attack (EA) is having the desired effect on the captive-carried ASCM seeker. Second, the captive-carried simulators do not demonstrate a kinematic response to EA by SEWIP Block 3 and thus do not demonstrate the effect that such kinematic responses will have on ships' hard-kill systems (e.g. missiles, guns). Third, Learjet aircraft that carry the captive-carried ASCM seekers do not fly fast enough to be credible representations of ASCM threats. Fourth, because Learjets fly substantially higher than ASCMs, the RF environment experienced by the captive-carry ASCM surrogate is different than that of an actual ASCM. These differences may make the captive-carry results unrealistic. Lastly, the Navy has very few captive-carry ASCM surrogates with which to test and many are not representative of modern ASCM threats. To mitigate these limitations, the Navy needs to develop high-fidelity ASCM surrogates that can be used to control aerial targets. These closed-loop targets could be used to demonstrate SEWIP Block 3 operational effectiveness in live testing. If these limitation are not mitigated it is unlikely that the Navy's current test assets will be able to credibly determine SEWIP Block 3 operational effectiveness. SEWIP Block 3 IOT&E is projected for FY23 on a DDG 51-class ship.

Developing Test Surrogates for Hostile Airborne and Surface Radar Systems

In addition to the ASCM surrogates described above, adequate operational testing of active EA systems like SEWIP Block 3 require development of threat airborne and surface (e.g., coastal defense) radars that active EA systems may be required to thwart. The Navy tests such capababilities at the Shipboard Electronic Systems Evaluation Facility (SESEF), where a pulse generator, known as the Combat Electromagnetic Environment Simulator (CEESIM), an amplifier, and an antenna are used to emulate hostile radars. Such test facilities provide some capability to demonstrate an EW system's ability to detect and identify threat radars, but the existing capability is not adequate to test EA systems. To test such systems, the threat radar surrogate must emulate the RF aspects of the threat radar, the signal processing of the radar, and the electronic protection aspsects of the radar. In October 2016, DOT&E directed the Navy to develop such threat radar surrogates. Without such test assets, it is unclear how the Navy will credibly test active EA systems like SEWIP Block 3.

Ship Self-Defense Test Capabilities

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

- Weapon scheduling with very little time for engagement
- 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 Evolved Seasparrow Missile (ESSM) guidance modes
- Conducting ballistic missile defense 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 (CIWS)

Multiple hard-kill weapon systems operate close-in, including the Standard Missile 2, the ESSM, and the CIWS. Soft-kill systems such as the Nulka MK 53 decoy launching system also operate close-in. The short timelines required to conduct successful ship self-defense stress 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 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. The Navy has invested in a seagoing, unmanned, remotely controlled self-defense test ship (SDTS) and is using it to overcome these safety restrictions. The Navy plans to validate and accredit a high-fidelity M&S capability – utilizing data from the SDTS as well as data from manned ship testing – so that a full assessment of the self-defense capabilities of ships can be completely and affordably conducted.

The SDTS is 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). DOT&E continues to recommend equipping SDTS with capabilities to support testing of ship self-defense systems' performance in the final seconds of the close-in battle and to acquire sufficient data to validate ship self-defense performance M&S.

Multi-Stage Supersonic Targets

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, CVN 78, DDG 51 Flight III destroyer, LHA(R), Air and Missile Defense Radar (AMDR), Ship Self-Defense System, Rolling Airframe Missile Block 2, and ESSM Block 2 operational test programs. The MSST underwent restructuring and rebaselining from 2013 – 2015 to address technical deficiencies and cost and schedule breaches, which would have postponed its IOC to 2020 and increased the total program cost to $962 Million. Based on the restructured/rebaselined 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 (ASN(RDA)) 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 Navy alternative are classified, DOT&E determined that it would be costly (the Navy estimates $739 Million), difficult to implement, dependent on the results of highly segmented tests, and would suffer from artificialities that would 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. MSST aerial target capabilities are still required to complete end-to-end operational testing of Navy surface ship air defense systems and to validate M&S capabilities for assessing the probability of raid annihilation for Navy ships.

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

Operational testing of anti-submarine warfare (ASW) platforms and torpedo defense-related systems includes the ability to detect, evade, counter, and/or destroy an incoming threat torpedo. The determination of system or platform performance is dependent on a combination of the characteristics of the incoming torpedo (e.g., dynamics, noise, sensors, logic, etc.). Due to differences in technological approach and development, U.S. torpedoes are not representative of many highly proliferated torpedoes. The need for threat-representative torpedo surrogates to support operational testing is detailed in DOT&E memoranda to the ASN(RDA) dated January 9, 2013, and June 18, 2015. Acquisition programs that require threat torpedo surrogates for future operational testing include: *Virginia* and *Columbia* class submarines, *Zumwalt* class destroyer, *Freedom* and *Independence* variants of the Littoral Combat Ship (ASW mission package installed), AN/SQQ-89 surface ship undersea warfare combat system, and Acoustic Rapid Commercial Off-the-Shelf Insertion (A-RCI) submarine sonar system. Based on the 2014 Naval Undersea Warfare Center (NUWC) Division study, the Navy has taken the following actions to address the gaps in threat representation of torpedo surrogates:

- NUWC Division Keyport commenced a prototype technology development project that is expected to deliver a threat representative, high-speed, quiet propulsion system. This effort was initially funded as an FY16 Resource Enhancement Program (REP) project at approximately $1 Million. This project experienced cost and schedule overruns and transferred to the follow-on General Threat Torpedo (GTT) REP project.
- NUWC Division Keyport commenced development of a GTT that will complete development of the high-speed, quiet propulsion system prototype and provide threat-representative tactics and countermeasure logic. The GTT project is funded as a FY17 REP project at approximately $6.2 Million. DOT&E expects the GTT to fill in many of the gaps in threat representation of torpedo surrogates; however, the ability of a successfully developed GTT to adequately support operational testing futher depends on future Navy decisions to procure a sufficient quantity of GTT units.

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 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 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.

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 capable of depth changes, high speeds, autonomous operations, and certified for representative 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.

Army Support of OT&E

In FY18, the Army initiated modernization and acquisition reforms through the establishment of eight Cross Functional Teams (CFTs) and the activation of the Army Futures Command (AFC). A primary goal of the AFC and the CFTs is to support the rapid acquisition and fielding of new warfighting capabilities to counter advancements made by near-peer adversaries. The CFTs are aligned with the Army's six modernization priorities: Long Range Precision Fires, Next Generation Combat Vehicles, Future Vertical Lift, Army Network, Air and Missile Defense Capabilities, and Soldier Lethality.

The warfighting systems developed under the six modernization priorities will be some of the more software-dependent, interconnected, and complex systems the Army has ever acquired. To ensure the Army is fielding combat credible weapon systems, it must demonstrate effectiveness and

suitability under the operationally representative conditions found in full-spectrum warfare. The Army Test and Evaluation Command (ATEC) will perform a critical role in supporting the Army's modernization efforts. The rapid development and acquisition of advanced warfighting capabilities will require a T&E workforce that is prepared and resourced to support shorter timelines. Substantial growth in the areas of autonomy, electronic warfare, cybersecurity, navigation warfare, and big data analysis continue to put increased demands on the Army T&E enterprise. The Army must contend with competition from industry as it struggles to recruit, retain, and grow an analytically and technically competent T&E workforce.

Beginning with the FY14 Annual Report, DOT&E expressed concern with the continued budget and staffing reductions at ATEC and the office of the Army Test and Evaluation Executive. When adjusted for inflation, there has been a 13 percent reduction in funding for Operational Test Command (OTC) and an 18 percent reduction in funding for the Army Evaluation Center from FY14 through FY18. DOT&E is concerned that these budget and staffing levels will not be sufficient to support the Army's aggressive modernization goals. DOT&E will continue to monitor the Army T&E workforce regarding its capability and capacity to support the evaluations of Army acquisition programs.

Electronic Warfare for Land Combat

Over the past 17 years of counterinsurgency warfare, the Army's EW capabilities have atrophied while its vulnerabilities have grown due to the expanded dependency on terrestrial and satellite RF-based networks and GPS. Recently, the Army began to rebuild its EW capabilities and strengthen its cyber defense through the development of new EW capabilities, the addition of EW and cyber threats during combat training center rotations, and by incorporating Cyber and ElectroMagnetic Activity (CEMA) sections into the staff elements of brigades, divisions, corps, and combatant commands. These efforts underscore that EW and cyber threats should be considered part of the operational environment.

During operational testing, threat EW capabilities are part of a broader combat force that is available to the opposing force (OPFOR) commander. Whenever possible, the threat systems and the TTP employed by the OPFOR during test should represent those of adversaries. Providing this realistic threat EW environment is complex and challenging due to the technical, safety, and regulatory conditions that must be met for each test. Satisfying these conditions often places severe limitations on the duration and emitted power of open-air EA, which will affect testing of the Army EA systems currently in development. To overcome these challenges the Army must continue to enhance EW test equipment and work to develop new practices and procedures. It must continue to support a technically competent and experienced workforce with appropriate training and resources.

A commitment to creating threat-representative EW environments during operational testing is necessary to ensuring that systems are survivable and will support units operating in contested electromagnetic environments. Threat EW environments should be considered for all operational testing, but are critical to the operational testing of future Army network initiatives, Nett Warrior/Leader Radio, Manpack Radio, Joint Battle Command – Platform, and Assured Positioning, Navigation, and Timing.

Tactical Engagement Simulation with Real Time Casualty Assessment

Realistic operational environments and a well-equipped OPFOR intent on winning are fundamental to the adequate operational test of land and expeditionary warfare combat systems. Force-on-force battles between tactical units represent the best method of creating a complex and evolving battlefield environment for testing and training. Tactical Engagement Simulation with Real Time Casualty Assessment (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. TES/RTCA systems should replicate the critical attributes of real-world combat environments, such as direct and indirect fires, IEDs and mines, and simulated battle damage and casualties. 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. Post-test playback of these data provide a critical evaluation tool to determine the combat system's capability to support soldiers and marines as they conduct combat missions.

All current TES/RTCA systems utilize the Instrumentable – Multiple Integrated Laser Engagement System (I-MILES) to ensure simulated engagements have realistic outcomes. Because these outcomes are based on the survivability and lethality characteristics of the systems they represent, I-MILES must be updated prior to IOT&E for every new or upgraded vehicle or weapon system. Timely updates to I-MILES are critical to enabling force-on-force training and ensuring that new and upgrated vehicles are prepared to be integrated into the Army Combat Training Centers (CTCs). The TES/RTCA systems used during operational test in FY18 were all training systems that were updated or modified to support operational testing and highlight the synergy that exists between the operational test and training communities.

Beginning in FY20, the Army cut funding that was programed for the Integrated Live, Virtual, Constructive, Test and Training Environment (ILTE) program. The ILTE program was established to acquire the TES/RTCA upgrades needed to support Army combat vehicle operational testing and is the only funding line dedicated to supporting major operational test instrumentation requirements in the Army. DOT&E believes that cutting funding to ILTE is counter to the lethality goals set by the National Defense Strategy, and the Army modernization and readiness priorities. Sustained investment and regular 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, Joint Light Tactical Vehicle, Stryker Upgrades, and Next Generation Combat Vehicle.

Test and Evaluation of Army Software-Defined Tactical Radios

Software-Defined Radios have become a cornerstone technology of the Army tactical radio communication systems. They provide the Army with improved capabilities such as simultaneous voice, data, and video communications; voice and data retransmission; increased throughput; multi-channel operations; and interoperability with fielded radios. Because of the complexity of these tactical radio networks and the added capabilities they provide, improved test instrumentation and data collection methods are needed to support the evaluations. The Army will need to develop instrumentation to support operational testing of radios with advanced networking waveforms. These improvements to instrumentation and data collection methods are necessary to support the T&E of the Leader Radio and Manpack Radio and experimentation of the Integrated Tactical Network.

Warrior Injury Assessment Manikin

Hybrid III is an anthropomorphic test device (ATD) currently used for LFT&E, but it lacks biofidelity in an underbody blast (UBB) test environment. It does not exhibit a human-like response when exposed to UBB loading conditions and can not fully assess operator survivability to vehicle shock, blast, and fragment damage. The Warrior Injury Assessment Manikin (WIAMan) Engineering Office (WEO) is developing the WIAMan ATD to address this LFT&E capability shortfall. The LFT&E section describes the WIAMan project on page 227.

Foreign Materiel Acquisition Support for T&E

DOT&E is responsible for ensuring U.S. weapons systems are tested in realistic threat environments. Use of actual threat systems and foreign materiel to create realistic threat environments in testing helps to determine a system's operational effectiveness in a combat environment. To acquire test capabilities, DOT&E/TETRA develops an annual prioritized list of foreign materiel required for upcoming operational tests. These requirements are submitted to the Defense Intelligence Agency (DIA) Joint Foreign Materiel Program Office and are consolidated with Service requirements to drive Service and Intelligence Community collection opportunities. DOT&E coordinates with the Department of State to identify other 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) and anti-tank guided missiles (ATGMs). Foreign MANPADS are needed to address significant threat shortfalls that affect testing for IRCM programs like Common Infrared Countermeasures (CIRCM), Large Aircraft Infared Countermeasure (LAIRCM), and Department of the Navy (DON) LAIRCM. For some programs, a large quantity of MANPADS is 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. Foreign ATGMs are required to support the testing of the Expedited Active Protection System.

Traditional sources have been fully consumed, and there is a critical need to identify and develop new sources and opportunities for acquiring foreign materiel. Foreign materiel acquisitions are usually lengthy and unpredictable, making it difficult to identify appropriate year funding. Programs have funded as much as $60 Million a year for acquisition opportunities that arise. DOT&E recommends a no-year or non-expiring funding line for foreign materiel acquisitions, funded at a level of $10 Million per year.

Range Sustainability

In previous reports, DOT&E highlighted the many challenges the Department faces in preventing various activities that may limit the ability of the Department to fully utilize the capabilities of its current test and evaluation infrastructure. At a time when the Department is attempting to define testing requirements for the leap-ahead technologies envisioned by the National Defense Strategy, it is imperative that the test capabilities it has today be preserved as a foundation for future testing needs. The following are the areas of particular concern.

Airspace. The newest generation of weapon systems are designed to create effects at longer distances, and new weapon systems under development will require extremely long distances for testing. Studies are in process to determine how best to accommodate these requirements. However, a number of external factors (to include urban development, incompatible infrastructure, electromagnetic interference, and the presence of endangered species) may act to limit the use of current, dedicated airspace.

Maritime Sustainability. The DOD requires extensive sea ranges for testing and training associated with naval warfare and for testing long-range weapons. However, potential for expanded oil, gas, and wind energy development may limit the use of these ranges through the introduction of fixed structures and increased surface vehicle traffic. The Department is especially concerned about increased development in the eastern Gulf of Mexico, where the current statutory moratorium on oil and gas development expires in 2022, and off the coast of California, which is being examined especially for wind 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 and implement systems that more effectively utilize the currently available spectrum. However, it is imperative that future sales be carefully structured to ensure no additional loss of capabilities and that additional spectrum be identified to satisfy current and future DOD testing requirements.

Water Usage. An emerging issue in some of the western ranges is the availability of sufficient water to sustain range operations. Long-term drought conditions have strained available water resources, and these water resources must be shared amongst all local users. Extensive collaboration with state and local entities will be required to ensure short- and long-term water issues can be resolved.

Renewable Energy. Renewable energy infrastructure, particularly wind turbines and the electrical transmission lines, create particular issues for the DOD test infrastructure. To date, the Department has been effective in limiting the impact of renewable energy projects. However, as renewable energy technology advances, and new locations are proposed (including offshore), the Department will face a continuing challenge in limiting deliterious effects.

Privately Operated Drones. Inexpensive yet highly capable remotely operated air vehicles have the potential to jeopardize safe and secure conduct of test operations. Recent actions by the Federal Aviation Administration to establish a regulatory regime for unmanned aerial vehicles (UAVs) are useful in establishing controls, as is recent legislative action to extend the SECDEF authority to protect facilities included in the Major Range and Test Facility Base from intrusion by UAVs. As new legislation and regulations emerge, measures to protect test activities and land, air, and sea range integrity will continue to be incorporated into T&E strategic and event planning.

Cyber Intrusion of Range Instrumentation. Some of the current range instrumentation rely on obsolete technology, which makes it difficult to harden them to protect sensitive information. Adequate funding for range instrumentation modernization is required to ensure that all instrumentation can be upgraded or replaced to standards that incorporate cybersecurity as a key performance parameter.

Foreign Investment. Foreign intelligence services may be able to conduct surveillance of weapon systems under test or training by investing in U.S. entities. Intelligence may be gathered either by establishing a physical presence in the vicinity of test or training activities or by investing in technology firms in order to obtain access to data streams during testing. DOT&E currently reviews projects under review by the Committee on Foreign Investment in the United States (CFIUS), 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. Although it is anticipated that the number of cases to be reviewed will increase substantially, DOT&E will continue to subject transactions to review.