TEST AND EVALUATION RESOURCES

Test and Evaluation Resources

T&E infrastructure must enable credible and comprehensive evaluation of the operational performance of DOD warfighting capabilities. To stay ahead of the adversary and keep pace with emerging and advanced technologies, the DOD must continue to advance the T&E infrastructure to accurately represent the complex and dynamic multi-domain operational environment in test and be prepared to evaluate future joint force capabilities. The DOD must also continue to recruit, train, and retain personnel with the unique skillsets needed to meet the T&E demands of the future.

As per the FY22 Consolidated Appropriations Act, Congress provided the T&E enterprise with $798,128,000 in additional appropriations:

- $422,728,000 to USD(R&E), the Space Force, the Navy, and DOT&E to upgrade lab and test range infrastructure in the areas of hypersonics, directed energy, space, targets and threats, and electromagnetic spectrum.
- $375,400,000 to USD(R&E), the Navy, and the Air Force to be put towards peer-representative threat environments for fifth-generation aircraft.

This section summarizes how these additional resources will help close some of the identified gaps in the specified areas. This section also summarizes known initiatives and the remaining T&E infrastructure and workforce shortfalls in the following areas:

- Hypersonics,
- Directed energy weapons,
- Cyber survivability,
- Chemical and biological defense,
- Nuclear modernization,
- Electromagnetic spectrum operations,
- Space,
- Autonomous and artificial intelligence (AI)-enabled systems,
- Multi-domain operations,
- Common range infrastructure,
- Threat and target surrogates,
- Knowledge management and big data analytics, and
- Range sustainability.

This section also summarizes the reports provided to DOT&E by the Service T&E Executives and Operational Test Agency (OTA) Commanders on the adequacy of their resources and the infrastructure required to accomplish the planned T&E across the Future Year Defense Program (FYDP). DOT&E did not have the detailed information to validate those reports but intends to initiate an FY23 action to support such validations in the future.

Lastly, this section summarizes other areas where the DOD needs to focus.

HYPERSONIC MISSILES AND HYPERSONIC MISSILE DEFENSE

Hypersonic missiles have unique flight characteristics designed to achieve speeds between Mach 5 and 20, ranges that can exceed 1,000 miles, and perform extensive maneuvers. These characteristics are partially distinguished from those of long-range ballistic missile weapons because hypersonic missiles fly in the Earth's atmosphere. Adequate

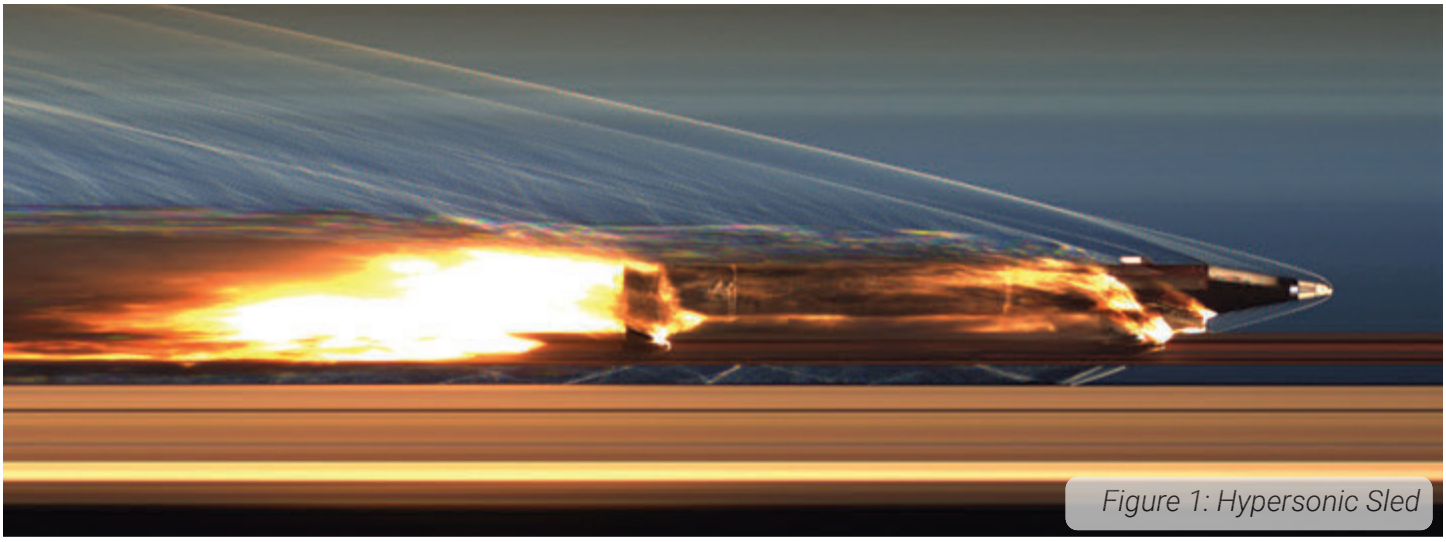

Figure 1: Hypersonic Sled

evaluation of the operational performance of such unique characteristics of hypersonic flight will require new or upgraded T&E range infrastructure and instrumentation.

Specifically, ground test capabilities are needed to recreate hypersonic flight. Ongoing investments are intended to:

- Improve pre-flight assessments of vehicle structural design and responses in flight (i.e., improvements to the Arnold Engineering Development Complex G-Range, Holloman High Speed Sled Track, and National Aeronautics and Space Administration Particle Impact Facility).
- Increase capacity and expand the capabilities of U.S. arcjet facilities that simulate the conditions of flight at given altitudes and velocities. All hypersonic missiles, hypersonic defense interceptors and advanced targets, and high altitude ballistic and maneuvering munitions require the use of arcjet facilities to test the thermal protection systems and vehicle aeroshells.
- Close critical T&E gaps in aerothermal structural and advanced propulsion ground testing of scramjet vehicles by providing a largescale, clean-air, variable-Mach test facility with long runtime. Most recently, the Naval Surface Warfare Center, Crane Division was awarded a contract to develop a hypersonics test bed, which will allow hypersonic technologies to mature in simulated flight and validate their performance prior to incorporation into existing weapon systems.

Additional missile test range modernization efforts are needed to support an increase in the tempo of testing and the development of new capabilities to measure hypersonic missile flight performance in increasingly complex threat environments. For example:

- Mobile instrumentation is needed to track and image atmospheric disturbances around the flight vehicle using radar and optical sensors in the visible and infrared regions of the spectrum.
- Mobile off-board sensors and additional telemetry are needed at the impact site for end-game scoring.
- The Test Resource Management Center (TRMC) is researching overland corridors that would impact at White Sands Missile Range (WSMR), referred to as the Mountain Desert Corridor (MDC). The associated Programmatic Environmental Impact Statement is expected to be complete before the end of calendar year 2022. While being pursued for long-range precision fires, the MDC may also provide an additional land-based impact site for limited hypersonic missile flight tests.
- TRMC intends to fund substantial unmanned aerial system-based range instrumentation for telemetry tracking and multispectral imaging. In FY22, two telemetry-configured Range Hawks were deployed to Marine Corps Air Station Kaneohe Bay, Hawaii to support a June 2022 flight

test. Additional data are needed to support the Missile Defense Agency (MDA) requirements.

- Flight corridors should include capacity for collection of debris dispersal, post-intercept, while also accounting for safety concerns caused by such debris.
- Development of credible models for flight and ground test venues needs to be accelerated.

OT&E of hypersonic missile defense systems continues to require threat hypersonic missile surrogates to evaluate the effectiveness of U.S. defensive capabilities against incoming hypersonic missiles. These surrogates need to be designed and built concurrently with both offensive hypersonic missiles and hypersonic defense interceptors. Multiple data collection assets are also required to capture both the dynamics of the hypersonic surrogate target as "truth" data for the test, and performance data from the hypersonic defense interceptors.

As per the FY22 Consolidated Appropriations Act, Congress provided $47.5 million to USD(R&E) and DOT&E to improve the hypersonic test infrastructure. DOT&E is focusing its investments ($7 million) on development of credible modeling and simulation (M&S) needed to support the operational effectiveness and lethality evaluations of hypersonic weapons. USD(R&E) will use its investments ($40.5 million) for: 1) the development of satellite communication relays for mobile broad ocean area scoring systems, 2) the upgrade of data collection capabilities at hypersonic flight test ranges, and 3) the development of a roll-on/roll-off range capability to support increased hypersonic flight test capacity, including telemetry, satellite communication relay, and optics capabilities.

DIRECTED ENERGY WEAPONS

Directed energy weapons are intended to disable large numbers of adversary targets at fast rates using concentrated energy in the form of high-energy lasers (HEL) or high-power microwaves (HPM).

Adequate operational testing and evaluation of HEL systems requires range instrumentation capable of characterizing laser beams as they propagate through the atmosphere and measuring their beam spot profiles on representative targets. The Mobile High Energy Laser Measurement (MHELM) project is a Joint Improvement Modernization (JIM) project supported by USD(R&E) and DOT&E. It provides advanced instrumentation needed by DOD test centers, including the High Energy Laser Systems Test Facility (HELSTF) and the Naval Air Warfare Center-Weapons Division (NAWCWD) to test and evaluate DOD HEL systems. The last MHELM project will achieve initial operational capability in FY23. The systems are being transitioned to the range partners as they are completed.

USD(R&E) manages the Directed Energy T&E Investment Roadmap for HEL. The roadmap outlines the execution of 51 HEL projects to reduce shortfalls in T&E infrastructure and instrumentation through FY30. These projects are intended to deliver representative threat lasers; infrastructure to conduct open-air tests (including range safety and predictive avoidance of satellites in orbit); ground test instrumentation for laser beam diagnostics and assessments of destructive power on real world targets; and M&S for improved prediction of atmospheric propagation characteristics. Threat representative targets (including adversarial countermeasures) are also needed to evaluate operational performance and lethality of HEL. Conversely, threat-representative HEL surrogates are needed to assess survivability of U.S. systems and performance of our countermeasures.

Adequate operational testing and evaluation of HPM systems requires range instrumentation capable of characterizing HPM envelopes and their effect on targets. USD(R&E) manages the Directed Energy T&E Investment Roadmap for HPM. The roadmap outlines 40 projects required to reduce shortfalls in HPM T&E infrastructure and instrumentation, some of which are still unfunded. Representative targets are needed for lethality assessments and accurate threat surrogates are needed to test performance and survivability. Range safety equipment is needed to protect range personnel and range equipment and to ensure stray

energy does not disrupt non-range-related persons and property. M&S are needed for U.S. and adversarial weapons and for targets to execute adequate end-to-end T&E.

As per the FY22 Consolidated Appropriations Act, Congress provided $34 million to USD(R&E) and DOT&E to improve the T&E capabilities for evaluating directed energy weapons. DOT&E is focusing its investments ($12 million) on delivering ground- and air-based instrumentation and targets to support detection/tracking and lethality assessments of HELs and HPM weapons against a wide array of adversary targets. USD(R&E) will use the investments to upgrade the mobile diagnostics suite for higher fidelity characterization of HEL beam and enhance target boards to improve characterization of performance.

CYBER SURVIVABILITY

All DOD warfighting capabilities heavily rely on cyber components to fulfill their missions and must be sufficiently cyber survivable to execute assigned missions in contested cyberspace. These include, but are not limited to, communication and networking technologies, software and hardware layers, and data transfer among subsystems. All of these systems are subject to cyberattacks by threat actors. The complexity and interdependence of these systems and the rapidly evolving nature of cyber threats necessitates that T&E capabilities evolve in lockstep to enable realistic cyber T&E at scale to assess system survivability.

Needed DOD investments in hardware and software to enable adequate cyber T&E include tools and techniques to: 1) conduct attacks against Internet Protocol (IP) and non-IP systems, 2) identify unauthorized users and spoofing attempts, 3) assess radio frequency datalinks, and 4) create an adequate radio frequency test environment to support the convergence of cyber and electromagnetic spectrum operations.

The National Cyber Range Complex continues to enhance its capacities to perform more realistic system-of-systems cybersecurity test and training

Figure 2: Red Team at Cybersecurity Event

events through upgrades to the Joint Mission Environment Test Capability. Additional tools and techniques are required to:

- Increase test efficiencies through rapid, accurate characterization and visualization (i.e., digital modeling) of the system or network and associated cyber vulnerabilities.
- Enable automated detection of cyber vulnerabilities in complex, interdependent systems and systems of systems, comprising various software and hardware layers.
- Manage the increasing scope of cyber assessments that 1) represent the system's functions, activities, and processes, and 2) determine mission impact from the cascading effects of cyber compromise.
- Emulate observable mission effects for systems under cyberattack.
- Enable automated adversary threat planning and emulation of routine threat capabilities.
- Provide data storage infrastructure and standards for secure handling and processing of T&E data.
- Decrease post-assessment time through integrated and standardized visualization, analysis, and reporting.
- Improve cyber countermeasure T&E frameworks, processes, and capabilities.

The scheduling and availability of operationally deployed weapon systems continues to limit the scope and breadth of cybersecurity assessments. Limited NSA-certified cyber Red Team and Blue Team

availability constrains the depth of the assessments and limits operational realism.

CHEMICAL AND BIOLOGICAL DEFENSE

Advancements in the T&E infrastructure are required to adequately evaluate chemical/biological threat detection systems and the survivability of DOD weapon systems against chemical and biological agents. Specifically, software-in-the-loop testing is needed to leverage previously collected agent signature data to reduce the time and cost associated with system algorithm development and testing. M&S tools need to be adequately verified and validated to reduce the time and expense associated with repeating agent chamber testing.

In FY22, the Chemical and Biological Center's BioTesting Division awarded a contract for upgrading the Aerosol Simulant Exposure Chamber (ASEC), a bio-safety level two (BSL-2) facility. The upgrades will more accurately reproduce a wider range of threat conditions.

The West Desert Test Center at Dugway Proving Ground, Utah is experiencing a high turnover in personnel as well as difficulty in recruiting and retaining qualified personnel. The Assistant Secretary of Defense for Nuclear, Chemical, and Biological Defense is working with the Army and DOD to establish a mechanism for continuing to fund the sustainment of existing T&E infrastructure and future investments required to adequately test and evaluate new chemical and biological defense systems at Dugway Proving Ground.

NUCLEAR MODERNIZATION

U.S. Intercontinental Ballistic Missiles and long-range, high-altitude, ground- and sea-based interceptors and platforms are potentially subject to nuclear detonations (NUDET) generated in atmospheric and space environments. High-altitude NUDET environments could contain x-rays, gamma rays, neutrons, blast effects, and aerothermal heating, depending on the geometry of the operational scenario. X-rays, gamma-rays, and neutrons can kill a missile or space asset kinetically or by creating current pulses that can disable electronics. High-altitude NUDET-generated x-rays and gamma-rays can ionize the upper atmosphere, disrupting radar and communications systems and generating high-altitude electromagnetic pulse (HEMP) effects. In addition, charged-particle bomb debris can be trapped in the Earth's magnetic field, potentially disabling satellites for hours to years after the event.

Currently, the System Radiation Hardening of Electronic Components Forum; the Nuclear Modernization T&E Working Group; and the Chemical, Biological, Radiological, Nuclear (CBRN) Survivability Oversight Group – Nuclear (CSOG-N) T&E Subgroup have contributed to the strategic roadmap for Nuclear Modernization T&E shortfalls. While significant improvements have been accomplished in FY22, the DOD still lacks the capability to test and analyze stress, strain, rotation, translation, and failure modes on nuclear components and systems following extreme environment tests. Joint interface testing, electronics testing, performance assessment, and fault analysis when integrating system- and box-level nuclear test units are also needed.

ELECTROMAGNETIC SPECTRUM OPERATIONS

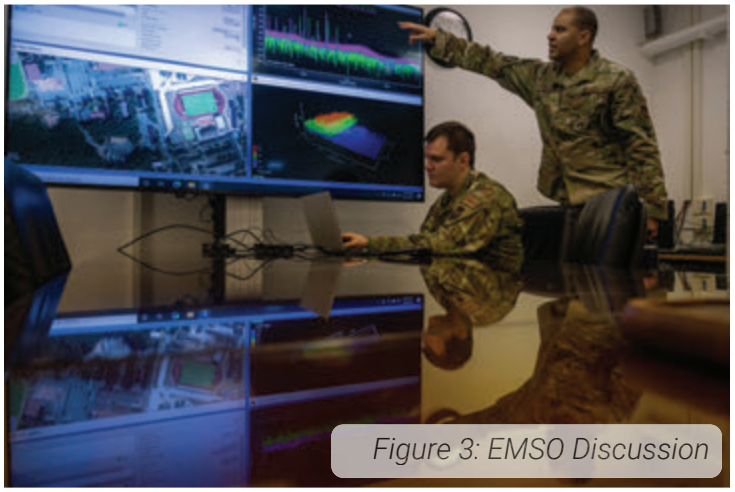

Figure 3: EMSO Discussion

The Electromagnetic Spectrum Operations (EMSO) environment is increasingly congested and contested by military and civilian systems and constrained by

national and international regulatory changes. EMSO comprises the coordinated military actions to exploit, attack, protect, and manage the electromagnetic spectrum environment. Electromagnetic warfare is a vital element of EMSO and includes electromagnetic attack, electromagnetic protection, and electromagnetic support. One area of active research and development to improve system operations in this complex environment is focused on cognitive EMSO systems (incorporating AI technologies to varying degrees). Cognitive EMSO systems create complex and autonomous behaviors that will adapt to changing environments as the system learns. These unique system attributes introduce new T&E infrastructure challenges.

In FY22, the DOD invested extensively in improving the threat densities and realism for the EMSO for Live, Virtual, and Constructive (LVC) environments. Joint Electronic Warfare Test and Evaluation Strategy (JETS) Increment I is a significant capability that will replicate a dense integrated air defense system (IADS) environment and is an early implementation of a multi-range LVC environment. However, airborne threat software-defined radars (SDRs) remain a shortfall. Adversaries are developing multi-static radars that utilize the transmissions from commercial transmitters, which will further complicate EMSO. Developing simulators to mimic these emissions is critical to OT&E of future joint warfighting capabilities. Additional details can be found in the Threat and Target Systems subsection below. The Army has also reported a need for electronic intelligence simulators that are required to test emerging Army sensors and offensive devices for weapon systems intended to identify and affect near-peer threats. In addition, shortfalls exist in the capacity and certifications to conduct frequent and simultaneous GPS jamming and spoofing across multiple test ranges.

As per the FY22 Consolidated Appropriations Act, Congress provided $375,400,000 to USD(R&E), the Navy, and the Air Force to develop peer-representative threat environments for fifth-generation aircraft. USD(R&E) is focusing its investments ($263 million) on developing new radars and decoy systems. The Navy and Air Force are focusing their investments ($37.1 million and $75.3 million, respectively) on upgrades to their radars.

SPACE

Critical DOD space assets are potentially subject to a range of adversarial attacks, including directed energy weapons, kinetic threats, cyberattacks, electromagnetic spectrum fires, and nuclear weapons. To adequately evaluate the survivability of U.S. space systems against such engagements and to mitigate any identified vulnerabilities, the Department requires space-range infrastructure (physical and digital), instrumentation, and high-fidelity-threat surrogates and M&S tools.

As per the FY22 Consolidated Appropriations Act, Congress provided $57 million to DOT&E, USD(R&E), and the Space Force. DOT&E is focusing its resources ($9 million) on the development of tools for operational and live fire T&E. USD(R&E), as managed by TRMC, is focusing its investments ($33 million) on prototyping space telemetry collection and replicating space radio frequency environments. The Space Force is focusing its investments ($15 million) on accelerating the National Space Test and Training Complex, specifically on developing a foundational and scalable software baseline for an enduring on-orbit capability, acquisition of a dedicated space command and control antennas, and a prototype model-based system engineering baseline for future digital space T&E campaigns informed by LVC testing.

AUTONOMOUS SYSTEMS AND ARTIFICIAL INTELLIGENCE

Autonomous and artificial intelligence (A&AI)-based systems are software-intensive and data-driven systems that can learn over time and develop emergent behaviors. Current range control and range safety systems will need to be updated to account for with A&AI systems during live testing systems, particularly with manned/unmanned teaming. The following T&E infrastructure investment

areas are projected to be required to evaluate A&AI performance as such systems evolve:

- Data – Massive amounts of data are needed to make adequate assessments of A&AI in OT. Input and output data are critical for a full understanding of system capability and its effect on the downstream systems that execute its decisions. Data management investments are key to ensuring viable data sets for training, stimulation, and validation of AI-enabled systems. Other important aspects of data management to T&E include storage, access, processing, visualization, and security.
- Software – Fully matured A&AI systems are highly reliant on stable software. While the machine learning and deep learning math libraries and algorithms are available via commercial off-the-shelf means, AI software development tools and services are required to load, build, and test the various AI models. Adequate understanding of A&AI software builds trust, determines cause and effect relationships, and most importantly, identifies vulnerabilities to adversary tactics.
- Architecture – To facilitate the use and sharing of data, high-performance computing and network investments are needed. Multi-site DOD networks, like the Defense Research and Engineering Network, that connect test venues and support test events, need modernization to access enterprise-wide services. T&E of A&AI systems will also expand OT&E's human factors assessment process. OT&E will evaluate human-machine teaming capabilities by conducting human factors analysis of warfighters using AI-enabled systems. This entails efficient data capture of message traffic across the machine-human interface, the tactical decision operating picture, and other services. Specific attributes to an efficient network architecture include high-bandwidth and low-latency data transfer.
- LVC – In order to present an AI or autonomous system with enough operationally representative scenarios, a robust LVC environment is needed. AI system performance will be validated via a combination of virtual and physical testing. Among other attributes, the LVC test environment will consists of sensors, cameras, computers, software (machine learning), and remote operators.

JOINT ALL-DOMAIN OPERATIONS (JADO)

JADO will move mission concept of operations away from single sensor-to-shooter solutions (i.e., kill chains), toward fusion of all sensor data into a single image of the battlespace utilizing Joint All-Domain Command and Control (JADC2). JADC2 will use the fused image to identify the most effective solutions to deny, disrupt, or destroy the enemy forces (i.e., kill webs). Similarly, an evaluation of a complete, integrated air, cruise missile, hypersonic, and missile defense portfolio is required to successfully assess such capabilities in the multi-domain operating environment.

T&E in the JADO environment will require the critical test and training ranges to be interconnected with high-bandwidth secure communications. During T&E, weapon systems will be evaluated on their contribution to the kill-web solution. In addition, T&E in the JADO environment will require:

- An adequate operational test venue for hardware-in-the-loop and distributed testing.
- Big Data Centers with A&AI-based tools to collect and assess the massive amount of data that will be generated during test events.
- Fusion engines to analyze and utilize the data.
- Credible models and simulations, including digital twins, to represent both the U.S. (blue) and adversary (red) systems.
- Tools and methods for assessing mission threads JADC2 decisions.

COMMON RANGE INSTRUMENTATION AND INFRASTRUCTURE

Significant changes to the T&E range instrumentation and infrastructure are needed to enable adequate evaluation of advanced weapon systems. For example, the DOD needs:

- State-of-the-art tracking radars, telemetry systems, infrared/optics, and threat emulators and targets to enable operationally representative evaluation of the future Joint Force.
- Expanded instrumented range space for advanced long-range weapons systems and modern blue and red weapon systems that operate over large distances.
- High-speed, multi-level, secure communications within and across test and training ranges to enable T&E in JADO environments.
- State-of-the-art, high speed test tracks.
- Develop a transmitting target detector for the Rolling Airframe Missile, a radio frequency interference model, an enterprise test bed Dual-Band Radar model, and an Evolved Sea Sparrow Missile Block 2 M&S tool in support of several surface warfare programs.

USD(R&E) has several ongoing efforts to modernize and equip T&E ranges to meet these needs:

- Development of MDC overland corridors impacting at WSMR, which is expected to deliver a Programmatic Environmental Impact Statement before the end of calendar year 2022.
- Development of the Next Generation Air Combat Maneuvering Instrumentation/Time Space Position Information to enable more realistic air combat exercises against networked integrated air defense systems.
- The Joint Mission Environment Test Capability Multi-Level Security project that will be evaluated from an OT&E perspective.
- Next Generation Optical Tracking Capability, which was successfully demonstrated this year and is on schedule for delivery in FY23.
- Assessment of alternatives for repair or replacement of the Holloman High Speed Test Track.

» WARRIOR INJURY ASSESSMENT MANIKIN (WIAMAN)

WIAMan is a military-specific anthropomorphic test device (ATD) the Army intends to use to evaluate injuries to ground combat vehicle occupants due to vertical accelerative loading typically observed in mine engagements. The WIAMan program consists of three main efforts:

- Development of the ATD with an integrated data acquisition system.
- Biomechanics research to accurately characterize and predict the injury.
- Development of a finite element model of the WIAMan to support future M&S assessments.

WIAMan was successfully used to assess injuries for the first time in Armored Multi-Purpose Vehicle full-up system-level testing, which was completed in FY22. In FY22, the U.S. Army Combat Capabilities Development Command Analysis Center investigated the range of applicable postures for the injury criteria.

The Army currently has 10 WIAMan ATDs and does not plan to buy any additional WIAMan ATDs. Some vehicles seat more than 10 occupants and LFT&E is ongoing for multiple programs simultaneously. DOT&E assesses that the current Army inventory of 10 WIAMan ATDs is not sufficient to support the LFT&E programs, to include, but not limited to: Mobile Protected

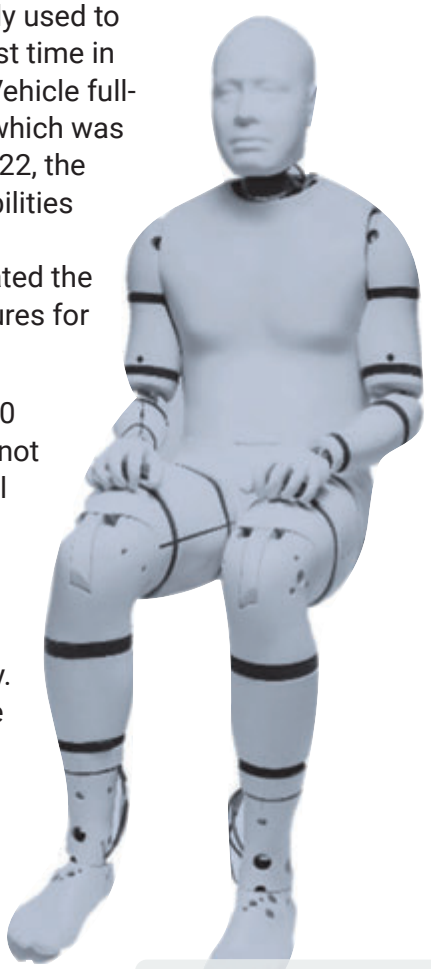

Figure 4: WIAMan ATD

Firepower, Optionally Manned Fighting Vehicle, Stryker 30mm, and M88 Recovery Vehicle. The cost of each WIAMan ATD is approximately $900,000.

DOT&E recommends that the Army investigate whether additional funding for the WIAMan program is needed to purchase additional WIAMan to support LFT&E; improve the accuracy of the injury criteria across all relevant postures; and determine if there is a joint need from other Services, such as, for example, the Marine Corps Advanced Reconnaissance Vehicle program.

THREAT AND TARGET SYSTEMS

The DOD needs additional advanced threat and target surrogates across all domains to conduct authoritative end-to-end, open-air testing, and credible virtual testing of U.S. weapons systems in an operationally representative contested environment. Specifically, the T&E enterprise needs to:

- Develop and field fifth-generation aerial targets.
- Develop and field representative surface-to-air threat system surrogates (i.e., accurate shapes and signatures).
- Develop or procure reprogrammable ground-, ship-, and air-based air defense radars and electronic attack threat surrogates capable of representing the capabilities of new and emerging near-peer threats.
- Develop or procure adversarial hypersonic missile and advanced Anti-Ship Cruise Missile (ASCM) threat surrogates.
- Develop or procure advanced ballistic missile threat surrogates with modern countermeasure suites.
- Field an unmanned test capability that provides a more realistic threat to evaluate the effectiveness of U.S. combat ships' self-defense systems and ship survivability unsupported by live tests against manned ships.
- Develop threat submarine targets with countermeasures that are representative of the current and emerging threats.
- Develop threat representative targets to evaluate the performance of hypersonic missiles and directed energy weapons (either offensive or defensive).
- Develop a set-to-hit target for the evaluation of Navy torpedo programs.

As per the FY22 Consolidated Appropriations Act, Congress provided $114 million to DOT&E, USD(R&E), and the Navy to develop peer-representative targets.

- DOT&E is focusing its investments ($19 million) for: 1) the development of validated threats surrogates (e.g., ballistic missiles, surface-to-air missiles, directed energy, air intercept radars, torpedoes, etc.) required for operationally realistic evaluations, and 2) development of weaponeering tools that will also be used for credible evaluation of the lethality of U.S. weapons against emerging targets.
- USD(R&E) is focusing its investments ($59 million) on the development of fifth-generation aerial target prototypes, an instrumented surrogate cruise missile target, and an HPM source suitable for airborne environments.
- The Navy is focusing its investments ($36 million) on recapitalizing the Sea Range Mobile Ship Target, accelerating the Atlantic Undersea Test and Evaluation Center (AUTEC) In-water Sensor Replacement Program, and developing supersonic sea-skimming target payloads.

KNOWLEDGE MANAGEMENT AND BIG DATA ANALYTICS

Data sharing obstacles among critical stakeholders continue to challenge timely and complete analysis by the assessment community. Limited investment in operationally realistic communication data architectures for distributed testing challenges interoperability testing. In accordance with the DOD Data Management Strategy, the T&E enterprise needs a multi-level secure enterprise knowledge and data management system to keep pace with the volume and complexity of T&E data needs. This includes:

- Development of data standards, data repositories, data marts, and an enterprise data architecture that make data and analysis artifacts easily ingestible, discoverable, and accessible.
- Big-data analytic capabilities that enable efficient search and analyses of large amounts of data at scale, and that include data fusion integrated across multiple test ranges and domains. This includes secure cloud-based parallel-processing capabilities.

This enterprise T&E knowledge and data management system must securely leverage both commercial and purpose-built big data analytics and cloud computing technologies to improve data discoverability and accessibility. This will drive higher evaluation quality and efficiency, leading to more comprehensive and timely information compilation for decision making.

THE T&E ENTERPRISE WORKFORCE

The T&E enterprise faces both workforce "demand" and "supply" challenges. On the demand side, T&E job complexity to support faster and more effective evaluation of complex and interconnected systems has increased dramatically over the last few years. Contributing factors include the rise of software-intensive systems and modern technologies such as autonomous/AI-enabled systems. In addition, the increasingly dynamic and joint multi-domain operations environment that includes advanced maritime, air, land, cyber, space, and electromagnetic spectrum threats must be accounted for throughout the system lifecycle. The demands of innovative, adaptive acquisition framework initiatives call for rapid delivery of new capabilities and at more iterative increments, placing added burden on the workforce to meet shift-left objectives including diminishing acquisition timelines.

On the supply side, the T&E enterprise faces strong competition for top talent. For example, it is difficult to attract and retain talent given the commercial industry's compensation advantages. Additionally, the half-life of technical T&E skills is increasingly shrinking, which further strains the T&E enterprise's learning and development capabilities.

Taken together, these challenges are overextending the T&E workforce without alleviating talent gaps and shortfalls. While each of the Services is addressing most of these shortfalls to varying degrees, we recommend taking a more holistic, T&E enterprise approach. Specifically, the T&E enterprise should get together to share their initiatives and lessons learned, as well as:

- Assess the T&E workforce architecture to identify gaps and opportunities to build future T&E skills, jobs, and workforce composition to support evolving mission requirements.
- Assess, recommend, and implement improvements to the T&E enterprise's talent acquisition processes and pipeline for recruiting high-quality talent in each project office and matrixed organization.
- Complete a Learning Needs Assessment to identify T&E training needs, curriculum gaps, duplicative courses, and opportunities to expand learning and development access across the T&E enterprise.
- Develop and sustain the execution of world-class training, internships, and job rotations in specific technical areas, with periodic refresh, to support the skills of the future.
- Continue to build partnerships with and create reach-back mechanisms to access subject matter experts within key universities, research organizations, industry, federal, and international partners, to share and apply lessons learned, and leverage T&E investments in areas of mutual interest. The Army has reported some success in this area.
- Evaluate the development of an occupational series career code for T&E.
- Evaluate the need to activate reserve officers for short tours providing unique blend of skill sets. The Missile Defense Systems (MDS) OTA has observed some success in this area.

Direct hiring authorities continue to add value to the T&E enterprise.

RANGE SUSTAINABILITY

» 5G AND RADIO FREQUENCY SPECTRUM FOR T&E

National spectrum policy supports turning over more spectrum resources to commercial users in frequency bands currently used to support testing and training. This spectrum sell-off is competing with the Department's increased need for additional spectrum as network-centric systems expand. While the Department continues to work with agency partners to develop transition plans to accommodate spectrum sales and joint use policies, there are several concerns that may limit the Department's ability to assess combat system effectiveness and survivability. These concerns are related to the ability to emulate 5G networks for: 1) accurate representation of the operational environment, 2) spectrum sharing strategies in the S-Band, and 3) impact of 5G L-Band on GPS and Iridium satellite telephone systems.

» WIND FARMS

The Department has well-established procedures to identify and mitigate known adverse effects of onshore wind turbines on test, training, and operational activities. The proliferation of offshore wind farms on both the East and West coasts, however, raise new concerns that the cumulative effects of multiple offshore wind farms may significantly affect air corridors and the performance of mission essential radars on test and training ranges, as well as surface and subsurface operating areas and transit routes. Offshore wind turbines may also introduce noise and vibration into the surrounding waters, while the cables carrying the generated power to the on-shore collection points may introduce electromagnetic interference along their paths. Noise, vibration, and electromagnetic interference could impact the accuracy of naval sensors (operational and developmental). The DOD and the Bureau of Ocean Energy Management should collect sufficient data to determine any effects of offshore wind turbine noise, vibration, and electromagnetic interference on testing, training, and operational activities to identify potential mitigation techniques.

SERVICE T&E ENTERPRISE INPUT

» ARMY T&E ENTERPRISE

The Army reported a balanced program across the Future Years Defense Program (FYDP, FY24-FY28). The Army increased T&E funds in FY24 and has reported significant investment across the FYDP to improve T&E capabilities ranging from investments in DT test centers and OT instrumentation, targets and threats, to include cyber improvements. The Army did indicate the need for TRMC's assistance with funding for threat systems.

» NAVY T&E ENTERPRISE

The Navy T&E enterprise reported a balanced and adequate Major Range and Test Facility Base, T&E Support, and target budget to support Navy T&E requirements. For example, the Navy added additional resources for the upcoming maintenance availabilities for the Self Defense Test Ship and Mobile At-Sea Sensor Barge to ensure the long-term viability of these test platforms. The Navy expressed concern over continued efforts to develop offshore renewable energy projects in offshore Warning Areas used to conduct test and training. The Navy also expressed a concern over the selloff of additional spectrum dedicated to exclusive federal use. Loss of maneuver space above, on, and below the surface, and access to dedicated spectrum will challenge the Navy's ability to ensure future readiness.

» MARINE CORPS OPERATIONAL TEST AND EVALUATION ACTIVITY (MCOTEA)

MCOTEA reported adequate funding to enable planning, execution, and reporting of mandated T&E responsibilities. MCOTEA also reported strong collaboration with the Navy to highlight any range limitations that would affect the evaluation of the

USMC mission. Examples include the ability to adequately represent the multi-domain operating environment, electromagnetic spectrum and infrastructure, tools, processes, and workforce needed to evaluate autonomous and AI-enabled systems.

» AIR FORCE AND SPACE FORCE T&E ENTERPRISE

The Air Force T&E enterprise reported a balanced and adequate FY24 funding program needed to meet OT&E and LFT&E requirements. The Air Force reported an increase in resources across the FYDP to support space system operational tests, the Weapon System Evaluation Program, and the Space Test Course. The Air Force also reported transferring additional resources to enable recapitalization of the space test and training range family of capabilities to conduct combat relevant space electronic warfare testing and training.

» JOINT INTEROPERABILITY TEST COMMAND (JITC)

JITC reported an adequately funded operating account while citing several critical unfunded requirements across the FYDP, to include a need to upgrade their facilities, modernize test bed operations, radio test capability engineering, tactical data link, M&S tools, and test automation. JITC also reported a continued challenge to recruit and retain specialized positions such as cyber security professionals.

» MDA AND THE MDS OTA

The MDA reported an adequate FY24 budget while acknowledging the benefits of Congressional support to meet the MDS Integrated Master Test Plan (IMTP) version 24.0 requirements. MDA assures full access to resources to enable the MDS OTA team's execution of mandated T&E responsibilities. The MDA and MDS OTA team continue refining the budget for future growth, including all-digital venue, space sensor layer, and hypersonic defense requirements as details mature. Specifically, MDS OTA:

- Partnered with the intelligence community and MDA to advance threat model development and ensure applicability to ground test venues.
- Deployed new cloud-based analytical tool suites to accommodate new mission areas, increase handling of large data sets, and use on-demand cloud computing to produce faster analysis and reporting.
- Provided M&S requirements and data needs for accreditation to support operational assessments.
- Enhanced reporting of OT accreditation and model limitations through web-based data tools.
- Strengthened reporting to Combatant Commands and Service elements.
- Collaborated with Service Reserve Components to tap unique civilian expertise and augmented cybersecurity teams with non-DOD cybersecurity experts.

MDA has identified the Pacific Collector/Pacific Tracker Ship Replacement as a critical shortfall. MDA also confirmed that the T&E infrastructure is currently limited by the availability and reliability of existing telemetry and range safety system assets in the broad ocean area, as discussed in the hypersonic section of this report. The capacity of test ranges will become stressed as the Sentinel test program ramps up while also stretching current T&E personnel.

SUMMARY

Accurate evaluation of warfighting capabilities requires an adequate representation of the theater-representative operating environment during test, which is accomplished by T&E resources. It also requires equipment that can adequately measure technical and operational performance of emerging or fielded warfighting capabilities in that environment. The DOD has an array of test and training ranges and capabilities managed, funded, and operated by different stakeholders. To enable efficient and structured modernization and sustainment of existing range capabilities while also transforming the ranges to meet the demands of the future, it is important to have an accurate and common picture of existing and required, future range capabilities. It will be equally

important to ensure this common picture is accurate, digitized, and transparent to key T&E stakeholders to enable collaboration in developing joint/interoperable solutions, avoiding redundancies while increasing capability delivery and efficiencies. In FY23, DOT&E intends to establish a multi-disciplinary team to kick off the following actions:

- Develop, digitally document, prioritize, and track T&E range capability and funding requirements including threats and targets needed for adequate operational and live fire T&E of current and emerging DOD warfighting capabilities. This will include physical and virtual infrastructure with focus on adequate operational T&E of emerging technologies and kill-webs within DOD scenarios, vignettes, mission threads, and joint warfighting concepts. The desired end state is an accurate and validated data dashboard of existing and required capabilities, and their statuses, accessible to key T&E and funding stakeholders.
- Review the range enterprise funding model to identify courses of actions that might introduce efficiencies.

The successful execution of these actions will depend on the cooperation of Service T&E Executive Offices, Program Offices, and range commanders to share relevant data and inform the dashboard design solutions. Success will also depend on input and collaboration with the TRMC within USD(R&E).