Proven Warfighting Capabilities Delivered at the Speed of Need

Sandra Hobson
sandra.hobson3.civ@mail.mil
703-614-5408

Jeremy Werner
jeremy.s.werner.civ@mail.mil
703-896-6897

Nilo Thomas
nilo.a.thomas.civ@mail.mil
703-695-8952

Kristen Alexander
kristen.l.alexander5.civ@mail.mil
703-695-8941

Abstract: The enduring mission of the Department of Defense (DOD) is to provide the military forces to deter war and ensure the Nation's security. Test and Evaluation (T&E) is critical to the DOD mission success: It enables delivery of the proven, combat ready systems needed to enable the lethality, suitability, resilience, survivability, agility, and responsiveness of the future Joint Force. With the complexity of the multi-domain operating environment increasing at more dynamic rates, the T&E tools, processes, infrastructure, and workforce must capitalize on the latest advances in science and technology to transform T&E strategies, stay ahead of the adversary, and continue to inspire trust and confidence in our warfighting capabilities while responding to the adaptive acquisition framework to deliver those capabilities at the speed of need. This paper focuses on identifying the transformational changes that the T&E enterprise needs to implement to enable accurate characterization of the operational performance and limitations of the DOD to prevail in conflict and defend the homeland. This paper summarizes the desired end state and preliminary actions to motivate a call for action across government, industry, and academia to define the right measures of performance and accelerate the proposed transformation.

Keywords: test and evaluation; mission threads, data management, software-reliant systems, continuous test and evaluation, adaptive acquisition framework, multi-domain operating environment, speed-to-field, culture.

Strategic Drivers

We have identified seven disruptors, there may be more, that are driving us to rethink the way we do T&E.

Engineering of Software and Software Reliant Systems.

The DOD Software Modernization Strategy lists an array of challenges that the acquisition and T&E communities need to overcome to deliver the next generation DOD software and software-reliant systems, at the speed of need. Modern software development techniques introduce one of the greatest departures from traditional T&E approaches – a need for a truly integrated, iterative, yet still independent T&E, from code conception to software deployment on our weapon systems.

Traditional operational testing and evaluation concepts that focus on one large test in support of a full-rate production decision are not suitable for modern software practices of rapidly deploying capability upgrades. Instead, the adequacy of software T&E design, execution, and reporting depends on their integration into the software pipeline and systems engineering process, while also ensuring continuous user engagement and operationally representative conditions.

Contractors' supply chain risk management, program protection, cloud services, software factories, and data rights represent critical factors in the evaluation of software operational effectiveness, suitability, survivability, and lethality (as applicable). The execution of such T&E within existing organizational structures, laws, and policies presents a challenge. It is not yet, for example, fully defined how government T&E could interface with software development teams while still maintaining their independence. It is also not clear how to invoke flexibility to keep pace with the software development cadence while still meeting all documentation requirements. As we consider these challenges for software we might also consider them for hardware-intensive systems, because there may be some lessons learned here for all of T&E.

Artificial Intelligence and Machine Learning

Related to engineering of software and software-reliant systems, artificial intelligence (AI) and machine learning (ML) are transformational technologies that introduce yet another layer of complexity to T&E. Rigorous, defensible testing of AI-enabled systems requires additional research to evaluate AI algorithms and ML models, and to ensure AI assurance and to certify that AI algorithms operate as intended and are free of vulnerabilities either from faulty design or from maliciously inserted data or code. T&E also needs to consider the uniquely contextual operational and responsible performance of AI/ML capabilities, especially as they learn and change during real operational use. Given that, where does AI T&E begin and where does it end? Or should it end at all? What tools and processes do we need to put in place to enable continuous evaluation of AI-enabled systems as they get exposed to new and different operational environments? Some form of T&E during operations and sustainment might be our new reality and we may have to use AI itself and other digital tools to enable such T&E and the related scaling challenges.

Joint All Domain Operations

Joint all domain operations bring into question the entire concept of testing one system at a time, as has been done historically. Is that approach still suitable in an environment where operational effectiveness, suitability, survivability, and lethality may depend on multiple sensors and shooters, joint targeting, joint kinetic and non-kinetic precision fires, and the like? This machine-speed warfare, integrated across all combat domains, requires us to focus intently on testing the mission threads that make up the system-of-systems environment, to include the entire potential attack surface and the persistence we expect from our adversaries. The sheer volume of systems, and their extensive reliance on each other to form effective kill webs, will require tools and infrastructure that facilitate continuous and automated T&E. It will also require a physical and virtual infrastructure that can adequately represent the operating environment that is changing in both space and time. Some initial thoughts are summarized in Figure 1.

T&E may also need to be more closely tied to training and large force exercises to leverage the various test and training events and corresponding infrastructure. In addition to the infrastructure and instrumentation to support such events, there are several other items that would have to be fully though through before leveraging training and large force exercises a regular part of our T&E practice: the appropriate range/training capability requirements, mission thread requirements, a joint T&E organization(s) to plan and execute such events, and the associated T&E concepts and cost.

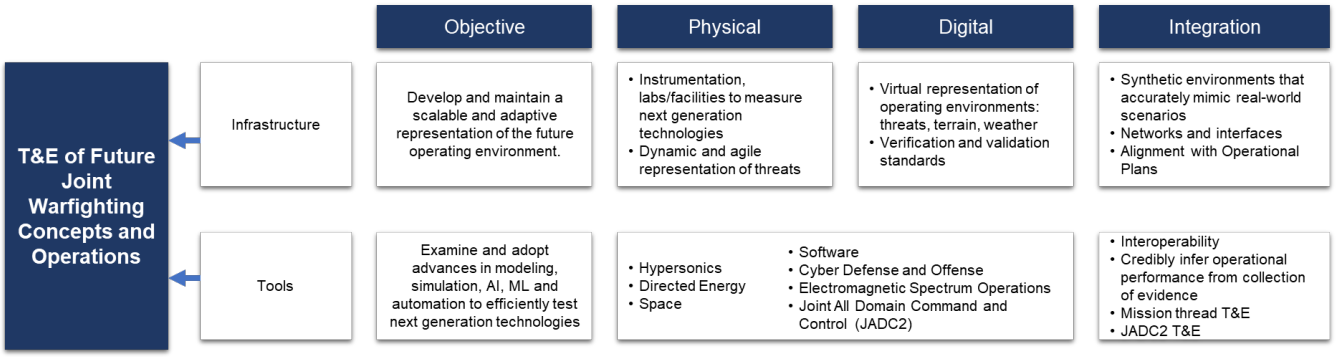

Figure 1. Crude summary of the physical and virtual infrastructure and tools needed to support T&E of joint warfighting concepts and operations.

Data

Related to joint all domain operations is the challenge of data. The effectiveness of joint all domain operations will hinge on the ability of relevant systems to deliver information advantage at the speed of relevance: the ability to ingest, sense, analyze, predict, decide, act, and secure data across the entire Joint Force, at every echelon, from the strategic level to the tactical edge, at machine speeds. This will require innovative T&E data management tools to measure and evaluate data-oriented operational performance, especially as data and elements of the kill webs change over time. Let's pause to consider the complexity of the interoperability of such concepts and let's then imagine them in contested space, electromagnetic spectrum (EMS), and cyber environments. This requires an array of different T&E changes – some of which we may have not even considered yet.

At a minimum, the T&E community needs T&E data management plans, standards, repositories, and a large-scale industrial computing infrastructure deployed across the T&E enterprise to enable credible, data-driven decisions on both the complexity level and rapid timescale of future joint warfighting operations. In other words, the collection, analysis, and high-level aggregation of test data must be networked and automated. Moreover, this infrastructure must be integrated with a unified data-driven, all-domain modeling and simulation (M&S) environment – all the way from the tactical edge to the C-suite – to complement live testing in conditions not possible in live tests due to environmental, fiscal, safety, classification, and ethical constraints. *At the edge* we likely would need raw streaming data from the platform, onboard data reduction, and distributed raw binary data stores. *Across the enterprise* we may need data post-processing to machine-readable formats; integration into data-backed M&S; "online" system performance analyses using an open, general-purpose automated data analysis environment; and ad hoc "offline" manual, analyst-performed experimentation and development. *At the C-suite* we should leverage the DOD's Advana[1] platform for big data-aggregated advanced analytics using a data mart[2] composed of high-level system performance analysis artificacts.

The rigor behind the automated data and analysis infrastructure described above will enable not only faster analysis but also the complex, tiered analysis necessary to glean high-level and

[1] Advana is the DOD's big data platform for advanced analytics, supported by the Office of the Assistant Secretary of Defense for Acquisition. It is accessible via DOD network only.

[2] A data mart is a structure/access pattern specific to data warehouse environments, used to retrieve client-facing data

synergistic mission effects: live data collected in simpler scenarios will be “remixed” and fused with M&S to create “digital arenas” for evaluating more complex warfighting scenarios and their related emergent behaviors, using a variety of advanced analysis techniques including AI and Bayesian networks. We look forward to this future.

Speed to Field

Speed to field is another challenge for the T&E community brought to us by an increasingly capable adversary with access to new science and technologies. Accelerating warfighting capability to the field while not compromising quality and while also confronting the complexity of the technologies themselves requires innovative, if not revolutionary, T&E approaches.

The DOD’s Digital Engineering Strategy states that *current acquisition processes and engineering methods hinder meeting the demands of exponential technology growth, complexity, and access to information.* Digital engineering offers an opportunity to enable the acquisition and T&E forces to automate and accelerate workflows and processes. For example, the development of interoperable digital data about systems under development and test could accelerate acquisition by enabling the coherent management of large numbers of systems and mission sets.

Adaptive test planning and execution also offer opportunities to enable faster and more efficient acquisition: the test adequacy for any phase of test is dependent on the outcome of prior testing. For example, the underperformance of a system that falls well below its reliability requirement can be determined with fewer trials than the over-performance of a system that falls slightly above its reliability requirement. Moreover, the development status of the system under test will mature over time (or acquisition milestones); often we will not have a production-representative test asset until initial operational test and evaluation, and yet this test asset will likely be strongly related to its prototype predecessors used in earlier phases of test. In addition, the capabilities and conditions tested in initial operational test and evaluation will often be more stressing than those examined in earlier test phases and subject to different limitations; though, again, the conditions and limitations will typically be related. These dependencies in time among prior observed test results, test assets, and tested capabilities/conditions/limitations suggest the creation of a test design that is both sequential and adaptive to support optimal but adequate T&E in a way that most efficiently leverages data collected across the test life cycle. Figuring this must be a priority.

Culture

There are several factors that affect the T&E culture that may have to be reconsidered to enable the transformation of T&E processes and outputs:

- Communication is key to success, no matter the situation. Disparate test communities, sometimes spread across different corners of the country, different appreciations for test as compared to M&S, different priorities, and misunderstandings can get in a way of progress, even though all acquisition and T&E stakeholders have the same objective – that is to support the warfighter. Common data and tool repositories, digital engineering, secured and available networks, and infrastructure may improve communication within T&E working-level integrated product teams or integrated test teams and within the T&E enterprise as a whole to identify, prioritize, and track T&E capability requirements.

- The value of T&E can be difficult to appreciate but not if it is characterized as an approach to quantify risk to the program and the warfighter. Programs would benefit from including T&E stakeholders in the development of requirements to evaluate their scope and testability. Similarly, acquisition contracts should also be informed by T&E to confirm access to needed data, artifacts, tools, support to government T&E, and similar.
- Change can be difficult to accept and even more difficult to implement, but continuous change will be the T&E reality as we transition into a digital ecosystem. Application of design thinking principles, for example, could help the T&E working-level integrated product teams solve problems in more structured and efficient ways. Continuous learning and training might become an inherent part of the acquisition and T&E career progression to help all stakeholders successfully maneuver in this new space.

Talent Management

This leads us to our last identified disruptor – talent management. As already alluded to, emerging technologies and digital transformation concepts will require unique skills that the existing workforce may not have. To complicate things, some fields such as software engineering, AI, and cyber science are changing rapidly, requiring continuous training and professional development. To further complicate things, the T&E community has been absorbing responsibilities to keep pace with emerging threats, leaving minimal to no room for training, learning, mentorships, or the like. In addition, high-demand skillsets are also sought by the commercial sector, making it even more challenging for the government to acquire and retain the right T&E workforce. The T&E community is left with the challenge to craft a new approach to recruitment, training, education, and long-term management of the talent pipeline.

Strategy

To respond to these disruptors, the Director, Operational Test and Evaluation, HON Nickolas Guertin, challenged us to work with him on a strategy that will help transform T&E and enable the delivery of the world's most capable warfighting capability. Under his leadership, we defined the desired end state as five strategic pillars, depicted in Table 1.

Table 1. Strategic Pillars of T&E Transformation and Capability Delivery

	Pillars	Key Actions	Desired End State
	**Test the Way We Fight**	Architect T&E around validated mission threads and demonstrate the operational performance of the Joint Force in multi-domain operations	• Accurate representation of the Joint, multi-domain operating environment in test • Adequate evaluation of Joint warfighting capabilities and mission threads (kill webs, system-of-systems performance)
	**Accelerate the Delivery of Weapons That Work**	Embrace digital technologies to deliver high-quality systems at more dynamic rates	• Discoverable, accessible, and secure data repositories • Near-real-time test data analysis and assessment • Established tools and processes that optimize integrated T&E • Digital documentation and tracking of T&E strategies and plans
	**Improve the Survivability of the DoD in a Contested Environment**	Identify, assess, and act on cyber, EMS, space, and other risks to the DoD mission – at scale and speed	• Minimized mission-critical vulnerabilities in a contested environment • Timely tracking and response to mission-critical vulnerabilities as systems and threats evolve
	**Pioneer the T&E of Weapon Systems Built to Change Over Time**	Implement fluid and iterative T&E across the entire system life cycle to help assure continued combat credibility as the system evolves to meet warfighter needs	• Standardized and increased use of credible digital twins in T&E • Adequate assessment of operational and ethical performance of AI-enabled systems • Effective tracking of any degradation of operational performance of DoD systems in theater
	**Foster an Agile and Enduring T&E Enterprise Workforce**	Centralize and leverage efforts to access, curate, and engage T&E talent to quicken the pace of innovation across the T&E enterprise	• Highly skilled T&E workforce prepared to meet the toughest challenges • Effective continuous learning program and a robust recruitment/retention plan • Agile and innovative workforce operating model

Pillar 1: Test the Way We Fight

This pillar is focused on accurate evaluation of next-generation warfighting capabilities and requires an adequate representation of the theater operating environment during test, training, and mission rehearsal. It also requires equipment, both physical and digital, 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 the existing and required future range capabilities and requirements. 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, and increasing capability delivery and efficiencies.

This pillar also considers real-world mission scenarios that involve the use of multiple systems of varying complexities and pedigrees working together to achieve the desired lethal effect. The emergence of highly network-centric concepts, greater dependency on connectivity, and the use of large amounts of data from a wide array of shooters and sensors across multiple domains, at machine speeds, warrants a review of our T&E processes within individual acquisition programs. Evaluating warfighting capability is further challenged by asynchronous updates and continuous evolution of the various components that comprise these system-of-systems operations. These evolutions demonstrate an inherent need to continually characterize the interoperability and effectiveness of such systems as they would be employed by the Combatant Commands. With the emergence of joint all-domain command-and-control solutions and the concept of kill webs, it is important to define the process and the required T&E tools that would effectively measure the success rates of mission threads, concepts, and solutions.

Pillar 2: Accelerate the Delivery of Weapons That Work

Data are strategic assets that fuel automation and algorithms designed to alleviate our workload, speed up our processes, help us achieve new insights, and achieve T&E at scale and speed. As data-driven and complex systems continue to proliferate, it is important to develop T&E data and interface standards, stores, and platforms to ensure that the data are credible, trustworthy, available, and secure across the T&E enterprise. The T&E community must demonstrate its compliance with and contribution to implementing the DOD Data Management Strategy and enable data collection, storage, visibility, sharing, accessibility, ingestion, and security across commercial and government stakeholders to expedite data analysis, optimize T&E planning and execution, and enable more automated T&E. This compliance translates to availability of data stores, knowledge management tools, and data fusion/analytics tools that will enable the new fluid and iterative nature of T&E demanded by software- and data-reliant systems. Data are also critical to verify and validate digital tools. Lastly, all data (contractor, developmental, operational, and live fire) must be effectively leveraged to adapt, inform, and optimize T&E plans – no data should be left behind.

Having a data management plan will also enable modern model-based engineering and adaptive inference processes that offer integrated, holistic approaches to generating and managing knowledge of system performance throughout its life cycle. Early test data from system components, for example, can be integrated into a larger system model to predict mission-level performance early in development. Advanced performance inference techniques (e.g., Bayesian) can be used to carry forward data from early prototypes through evaluation of

production-representative systems. Moreover, model-based engineering can eliminate manual workflows through automation that enables generation and distribution of up-to-date dynamic reports on systems and their status in the acquisition life cycle.

This is further emphasized in Section 223 of the Public Law 117-81. The T&E community will have to leverage heavily model-based systems engineering and other digital tools and technologies to enable full-spectrum survivability (and lethality) evaluations. Full-spectrum survivability evaluations are intended to enable the survivability of DOD systems and services in a multi-domain operational environment, accounting for both kinetic and non-kinetic threats – such as cyber; directed energy weapons; EMS fires; chemical, biological, radiological, and nuclear threats; and any combination thereof. Moreover, full-spectrum survivability evaluation is intended to leverage digital technologies required to enable such evaluation throughout the life cycle of the acquisition program, as both the fielded system and the threat(s) evolve over time at more dynamic rates.

Pillar 3: Improve the Survivability of the DOD in a Contested Environment

Seamless integration of various systems and technologies working together across multiple domains introduces the potential for vulnerabilities that cannot be evaluated one system or one threat at a time. As discussed under the first pillar, testing must consider the mission thread, specifically the composition of weapon systems; networks; critical infrastructure; equipment; and tactics, techniques, and procedures. A rapid and accurate mission-based survivability assessment would define specific steps to enhance mission assurance and identify the defenses required against threats to those missions.

To add to this complexity, since weapon systems of today and the future are defined by both software and hardware, battle networks are central to the kill web, and information technology is at the heart of cyber, space, and EMS warfare. The complex interactions between software and hardware can sometimes be difficult to predict or evaluate. Our challenge is to evaluate cyber-physical systems against advanced cyber and EMS threats at scale and speed. Attack surfaces are growing exponentially, reaching into supply chains, software pipelines and factories, the EMS, and an array of cloud solutions. We therefore must aggressively pursue verified and validated digital tools and transformative technologies to manage cyber, EMS, and advanced kinetic threat survivability T&E and assess the effectiveness of countermeasures and other self-defense solutions.

In addition, space is increasingly congested and highly contested, with a broad array of rapidly evolving threats warranting its own focus. Reliance on space-based capabilities has sharpened the DOD's – and our adversaries' – focus on deploying both offensive and defensive weapons in space. Because the DOD must operate in this contested environment, the T&E enterprise must be ready to accurately evaluate space-based and space-dependent systems' operational performance, including survivability against current and anticipated threats.

Pillar 4: Pioneer T&E of Weapon Systems Built to Change Over Time

The fourth pillar is focused on addressing the T&E challenges associated with complex, largely software-reliant systems, the operational performance of which could be affected by incremental and frequent software upgrades and/or frequent and dynamic changes to the operating environment. Related to software-reliant systems, this pillar also focuses on the challenges brought by AI and ML capabilities. All elements of this pillar are counting on advances of the

digital ecosystems, which start with the development of credible digital twins – high-fidelity digital representations of physical objects.

In addition, the combination of new domains and operational constraints makes verified and validated digital technologies the necessary, practical approach for development and T&E of certain systems where live T&E is not possible or practical. For example, digital twins that can be subjected to repeated cyber attacks – as the system itself, the threats it will face, and adversary tactics, techniques, and procedures change over time – will help developers and program managers improve system cyber survivability at an increased pace. These types of models allow us to find out how real-world objects might behave under different conditions or requirements. The defining feature of a digital twin is the ongoing data integration between the digital model and its physical unit counterpart. Digital twins have demonstrated the capability to incorporate transmission of real-time data sensed by the real-world object. These new, higher-resolution sensor data allow the digital twin to reason about future behaviors, then transmit feedback to the physical object. This ability could be particularly useful in enabling continuous monitoring of operational performance of systems as they evolve over time. Unfortunately, while digital twins create new opportunities for T&E to determine the performance of continuously evolving systems, they also create new verification, validation, and accreditation challenges.

On a related note, AI-based systems have accelerated the need to re-engineer T&E to enable continuous assessment once fielded. The T&E enterprise must be positioned to monitor and evaluate the drift in deployed AI models' behavior, which could occur when real-world data deviate from the training data used to create the model. Testing also must demonstrate with confidence that AI-based systems are responsible, ethical, equitable, traceable, reliable, and governable. Ethical and safe use of AI is necessary to reduce risks to U.S. strategic initiatives, reputation, operations, legal standing, and privacy issues. Due to their reliance on ever-changing data, however, AI-based systems are uncertain by nature. Emerging approaches that have the potential to address such uncertainty propagation deserve further investigation. Additional research is also needed to re-envision the T&E process with increased AI and automation tools to support T&E professionals and identify opportunities where AI can assist them – relieving them of tedious tasks so they can better focus on tasks that require the creativity and innovation that only humans can provide.

Lastly, and as discussed in the Strategic Drivers section, modern warfighting systems are increasingly software-reliant. They are developed through complex software pipelines filled with a myriad of tools intended to ensure automatically that the product is effective and secure. However, developers frequently use open-source and third-party software, which raises the risk from the security and sustainability perspectives. It is important to identify new approaches to address change propagation within software-reliant systems. For example, the survivability T&E community needs to influence and measure the development and cyber defense of software pipelines up front with accredited tools, techniques, and procedures. Automated testing should be embraced at every level, and a rigorous standard of testing should continue to continue to be implemented at the speed of relevance.

Pillar 5: Foster an Agile and Enduring T&E Workforce

A structured approach for the collective development and sustainment of the T&E enterprise workforce will enhance workforce agility and response to emerging T&E requirements. Dedicated T&E skill codes and qualifiers to track T&E professionals' knowledge, skills, and abilities would improve the DOD's awareness of the T&E workforce's overall health and development. An infrastructure to make data-driven workforce planning decisions would enable

the T&E enterprise to forecast, track, and address gaps in the T&E workforce's collective capabilities. It would also enable unified development of the T&E enterprise workforce, as well as its agility to move among the requirements developers, technology developers, buyers, and across the Service T&E communities.

T&E professionals of the future require access, bandwidth, and clear requirements to engage in continuous learning opportunities. Providing these opportunities will better prepare them for the advances in T&E operational and technical capabilities needed to perform their duties. It is important to establish enterprise-wide baseline education and training needs and the ability to identify all T&E-related course offerings to strengthen workforce capabilities. The T&E learning apparatus should change as quickly as the T&E operating environment, with easily adaptable courses, content, and training based on current workforce demands. It is also important to establish a continuum of cutting-edge learning opportunities that can tie training and education to specific job and career outcomes across the enterprise; this would improve and incentivize T&E learning and workforce retention. To compete with private sector organizations for top-tier talent and promote retention, the T&E enterprise will need to invest in workforce experiences and the Skillbridge program to appeal to a diverse T&E workforce in terms of skill development, rotational opportunities, and leadership roles.

Implementation Plan

Requirements, intelligence, and the acquisition pathways are the foundation of the T&E process. Changes in capabilities, such as kill webs, complex all-domain environments, and gaps newly identified by intelligence reports, will steer acquisition decisions and commensurate T&E responses. Based on the requirements, intelligence, and mandates sourced from the six acquisition pathways, the T&E community must collaborate to identify and develop the T&E capabilities necessary to test and evaluate systems in the acquisition pipeline. These T&E activities will realize the goals of the five strategic pillars that will in turn inform T&E policy and guidance with the potential to inform operational and system requirements, system development, and acquisition contracts. It is imperative to work together and promote a pioneering spirit, as well as a culture of continuous learning, agility, transparency, and co-ownership, to use our combined talents most effectively and accelerate research and development needed to transform T&E tools, processes, infrastructure, and human capital.

Conclusion

The DOD faces a shifting threat landscape and the need to swiftly leverage advanced technologies to increase the lethality, suitability, resiliency, survivability, agility, and responsiveness of our future Joint Force. To continue to deliver credible warfighting capability at the speed of need, the acquisition and T&E enterprise must rethink traditional approaches. we must respond with agility, efficiency, and effectiveness to adequately account for the technology disruptors as we face an inflection point in the scope, scalability, and capabilities of our infrastructure, tools, processes, and workforce. It is our responsibility to set the framework to leverage ongoing government-based activities, the best practices of industry, academia, and our allies to develop a future-ready T&E enterprise.

The T&E enterprise of the future must be agile, motivated by mission thread approaches, joint warfighting concepts, and the power of digital tools and technologies. It must be strengthened by the effects of these changes on our ability to support the warfighter. It must be empowered by continuous learning and supported by unbound access to state-of-the-art skills and

technologies to be better positioned to stay ahead of the adversary and continue to advocate for the warfighter and its mission as defined by the National Defense Strategy 2022.

Biography

Dr. Sandra Hobson was appointed to the Senior Executive Service in 2014 as a Deputy Director in the Office of the Director, Operational Test and Evaluation (DOT&E), within the Office of the Secretary of Defense. She is currently responsible for defining and executing strategic initiatives, and supporting the development of policy and guidance to meet the test and evaluation demands of the future as the complexity of Department of Defense weapons systems and multi-domain operational environments evolve. Dr. Hobson was selected to perform the duties of the DOT&E Principal Deputy Director from January 20 to December 19, 2021.

Prior to this appointment, Dr. Hobson supported DOT&E in two other capacities: first as a Research Staff Member at the Institute for Defense Analyses and then as an Aircraft Systems and Weapons Staff Specialist. During these tenures, she provided technical oversight of test and evaluation programs to enable adequate assessments of the survivability and lethality of a subset of Department of Defense aircraft and weapons acquisition programs.

Dr. Hobson earned her Bachelor of Science degree in Aerospace Engineering from the United States Naval Academy and her Doctor of Philosophy degree in Aerospace Engineering from A. James Clark School of Engineering at University of Maryland. Dr. Hobson is a recipient of the National Fellowship for Exceptional Researcher awarded by the United Nations Educational, Scientific and Cultural Organization (UNESCO), and two Secretary of Defense Medals for Meritorious Civilian Service. She currently resides in Virginia with her husband and two German Shepherd dogs.

Dr. Jeremy Werner was appointed DOT&E's Chief Scientist in December 2021 after initially starting at DOT&E as an Action Officer for Naval Warfare in August 2021. Before then, Jeremy founded a data science-oriented military operations research team at JHU/APL that transformed the analytics of an ongoing military mission. Jeremy previously served at IDA supporting DOT&E in the assessment of a variety of systems. Jeremy earned a PhD in physics from Princeton University where he was an integral contributor to the Compact Muon Solenoid collaboration in the experimental discovery of the Higgs boson at the Large Hadron Collider, CERN, Geneva, Switzerland.

Dr. Kristen Alexander is the Chief Learning and Artificial Intelligence Officer for DOT&E. Dr. Alexander previously served as the Technical Advisor for the Deputy DOT&E for Land & Expeditionary Warfare. As Technical Advisor, she provided technical and analytical advice for test design, evaluation, and reporting on over 50 Army and Marine Corps programs. Dr. Alexander has been involved with operational test and evaluation since 1999 as a research staff member at the Institute for Defense Analyses. She holds B.S. and Ph.D. degrees in chemical engineering from University of Rochester and Carnegie Mellon University, respectively.

Mr. Nilo Thomas graduated from New Mexico State University in 2013 with a BS in Aerospace Engineering. He worked for the Air Force's 47th Cyberspace Test Squadron for 8 years, where he was a test manager leading the largest test programs in the test squadron, Unified Platform and Joint Cyber Command and Control, the DoD's premier cyberspace weapon systems. In 2021, he started working for DOT&E and works as the organization's Software and Cyber Advisor, managing the diverse portfolio of DOT&E software and cyber initiatives on behalf of operational test and evaluation.