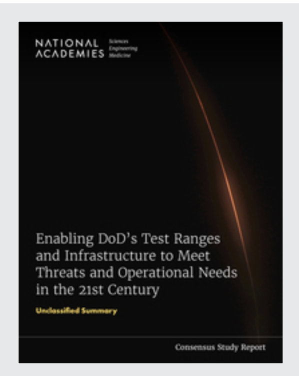

Enabling DoD's Test Ranges and Infrastructure to Meet Threats and Operational Needs in the 21st Century: Unclassified Summary (2022)

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Unclassified Summary

Committee on Assessing the Operational Suitability of the DoD Test and Evaluation Ranges and Infrastructure

Board on Army Research and Development

Division on Engineering and Physical Sciences

Consensus Study Report

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Reviewers

This Consensus Study Report was reviewed in draft form by individuals chosen for their diverse perspectives and technical expertise. The purpose of this independent review is to provide candid and critical comments that will assist the National Academies of Sciences, Engineering, and Medicine in making each published report as sound as possible and to ensure that it meets the institutional standards for quality, objectivity, evidence, and responsiveness to the study charge. The review comments and draft manuscript remain confidential to protect the integrity of the deliberative process. We thank the following individuals for their review of this report:

Bill Conley, Mercury Systems,
Derrick Hinton, Scientific Research Corporation,
Gregory Johnson, Lockheed Martin Corporation,
Hans Miller, The MITRE Corporation,
Gary Polansky, Sandia National Laboratories,
Julie Ryan, Wyndrose Technical Group,
Johnny Sawyer, The Sawyer Group, LLC, and
Donald C. Winter, NAE,[1] U.S. Navy (ret.).

Although the reviewers listed above provided many constructive comments and suggestions, they were not asked to endorse the conclusions or recommendations of this report nor did they see the final draft before its release. The review of this report was overseen by Alton D. Romig, Jr., NAE Executive Officer and Lockheed Martin (retired). He was responsible for making certain that an independent examination of this report was carried out in accordance with the standards of the National Academies and that all review comments were carefully considered. Responsibility for the final content rests entirely with the authoring committee and the National Academies.

[1] Member, National Academy of Engineering.

Preface

Understanding the critical role of operational test and evaluation (OT&E), the Office of the Director of Operational Test and Evaluation (DOT&E) tasked the National Academies of Sciences, Engineering, and Medicine with conducting two studies, one unclassified (referred to as Phase 1) and one classified (referred to as Phase 2) to assess the suitability of the Department of Defense (DoD) ranges and infrastructure to accommodate OT&E in the and around 2035. The Phase 2 builds on the work of the Phase 1 study[1] and additionally assesses threat replication in OT&E and emerging technologies expected to be enter OT&E in the coming decades.

The fundamental conclusion of the Phase 1 study was that the OT&E community must change its paradigm from a system-by-system approach to a system-of-systems approach if it is to test in a manner representative of how the joint force will fight in 2035. The pace of adversary technological advancement, particularly China, combined with accelerating diffusion and proliferation of dual-use technologies, has changed the risk calculus for the United States. The strategic risk of failing to invest in the capability to truly test against a realistic adversary at scale is now too high. DoD must implement a broad range of materiel and non-materiel solutions related to test range infrastructure, data management and data sharing, modeling and simulation, and human capital if it is to maintain its qualitative edge in OT&E.

This Phase 2 report of the Committee on Assessing the Operational Suitability of the DoD Test and Evaluation Ranges and Infrastructure will illustrate that, while the test and evaluation (T&E) community contains pockets of exquisite capability and has initiated many of the programs necessary to modernize the T&E community, significant shortfalls and obstacles remain. The committee was grateful for the opportunity to visit several test and evaluation facilities, both during site visits and virtually. It is clear to the committee that the T&E workforce is comprised of dedicated and extremely competent professionals from a diverse collection of disciplines, and they consistently and routinely exhibited impressive ingenuity, both individually and collectively. It is this spirit of ingenuity and innovation that has enabled the United States to maintain its competitive edge, despite its relatively low investment in T&E.

The pace of adversary advancement in military capability, reach, and ambition has clearly overcome the ability of the T&E workforce to simply do more with less. This report builds on the themes from the Phase 1 study, adding classified details where applicable, fills in missing gaps in the first report, and closely examined how scientific and technical intelligence (S&TI) informs OT&E. This report also provides an examination of how OT&E must evolve in critical technical areas if DoD is to have confidence that its people, our national treasure, will be equipped with weapons systems upon which they can rely.

Finally, the report ends with an analysis of how the Range of the Future connects to its ultimate T&E customer—the services that provide able and ready forces and the Combatant Commands that employ them, and by extension, our Allied partners. Complementing this discussion of the Range of the

[1] National Academies of Sciences, Engineering, and Medicine, 2021, *Necessary DoD Range Capabilities to Ensure Operational Superiority of U.S. Defense Systems: Testing for the Future Fight*, Washington, DC: The National Academies Press, https://doi.org/10.17226/26181.

Future is a section on innovation, where the report will present how to build and nurture an innovation infrastructure, which must accompany the material and non-material solution space identified above. If implemented, it will allow DoD to match speed to field with current and future warfighter needs.

Unclassified Report Summary

Operational test and evaluation (OT&E) is a critical part of U.S. military capability development and essential to the effective employment of new operational systems. OT&E ensures that every operational system meets its operational requirements in a realistic representation of the operational environment. In an era of near-peer strategic competition in the Western Pacific, conflict in Eastern Europe, emerging technologies, increasingly capable adversaries, new competitive operational domains (cyber and space), rapid, rigorous, and realistic OT&E is essential to ensuring competitive advantage for the Joint Force and preserving a credible deterrence.

New battlefield capabilities—in particular, autonomous systems, artificial intelligence (AI), machine learning (ML), cyber weapons, electronic warfare (EW) systems, directed energy weapons, space-based platforms, and hypersonic aircraft and missiles—will define the next near-peer conflict. Preparing the U.S. military will require extensive and realistic operational testing that not only validates new operational systems for the future operating environment, but can also catalyze the Services and Joint Force to assess how well they adapt doctrine, tactics, and training to new paradigms of warfare.

Understanding the critical role of OT&E, the Office of the Director of Operational Test and Evalutation (DOT&E) tasked the National Academies of Sciences, Engineering, and Medicine with conducting two studies, one unclassified (referred to as Phase 1) and one classified (referred to as Phase 2). The goal of the combined effort of two committees was to investigate and assess the state of Department of Defense (DoD) ranges, their capacity to support OT&E in the coming decades, and recommend actions to mitigate and overcome any identified deficiencies. The Phase 1 report committee focused its efforts on the technical and physical infrastructure of DoD ranges. That committee and report,[1] while limited by classification, addressed a wide spectrum of range needs and recommended key steps that DOT&E and the OT&E community writ large can take to prepare to support future operational test (OT). This Phase 2 report picks up where the Phase 1 report ends—expanding on several areas and incorporating threat modeling and replication/representation in OT&E based on briefings, reports, and discussions at the Secret level.

This report is organized around five (5) key themes and recommendations that will prepare the test community to effectively support OT&E in the coming decades.

- Theme 1: Improve threat modeling and prototyping to maintain pace with adversary developments.
- Theme 2: Address gaps in testing of emerging capabilities driven by new technologies.
- Theme 3: Test as You Fight—Testing to operational capability versus program requirements.
- Theme 4: Formalize a live, virtual, and constructive (LVC) test range capability for joint multi-domain OT based on digital engineering and LVC technologies.
- Theme 5: Test at the speed of operational needs.

[1] National Academies of Sciences, Engineering, and Medicine, 2021, *Necessary DoD Range Capabilities to Ensure Operational Superiority of U.S. Defense Systems: Testing for the Future Fight*, Washington, DC: The National Academies Press, https://doi.org/10.17226/26181.

The report structure consists of six core chapters detailing the findings, conclusions, and recommendations of the committee.

Chapter 1 summarizes and expands on the Phase 1 report, noting its key themes and recommendations and describes how it lays the foundation for Phase 2. The Phase 1 study examined the physical and technical infrastructure of DoD ranges and infrastructure in an unclassified capacity. The report concluded that the challenges facing the OT&E community are driven by limited test capacity, the age of test infrastructure, the capability to test advanced technologies, and encroachment, which hinder the ability to inform integrated system performance and slow the overall pace of testing. The Phase 1 report emphasized three fundamental themes that included (l) a vision of future combat that will rely on connected kill chains in a joint all-domain operations (JADO) environment; (2) the role of digital technologies in dramatically reshaping the nature, practice, and infrastructure of OT; and (3) the use of "speed-to-field" as today's measure of operational relevance.

To address these challenges, the Phase 1 study developed conclusions and recommendations around the following five major categories: (1) Develop the "Range of the Future" to test complete kill chains in JADO environments. (2) Restructure the range capability requirements process for continuous modernization and sustainment. (3) Bootstrap a new range operating system for ubiquitous modeling and simulation (M&S) throughout the operational system's development and test life cycle. (4) Create the test-development-operations (TestDevOps) digital infrastructure for future operational test and seamless range enterprise interoperability. (5) Reinvent the range enterprise funding model for responsiveness, effectiveness, and flexibility.

This Phase 2 report carries forward a number of themes from the Phase 1 report, namely the following: future combat will be built on connected system-of-systems kill chains in JADO environments; digital technologies are dramatically reshaping the nature and infrastructure of testing; and "speed-to-field" is the measure of operational relevance in today's competitive near-peer environment.

Finally, the Phase 1 report introduced the concept of the Range of the Future that this Phase 2 report builds on to develop its core recommendation—namely, that the future of OT&E will rely on geographically distributed, LVC systems. These systems will need to be capable of testing at scale in environments representative of future JADO.

Chapter 2 examines and assesses the changing threat environment in 2035. It details how scientific and technical intelligence (S&TI) supports OT&E through modeling and threat replication. The committee reviewed and assessed the threat replication capacity across the OT&E community and found that core challenges stemmed primarily from the S&TI process, the lack of consistent resourcing for threat model development, and the long timeframe for threat model release to the OT&E community. The committee's key recommendations are to adopt threat agnostic models to support OT&E, consistent resourcing of threat model development, and continued S&TI support after Acquisition Milestone C or at key points in alternative acquisition pathways such as rapid prototyping acquisition.

Chapter 3 investigates several emerging technologies and technology areas that will define future conflicts and the unique challenges they pose to OT&E. These technologies include hypersonic systems, space systems, directed energy, 6th-generation aircraft, advanced electronic warfare systems, advanced acoustic and non-acoustic systems for undersea warfare, AI, autonomous systems, and cyber capabilities. The committee divided the technologies into the following two main categories: (l) relatively mature technology and primarily physical systems that will require additional OT&E resources to keep pace with threat conditions and (2) emerging software-based technologies that are cross-cutting, rapidly evolving, and will require OT&E to engage early in the life cycle to adapt their test strategies as the technologies continue to mature. Chapter 3 includes specific findings, conclusions, and recommendations for each technology area.

Chapter 4 focuses on a system-of-systems approach to T&E and the need for the OT&E community to adhere to an oft heard mantra by the committee, "test as you fight," which is to provide OT plans that align as closely as possible to realistic warfighting. The overwhelmingly consistent message heard by the committee was the challenge of testing to the scale of the future fight. Current and emerging

DoD warfighting doctrines emphasize the need for the Joint Force to operate as a multi-domain or all-domain capable force. The development of mechanized forces in the early 20th century, the emergence of new warfighting domains in the air, undersea, space, and cyberspace throughout the 20th and early 21st centuries, and the rapid development and advancement of communications technologies over the past century have driven integration of warfighting domains and their respective domain-centric platforms into a system-of-systems architecture that fuses warfighting elements into a coherent Joint Force operating in all domains.

This system-of-systems approach and all-domain character of future warfare are not represented in OT&E today. Chapter 4 details this changing character of warfare, the shift it demands of OT, and pockets of excellence found within the Services.

Chapter 5 details the Range of the Future and expands on it in light of new information and subsequent analysis by the Phase 2 committee. This future reality must be accounted for by OT&E in a way that realistically replicates all-domain operations at scale. Notable challenges include the time and resources necessary to conduct physical testing at realistic scales, the potential for adversary intelligence collection on OT, and the need to keep pace with changing doctrine. The solution to this challenge is the development, adoption, and implementation of geographically distributed, but connected, LVC systems.

The committee identifies a number of LVC systems in various states of development and operation, most notably the Joint Simulation Environment developed for the F-35 program, which can serve as the building blocks for the Range of the Future. This encourages the further development of these systems and their proliferation across the Services.

Chapter 5 also identifies key attributes of the LVC range of the future and core considerations that must be taken into account during its development and operation. The DOT&E will play a critical role in championing the development of these systems and in ensuring their capability to connect across the Services and domains to realistically replicate the future near-peer operating environment.

Chapter 6 discusses the need to keep up the pace of innovation to ensure the U.S. military does not lose ground to its adversaries' technology development curves. U.S. military capability development is an interconnected process moving from R&D, to acquisition programs of record, to developmental testing, to operational testing, and then on through training and fielding and sustainment. The interconnected relationship and reciprocal feedback loops between all of these stages means that a slow-down in one area can affect the progress in development. The committee strongly believes it is absolutely critical that OT&E serves as an accelerator in this process. Through the use of LVC systems, changes in process (detailed in the report), emphasis on improved information sharing, and the adoption of key emerging technologies such as AI, the DOT&E can serve as a key enabler of rapid capability development in this dynamic environment.

The success of OT&E, much like operational military forces, hinges on adaptability and continuous improvement based on the feedback and lessons learned from experience. A future vision of operational testing based on a system-of-systems approach to replicate the realistic employment of the of operational systems across their life cycles can only be achieved through continuously updated threat models, engineering assumptions, and applied real-world experience.

Additional details, including the study's findings, conclusions, and recommendation, are available in the classified study report.

Appendixes

A

Statement of Task

The Department of Defense operates several ranges across all service branches to test the effectiveness of military systems in the land, sea, air, space, and cyberspace domains. These ranges and infrastructure represent a critical part of the DoD acquisition and systems development process.

The DoD's Office of Test and Evaluation (DOT&E) has asked the Board on Anny Research and Development to assess how effectively these ranges fulfill DOT&E's mission to determine operational effectiveness and lethality of systems currently under development. This study will specifically evaluate whether these ranges are prepared to simulate threats, countermeasures, and operations against near-peer adversaries.

NASEM will convene an ad hoc committee to assess the operational suitability of the Department of Defense's (DoD) ranges, infrastructures, and tools used for the test and evaluation (T&E) of military systems' operational effectiveness, suitability, survivability, and lethality across all domains (land, sea, air, space, and cyberspace).

Specifically, the committee will:

1. Assess the aggregate suitability of ranges to incorporate Scientific and Technical Intelligence (S&TI) for threat and threat countermeasure replication, their capacity for realistic weapons testing and evaluation, and their autonomous testing capabilities.
2. Assess the adequacy of ranges, infrastructure, and tools, on land, at sea, in the air, in space and in cyberspace, to accommodate future technologies anticipated to arrive between now and 2035. These technologies include, but are not necessarily limited to: Directed energy, hypersonic systems, autonomous systems, artificial intelligence, space systems and threats, 6th generation aircraft, advanced acoustic and non-acoustic technologies for undersea warfare, and advanced active electronic warfare/cyber capabilities.
3. Evaluate a cross-section of ranges across the domains to assess their aggregate ability to simulate, test, and evaluate threats and countermeasures (through an appropriate combination of modeling & simulation, experiment, and physical testing) that sufficiently represents adversary capabilities.
4. For each area discussed above, the committee will recommend how the DoD can address, and/or mitigate, any existing or anticipated deficiencies.

B

Biographies of Committee Members

HEIDI C. PERRY, *Chair*, is the chief technology officer at the Massachusetts Institute of Technology (MIT) Lincoln Laboratory. She previously held the position of assistant head of the Air, Missile, and Maritime Defense Technology Division, where she focused on enhancing the division's efforts to develop advanced naval undersea and surface fleet systems and technology. She joined Lincoln Laboratory as a principal staff member in that division in September 2018. Ms. Perry joined Lincoln Laboratory after 23 years at Draper Laboratory, where she most recently served as director of systems engineering and oversaw approximately 300 staff supporting Draper's programs in strategic systems, space, defense, biomedical, special operations, and energy systems. She was responsible for Draper's strategy and execution for technology development in guidance, navigation, and control systems; autonomous systems; communication systems; modeling and simulation; human-machine cognitive systems; and biomedical systems. She has also served in many project leadership roles at Draper and in previous assignments at IBM Federal Systems as an avionics engineer and at General Electric as a systems engineer on the AN/BSY-2 submarine combat system. Ms. Perry has also been affiliated for more than 11 years with the National Academies of Sciences, Engineering, and Medicine, including being a long-standing participant in their Naval Studies Board. She was the co-chair for the Naval Studies Board investigation into mainstreaming unmanned undersea vehicles. She was appointed as the chair of the National Academies of Science, Engineering, and Medicine's Transportation Research Board committee for the Update of the National Naval Responsibility for Naval Engineering project. Ms. Perry received a B.S. in electrical engineering from Cornell University in Ithaca, New York, and an M.S. in computer engineering from the National Technological University in Fort Collins, Colorado.

KEVIN G. BOWCUTT is a senior technical fellow and chief scientist of Hypersonics with the Boeing Corporation, in Long Beach, California. Dr. Bowcutt has been with Boeing (formerly Rockwell International, North American Aircraft) since 1986 and was named a senior technical fellow by Boeing in 1998. Much of his professional career has involved research in and development of air breathing hypersonic vehicles, including missiles, aircraft and space launch vehicles. In 2015, Dr. Bowcutt was named to the National Academy of Engineering (NAE) for development and demonstration of air-breathing hypersonic vehicles and the implementation of design optimization methods. In addition, he is an American Institute of Aeronautics and Astronautics (AIAA) fellow and a fellow of the Royal Aeronautical Society. Notable accomplishments include developing the modem viscous optimized hypersonic wave rider; serving in technical leader ship roles on the National Aero Space Plane program; leading a project to flight test scramjet engines by launching them from a light gas gun; originating the concept and optimizing the design of the U.S. Air Force/Defense Advanced Research Projects Agency X 51A scramjet powered wave rider vehicle; leading a team that designed an air breathing reusable launch vehicle concept; and working on the space shuttle *Columbia* accident investigation, simulating wing aero thermal structural failure.

COL (RET.) KATHERINE J. GRAEF is a retired U.S. Army officer with 30 years of experience in a variety of leadership and staff positions, including senior command and three combat deployments. She is a distinguished military graduate of the University of Texas at Austin where she earned a degree in classical archaeology. COL Graef holds three master's degrees, is certified as a Demonstrated Master Logistician by the International Society of Logistics and is also an inaugural member of the Halifax International Security Forum Peace with Women Fellowship. The second half of her career was almost entirely joint, including assignments to U.S. Strategic Command as a J4 and sustainment chief focused on eliminating weapons of mass destruction, and to the U.S. Naval War College as a military professor in the Joint Military Operations department. Her final assignment before retirement was as the logistics director and Army element commander for Special Operations Command Africa, headquartered in Stuttgart, Germany. She possesses extensive experience in the Middle East, Europe, and sub-Saharan Africa with some experience on the Korean Peninsula.

CONRAD J. GRANT became the inaugural chief engineer of the Johns Hopkins University (JHU) Applied Physics Laboratory (APL) on August 22, 2016. As chief engineer, Mr. Grant works with engineers and scientists across APL and throughout the nation's research and development (R&D) community to explore innovative approaches and technical concepts that will better position APL's contributions with future challenges. As the nation's largest University Affiliated Research Center, APL performs research and development on behalf of the Department of Defense (DoD), the Intelligence Community, the National Aeronautics and Space Administration, and other federal agencies. The laboratory has more than 8,000 staff members who are making critical contributions to a wide variety of nationally and globally significant technical and scientific challenges. Prior to this appointment, he served as the head of the Air and Missile Defense Sector at APL since 2005. Mr. Grant has extensive experience in the application of systems engineering to the design, development, test and evaluation, and fielding of complex systems involving multisensor integration, command and control, human-machine interfaces, and guidance and control systems. Mr. Grant's engineering leadership in APL prototype systems for the Navy is now evidenced by capabilities on board over 100 cruisers, destroyers, and aircraft carriers of the U.S. Navy and its Allies. Mr. Grant began his career with APL developing human-machine interactive systems for Navy command and control and served as the technical lead for the analysis, design, rapid prototyping and testing of network based command and control systems in large-scale at-sea tests that proved out advanced capabilities, leading to rapid fielding in operational systems. He has since led development efforts in almost all aspects of Navy and Missile Defense Agency combat and weapon systems. He has served on national committees including as a technical advisor on studies for the Naval Studies Board of the National Academies as well as membership on the U.S. Strategic Command Senior Advisory Group. He is a member of the program committees for the Department of Electrical and Computer Engineering and the Engineering for Professionals Systems Engineering Program of the JHU Whiting School of Engineering. Mr. Grant earned a B.S. in physics from the University of Maryland, College Park, and an M.S. in applied physics and an M.S. in computer science from JHU.

EDWARD R. GREER is the former Deputy Assistant Secretary of Defense for Developmental Test and Evaluation. He served as the MIL Corporation (MILCORP) chief operating officer (COO) for the DoD Business Unit from July 2018 through September 2020. Prior to serving as COO, Mr. Greer served as the chief executive officer (CEO) of Greer Consulting, LLC, from December 2015 through June 2018 supporting various customers throughout industry and government. He served as the MILCORP COO from January 2013 through October 2015. Mr. Greer served as the Deputy Assistant Secretary of Defense for Developmental Test and Evaluation (DT&E) being sworn in March 2010. He also served concurrently as director, Test Resource Management Center. Prior to his political appointment and since 2002, Mr. Greer served as the deputy assistant commander for test and evaluation, Naval Air Systems Command, Patuxent River, Maryland. He also served concurrently as the executive director, Naval Air Warfare Center Aircraft Division (NAWCAD). In 1998, Mr. Greer joined the Senior Executive Service as director of the Atlantic Test Ranges and Facilities within NAWCAD. From 1995 to 1998, he served as principal deputy program manager for the E-6B Aircraft.

LT. GEN. (RET.) MICHAEL A. HAMEL is an independent consultant, is a space professional and leader, with a career in government and industry spanning over 40 years. He has diverse experience in all aspects of space policy, planning, development, and operations—including launch, satellite, ground, and integration programs. His experience has included senior leadership roles in the military space sector, as well as work in intelligence, civil and commercial/international space. Most recently, Gen. Hamel served in Lockheed Martin Space, both as vice president and general manager of commercial space and country executive for the Kingdom of Saudi Arabia. In these roles, he was responsible for all commercial space business including communication and remote sensing programs, and new product development beginning in November 2013. In January 2017, Gen. Hamel became responsible for developing new business opportunities with the Kingdom of Saudi Arabia, including joint and in-country ventures. He retired from Lockheed Martin in August 2018. Prior to that employment, Gen. Hamel served as senior vice president of corporate strategy and relations for Orbital Sciences Corporation, where he was responsible for leading Orbital Science's strategic planning, product and business development, government relations, and corporate communications. Gen. Hamel served in the U.S. Air Force for more than 30 years in a broad range of space operations, development, acquisition, policy, and command positions, concluding his military career in 2008 as a Lieutenant General. In his later years in the Air Force, Gen. Hamel was commander of the Air Force Space and Missile Systems Center and Air Force program executive officer for space and commander of the 14th Air Force. He served in senior command and staff positions at U.S. Air Force Headquarters and Air Force Space Command and was military advisor to the vice president on defense, arms control, non-proliferation, and space policy. Gen. Hamel holds a bachelor's degree in aeronautical engineering from the U.S. Air Force Academy and a master's degree in business administration from California State University. He is a graduate of the Industrial College of the Armed Forces and the program in national and international security at Harvard University. He is a member of the Council on Foreign Relations and a follow of the AIAA. He also serves on the boards of several corporate and advisory groups.

DANA "KEOKI" JACKSON is senior vice president and general manager, MITRE National Security Sector. In this role, he is responsible for the strategic growth and execution of MITRE's national security programs, including support to DoD, the Department of Justice, and the Intelligence Community. He also leads the National Security Engineering Center. After more than two decades at Lockheed Martin, Dr. Jackson brings robust technical leadership and business experience, including directly contributing to the design, development, deployment, and flight operation of major national security spacecraft and programs. He also held management roles on the GPS III position, navigation, and timing program, and the Space-based Infrared System missile warning program. Dr. Jackson held several executive and senior management roles at Lockheed Martin, including chief technology officer and chief engineer, and vice president of engineering and program operations. He most recently served as vice president of supply chain and program performance and was responsible for program and supply chain management strategy, execution, and success across the enterprise. Before joining Lockheed Martin, Dr. Jackson was a NASA research fellow at the MIT in the field of human adaptation to the space environment. He is a fellow of the United Kingdom Royal Aeronautical Society and the AIAA. He is a member of the NAE, Sigma Xi, the International Academy of Astronautics, and the Institute of Electrical and Electronics Engineers. He previously served on the Sandia Corporation board of directors, the AIAA Foundation board of trustees, the Georgia Institute of Technology president's advisory board, the University of Maryland Clark School of Engineering board of visitors, and the MIT Department of Aeronautics and Astronautics visiting committee.

TERRY P. LEWIS is a senior associate and senior technical program manager at Booz Allen Hamilton where he is the chief engineer for electronic warfare. He recently served as the U2-Dragon Lady technical director at Beale Air Force Base. Previously, he was a senior program manager and off-site executive for the Raytheon Company, where he led an organization focused on radio frequency engineering, reverse engineering, cyber technology development (offensive and defensive), rapid prototyping, and system development. He had responsibility for portfolio management and profit and loss. Dr. Lewis's areas of expertise include command, control, communications, and information systems; intelligence, surveillance and reconnaissance collection and dissemination; digitized battlespace systems; COMSEC I TRANSEC security for tactical systems; wireless network security; and network management authentication techniques for robust security architectures and key management. Dr. Lewis is an anti-tamper technologies pioneer and has developed architectures to prevent or reduce the ability of potential aggressors to reverse-engineer critical U.S. information technologies. He led an agile group of engineers focused on information operations (cyber applications) as they related to signal processing and embedded systems. Dr. Lewis has experience working on various missile systems while at Hughes Aircraft (later purchased by Raytheon). He was a Raytheon scholar and received the Most Promising Engineer of the Year Award conferred at the 2002 Black Engineer of the Year Award Conference. Dr. Lewis has been an executive board member of the National Academies Naval Studies Board and has served on multiple boards and participated in a multitude of committees and workshops for the National Academies, including the Committee on Distributed Remote Sensing for Anti-Submarine Warfare, the Committee on Optimizing the Air Force Acquisition Strategy of Secure and Reliable Electronics Components, and Committee for a Review of USN Cyber Defense Capabilities, and various Army Research Laboratory assessments. Dr. Lewis received an associate degree in pre-engineering from Queensborough Community College (1990), BEEE (1994) and the MEEE (1996) degrees from the City College of New York, and a Ph.D. in electrical engineering systems (2012) from the Communications Sciences Institute at the University of Southern California.

LTC (RET.) ALBERT A. SCIARRETTA, PE, is president of and sole performer within CNS Technologies, Inc. He established this company in 1999 and works primarily as an independent consultant to various organizations. For almost 40 years, as a U.S. Army officer (retired as a Lieutenant Colonel) and civilian contractor, he has used his operational, research and development, operations research, prototyping and experimentation, mechanical engineering, and human performance assessment experience to assess the military benefits of technologies and develop technology investment strategies. As a consultant to the DoD Test Resource Management Center (TRMC), he has served more than 18 years as a subject matter expert for advanced test technologies. Currently, he is assisting TRMC in identifying test range infrastructure needs for testing counter-small aircraft system (C-sUAS) systems. In another consulting job, the U.S. Bureau of Prisons has asked Mr. Sciarretta to design and execute two tests at federal correctional complexes: (1) a test of commercial C-sUAS systems and (2) a test of commercial devices designed to use ad tech to remotely detect cell phones. Mr. Sciarretta is the chair of the ASA(ALT) Board on Army ROT&E, System Acquisition, and Logistics; as well as a member of the National Academies Board on Army Research and Development and the Intelligence Science and Technology Experts Group. He previously served as a member of the Board on Army Science and Technology. In the past, he chaired the 2017 ad hoc study on "Counter-Unmanned Aircraft System (CUAS) Capability for Battalion-and-Below Operations" He has also served as a committee member for six separate National Academies studies, including "Technology Development for Army Unmanned Ground Vehicle," "Advanced Energetic Materials," and "Making the Soldier Decisive on Future Battlefields." Mr. Sciarretta served as a part-time contractor and then Special Government Employee (Highly Qualified Expert) in a think tank at the National Defense University from 2004 to 2017. In addition to conducting studies, he developed a course on prototyping and experimentation that was eventually incorporated into the Defense Acquisition University curriculum. For his first 7 years in the Army, Mr. Sciarretta served primarily in armored cavalry units. For the following 13 years, Mr. Sciarretta received advanced degrees, taught engineering and operations research at the U.S. Military Academy (1984-1987), and conducted individual research efforts for Army program managers for Mobile Protected Gun System, Howitzer Improvement Program, and Electromagnetic Railgun. He also served as technology officer in the Armored Family of Vehicles Task Force, military assistant chief scientist in Army Materiel Command, and chief technology officer in the Army MANPRINT Office. Mr. Sciarretta has a B.S. degree in general engineering from the U.S. Military Academy (1973), and dual M.S. degrees in mechanical engineering and operations research from Stanford University (1982-1984). He completed a 1-year British military school undergraduate course on designing armored vehicles (1981) and a 6-month DoD program manager course (1982).