



17th Annual Verification and Validation Summit *"Enabling Dynamic Innovation with Rigor"*

2022 Event Record

The 17th Annual Verification and Validation (V&V) Summit was held virtually in 2022 on September 21 and September 22 (8:30 a.m.–12:30 p.m.), with 260 people in attendance across both days. The V&V Strategies and Practices Branch conducted the event from the National Aerospace Research and Technology Park (NARTP) in a hybrid format with some in-person attendees at NARTP and others participating remotely via Zoom. V&V Strategies and Practices Branch Manager John Frederick organized the summit along with summit coordinator Wanda Lopez-LaBarbera. Speakers and presentations delved into concepts, strategies, and proven methods addressing the summit's theme: "Enabling Dynamic Innovation with Rigor."

The event was sponsored by the Federal Aviation Administration (FAA) William J. Hughes Technical Center (WJHTC) and featured speakers from government, industry, and academia. Presentations, discussions, informational videos, and interactive surveys addressed the summit's theme, "Enabling Dynamic Innovation with Rigor," and the challenges of innovating with agility at the pace of technology, while ensuring that mission-critical systems and services are safe, effective, and secure. There were 15 speakers from:

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- FAA
- United States Space Force (USSF)
- United States Air Force (USAF)
- Department of Defense (DoD)
- National Aeronautics and Space Administration (NASA)
- Carnegie Mellon University (CMU) Software Engineering Institute (SEI)
- Stevens Institute of Technology
- Verizon
- Science Applications International Corporation (SAIC)

The V&V Summit presentations addressed topics that included:

- Preparing Space Force for the future
- Challenges in commercial space transportation research and development
- Calibrated trust versus blind faith
- Urban Air Mobility (UAM) roadmap
- Incremental assurance of critical software systems

- Frameworks and measures for dynamic innovation with rigor
- Artificial Intelligence (AI)
- Accountable agility
- Defining digital twins in the real world
- Adapting to change while preserving rigor

To provide additional insight and foster understanding, the following videos were shown: *The Importance of Mistakes by John Cleese* (Holey and Moley Motion Graphics Company), *DoD Acquisition Revolution* (Airman Magazine), *Air Force Operational Test and Evaluation Center (AFOTEC)* (Airman Magazine), and *Ameca and the Most Realistic AI Robots* (Digital Engine). Throughout the summit, Angela Moore of the V&V Strategies and Practices Branch moderated several virtual interactive surveys to gauge how participants viewed the theme.

The following lists the 14 distinguished speakers and a summary of their presentation:

Day 1 —

• John Frederick, Manager, V&V Strategies and Practices Branch, FAA, welcomed attendees to the 17th Annual V&V Summit and introduced the theme of "Enabling Dynamic Innovation with Rigor." He said the summit was being held in a hybrid format with some presenters and attendees in person and others connecting via Zoom. He reviewed the summit agenda, presentations and surveys, and solicited feedback at the summit website.

Mr. Frederick said that the need to adopt agile principles and practices is driven by the speed of technological development and the velocity of obsolescence. Computer processing speed now doubles approximately every 18 months, and digital innovation spurred by the COVID-19 pandemic has put AI and analytics at the center of business operations. Ninety-seven percent of enterprises say it is essential to have mature processes to deploy and operationalize Machine Learning (ML). Mr. Frederick said Agile is about thinking big and acting small, failing fast and learning rapidly, learning along the way and being smarter when you are ready to deploy. Agile acquisition practices narrow the cone of uncertainty and stress staying on target and on time. Agile embraces the idea that you won't know much at the beginning of a project, so that is not the time to lock in scope and requirements. Successful agile acquisition delivers what you really need instead of what you thought you needed.

Mr. Frederick said V&V summits are intended as forums for knowledge convergence with a focus on new concepts and improved perceptions. He used the digital computer as an example, saying all the necessary knowledge to build such a computer was available in 1918 but an operational model didn't appear until 1946. Innovation is both conceptual and perceptual, and would-be innovators must go out and look, ask, and listen.

• Eric Neiderman, Deputy Director, WJHTC, FAA, greeted attendees and thanked Mr. Frederick and the V&V Strategies and Practices Branch for organizing the summit. He said the WJHTC is the FAA's premier air traffic systems laboratory, providing research and development, test and evaluation, V&V, and sustainment of aviation systems. Its employees support the evolution of new ideas by applying conventional and cutting-edge practices. He said V&V ensures the highest standards of safety, security, efficiency, and suitability.

Mr. Neiderman said aviation is currently in its third revolution, with the growing importance of autonomy, AI and ML, "Big Data," cybersecurity, and electronically enabled aircraft. This revolution involves the use of advanced propulsion, composite materials, and supersonic commercial aircraft, as well as additive manufacturing, drones, and other

robotics. He said the third revolution in aviation also values sustainability and carbonneutral platforms. Now more than ever, rigorous V&V will be essential for enterprises to keep up with the accelerated pace of investment and increased global competition. It is critical that V&V shift left and that teams push the envelope toward developing minimal viable products (MVPs) on a faster timeline while maintaining the proper balance of innovation and rigor.

Nackieb Kamin, Program Manager, Science, Technology and Research Directorate, USSF, spoke about the critical role of science and technology in the current security environment. He said the United States fundamentally depends on space technology today, and has seen competitors like China continue to pursue space dominance with a willingness to deploy kinetic capabilities such as anti-satellite weapons. USSF was established to counter strategic competition and threats in space, and monitor the growing number of space missions and expanding commercial space investments.

Mr. Kamin said USSF has partnered with multiple universities through Strategic Technology Institutes (STIs) to define space-based applications and applied research, develop prototypes, and review experiments and data. It is formalizing partnerships with the USAF, NASA, and the Department of Commerce to study advanced concepts and improve space situational awareness. USSF is also working with international allies through the DoD and Department of State, he said. Mr. Kamin said he would also like to get the FAA involved to formalize a V&V model.

By 2030, the space economy will be worth more than \$1 trillion, Mr. Kamin said, and the buildup of domain congestion will create a challenge in identifying and tracking objects in orbit. USSF is working to expand its tracking capabilities, develop its force design, and forecast needs beyond the next 20 years. He said futurists of the past like Jules Verne and Arthur C. Clarke once predicted humans would travel to the moon, but that was perceived as impossible. USSF has to look outside the box at things that appear beyond the possible, he said.

• Angela Moore (Summit Day 1 and Day 2), Program Analyst, V&V Strategies and Practices Branch, LS Technologies, conducted three interactive activities over the course of both days. Using the Vevox application, she polled participants on numerous topics and offered extemporaneous analysis of some results, which were displayed in real-time as word clouds, charts, and graphs.

The questions covered: the attendees' professional affiliation, what V&V super power they would want, common barriers to innovation, at what point in the V&V process are system problems or defects found, and why "Agile" is important to innovation.

Responses indicated there were attendees from government, including FAA, NASA, DoD, and other agencies; nonprofits, academia, and private industry. Most respondents said they would choose seeing into the future as their super power. Such powers would allow people to "reverse engineer" what is known to work in the future.

Respondents listed common barriers to innovation such as funding, ego, politics, fear, complacency, communication, and resistance to change, among many others. Ms. Moore

said current structures such as contract types, traditional development methods, and organizational silos may prevent an environment where ideas and people are free to brainstorm, build, fail, learn, adjust, and repeat without fear from punishment, loss of prestige/respect, withholding of funds, or other negative outcomes.

Most respondents said that system problems or defects are found on the right side of the V&V process, or Vee Model, when they are more expensive to fix. Pushing those discoveries to the left will save money and potentially deliver a better product.

Finally, most respondents said Agile is "continuous collaboration," "being responsive to requirement changes," and "working smarter."

• Brian Rushforth, Manager, Innovation Division, FAA, spoke about challenges in commercial space research and development. His division helps encourage, facilitate, and promote commercial spaceflight with a focus on the safety of the uninvolved public. The Innovation Division liaises with commercial applicants but the FAA does not certify pilots, crew members, or space vehicles due to the Human Spaceflight Moratorium. The moratorium is set to lapse in October 2023 if Congress does not approve an extension, Mr. Rushforth said, but its effect has been pronounced. The moratorium created a learning period for commercial spaceflight and has led to several years of exponential growth similar to the 1920s–40s in the aviation industry. The industry faces several ambiguities in the future, such as the Outer Space Treaty of 1967 and the complexities of Space Traffic Management. The Department of Commerce currently has authority over Space Traffic Management, he said, but no budget for it.

Mr. Rushforth said the motto of the commercial space industry now is "Fail forward fast." There is a lot of proprietary research being done by private industry but they don't share it or make it public. Still, 70 percent of space launches take place at Cape Canaveral, Florida and an even greater majority take place at federal ranges. The FAA's Office of Commercial Space Transportation (AST) has worked with a consortium of universities across the country to leverage almost \$6 million in research and development funding. Mr. Rushforth said AST is focused on four research areas: 1) aerospace access and operations, 2) aerospace vehicles, 3) human operations and spaceflight, and 4) industry innovation. That research includes LOX/Methane propulsion systems, human space flight, orbital debris mitigation, and vehicle/occupant safety. The research alliance is modeled on the Department of Energy's program, and includes academia, government, and industry.

The future of the commercial space industry involves integrating launches into the National Airspace System (NAS). Currently, space launches cause less than 0.5 percent of flight delays, he said. Mr. Rushforth said AST is developing a Space Data Integrator prototype and coordinating with the FAA's Air Traffic Organization (ATO) to continue looking at tracking launches and how to develop hazard areas in the event of a mishap.

• Colonel Daniel Javorsek, Commander, Detachment 6, AFOTEC, Nellis Air Force Base, and Director, F-35 U.S. Operational Test Team, spoke about calibrated trust versus blind faith in testing AI- and ML-powered emerging aviation technologies. He said we are currently at the start of what he called the "Augmented Age," which would be enabled by software-defined systems augmenting human decisions. How many people consider

themselves to be augmented cyborgs? Probably not many, but Col. Javorsek said that is what we're becoming in the 21st Century through the use of smart devices. It is now second nature to use our cell phones for many different tasks, he said. Pilots now strap themselves into what can be best described as flying supercomputers, Col. Javorsek said. Such systems redistribute the cognitive workload, he said, including in the cockpit.

Col. Javorsek described the history of AI, starting with the first wave of AI using handcrafted knowledge rules. These proved to be very brittle, since there is an exception to every rule. The second wave of AI used more structural learning and was more biologically inspired, with neural networks that bear a resemblance to the human brain. By 2010, this type of AI had made remarkable advances in facial recognition, self-driving cars, and digital assistants like Apple's Siri. But these AI systems are not able to explain their decisions, Col. Javorsek said. They really don't learn once their training is complete, and over time they fall out of line. But that is slowly changing, he said, and we might be on the verge of a third wave of AI. This wave would see AI systems build explanatory models themselves and use reinforcement learning.

Col. Javorsek said AI can be applied to air combat problems and maneuvers. ML or neural networks manipulate data, stretching and squashing data space until the many manifolds are clearly separated. He said these systems are astonishingly powerful, but they do nothing without explicit instructions. The current toolbox is still primitive, showing great success in narrow aspects but struggling with general applications. The challenge for future AI is to move from Spock to Captain Kirk—from pure logic to more intuition. Intuition is what war fighters use in combat, Col. Javorsek said, with decisions arrived at in a split second. He likened future AI to training a horse, which has its own mind. Relationships with AI will have to be based on performance and trust, he said. Testing AI systems will have to take that into consideration, akin to biological systems. Col. Javorsek said that once you feel comfortable enough with a system, you have to let it perform. It's a question of balancing over trusting the agent versus under trusting.

AI use in air combat will require a change at the organizational and cultural level too, Col. Javorsek said. The move from horse-mounted cavalry to mechanized divisions was difficult because it threatened the values, dignity, and honor of established forces. He said automatic ground avoidance systems in fighter jets were implemented in 2014 though the technology was available in the 1980s. Other programs like "Death Claw," a gun targeting system, and Alpha Dogfight, an AI agent for dog fighting simulations, have shown super-human performance in specialized tasks. Continual V&V will help verify AI performance while building trust, he said. Lethal combat employment will keep humans in the loop for the foreseeable future, however. Col. Javorsek said it will be a long time before the U.S. military changes its perspective on that due to moral, ethical, and legal reasons.

• Dr. Ian Levitt, Principal Engineer, Air Traffic Management eXploration (ATM-X) UAM Airspace Subproject, NASA, spoke about developing a research roadmap for UAM airspace. He said the roadmap is a living document that describes how research informs the progression of complex system capabilities by way of high-level requirements, assumptions, and constraints. The name can be a misnomer, he said, because it does not use time frames and can include contradictions found in research.

Dr. Levitt said work on UAM is aimed to provide more transportation access to more people, from small package delivery drones to air taxis operating above populated areas. NASA produced a technical memo in October 2021 and began collaborating with the FAA that same year. That baseline document will be used for System Engineering, and will be informed by community input as it is matured. NASA is also working with the WJHTC to create a mature sandbox environment around Atlantic City. The aim is to take the UAM prototype and integrate it with operations out of the Atlantic City International Airport, assessing capabilities and integrating UAM and non-UAM traffic. Key objectives include accelerating operationalization; evaluating and exploring air traffic management, flight crew, and operator functions; and identifying barriers associated with minimum controllable airspeed and instrument meteorological conditions (IMC).

Dr. Levitt said the process is iterative and agile, involving a continuous process of requirements discovery and research system test and evaluation (T&E). The agile process should add rigor, which can easily be lacking. That is important, he said, because the team is starting to apply AI and ML to testing. Automated techniques can be applied to extract useful information and drive research, he said. Dr. Levitt said a baseline UAM Airspace Research Roadmap version 2.0 should be ready in January 2023.

Day 2 —

• Nathan Tash, Deputy Assistant Administrator, Acquisition and Business Services (ACQ-001), and Chief Acquisition Officer, FAA, spoke about accountable agility. He said there is a question of how to define success when using agile practices. What is the baseline? What's the schedule? How do we know when we are done?

Mr. Tash said traditional development programs come before the Joint Resources Council (JRC) in a way that is known and comfortable. They request an amount of money over a given amount of time and promise to deliver a system or service. There are defined milestones and decision points that people can plan toward. Requirements lead to specifications, which lead to a test plan. The test plan generally equates to success, he said. Mr. Tash said the Acquisition Management System (AMS) allows for flexibility when needed. He called it a laborious process, but said people are generally satisfied when it is complete.

Mr. Tash concluded his presentation by offering some open questions to the audience. He asked if agile practices create the same basic level of user acceptance as traditional development practices, and how requirement changes are managed in an agile environment. Is there some level of agility that can be allowed while still maintaining the traditional process? He asked who takes the risk in an agile process—the government or the contractor? How does Agile define success so that the contractor can build to the test plan and does that require different contract types? Mr. Tash said he will remain somewhat skeptical of agile development until these questions can be answered.

• William S. Hayes, Principal Engineer, CMU SEI, said he leads the Agile Transformation Team at CMU SEI where they look at the lessons from Agile success stories and how to translate them into standard practices. He said one key to agile development is asking very good questions early on, which allows a team to build viability into the system. He said

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agile practitioners have to assess outcomes that may not necessarily be part of the plan and want to have permission to change their minds later on.

A key to agile practices is involving and integrating stakeholders into development. The nature of the work is not so deterministic, he said. Data and test results should be available before the deadline so that examination can occur earlier when corrective actions are less expensive to make and options are more varied. The problem is cultural, Mr. Hayes said. Traditional development processes are adamant that a completed system be certified. Agile development is iterative and produces MVPs as part of its assurance process, he said.

Mr. Hayes said agile development does not anticipate a final design, but leaves the opportunity open to have a better system at the end. Abstractions of the product may not all be deliverable components. Agile practitioners must incrementally assure viability, which requires knowledge of the system, how it will be used, and the domain in which it will be used. For systems engineering cases, perfect can be the enemy of good enough, he said. A good process and work flow is essential to a successful program. Stakeholder feedback has to be a continual process and not just a gate that you have to pass through at the end, Mr. Hayes said. Agile is responsive and a constant process, he said. It is more than just rescheduling testing earlier in time.

• William D. Miller, Adjunct Professor, School of Systems and Enterprises, Stevens Institute of Technology, said that the theme of this year's summit, "Enabling Dynamic Innovation with Rigor," can seem like a conundrum. People often think of rigor as requiring time and resources, which seems contrary to innovation, but Mr. Miller said that is not the case. He defined dynamic innovation as a multi-faceted approach with concrete action plans to accelerate synergistic innovation across multiple fields toward a balanced set of dynamic, evolving complex objectives.

Mr. Miller said that we need to be mindful of precision as a key characteristic of rigor in dynamic innovation. What level of precision is acceptable to stakeholders? What frameworks and measures are being used to assess how a program is doing? The Systems Engineering Research Center (SERC) uses measures such as Quality, Velocity/Agility, User Experience, Knowledge Transfer, and Adoption, he said. Other measures include product quality and functional correctness, process effectiveness, efficiency, speed, technology effectiveness, and performance. V&V is at the crossroads of dynamic innovation and rigor with needed assessment frameworks and measures, Mr. Miller said.

Mr. Miller said that systems engineering needs to adapt to complex systems. There is a difference between complicated systems, which are decomposable, and complex systems, which are no longer strictly decomposable. Just adding processes is not the right answer, he said. Systems engineering can no longer be primarily concerned with characterizing the interactions between elements, but must understand the dynamic behavior of those interactions. Mr. Miller said an "elegant" system design actually works; is robust and resilient; is efficient; and minimizes unintended actions, side effects, and consequences.

Mr. Miller said V&V faces significant challenges in concurrent technology advances, complexity, scale, interconnections, and uncertainty. He said engineering tools today often lack the power of adequately modeling and predicting interactions within systems of

systems, which results in unplanned and undesired systemic consequences. Early validation and qualification of the system is key in integration, he said. Qualification needs to include V&V of both requirements and the system design, followed by stakeholders' acceptance.

 Jonathan Elliott, Chief of Test and Evaluation, Chief Digital and Artificial Intelligence Office (CDAO), DoD, spoke about the challenge and opportunities in T&E of AI. He said CDAO is tasked with leading and overseeing DoD's strategy development and policy formulation for data, analytics, and AI. AI assurance is an opportunity for asymmetric advantage in the AI arena, he said. DoD does not need to be the fastest, but it should develop fast enough and better. AI assurance provides arguments and evidence to establish trustworthiness and justify confidence, he said. Trust can be a loaded word, he said. Verification should guarantee that the system works when you need it to, but does not need to go beyond that. CDAO's AI Assurance Goal is to provide stakeholders with justified confidence that DoD AI-enabled systems meet requirements and support the mission through ethical action, he said.

Mr. Elliott said DoD must update its T&E process for AI and produce its own solutions. AI is still a nascent field. AI tasks are dynamic and poorly constrained, he said, and success is hard to define or measure. Failures can be catastrophic. Future AI systems could be tasked with operating a driverless vehicle transporting supplies to a forward operating base, dealing with potential attacks, pedestrian traffic, etc. That is a complex environment that AI will have to deal with. Mr. Elliott said DoD must integrate adaptive T&E across the cradle-to-grave system life cycle as it develops AI. Current integration efforts include developing methods to measure, model, and analyze AI system test results; and garnering resources such as test beds, data, computational infrastructure, storage, and automated analyses to enable effective T&E.

Mr. Elliott said the focus needs to be smaller and more frequent. Algorithms should be tested as they are completed in smaller operational tests, he said. That serves as a more frequent "gut check" with reality and builds a larger assurance case. AI T&E will also need to continue through deployment and sustainment as software is continuously updated or possibly learning. Adversaries will also adapt to target system weaknesses, and data drift can degrade performance over time, he said. He said CDAO's goal is to publish an AI best practices guide by next year.

• Aleksai Kac, Head of Engineering, New Business Incubation Team, Verizon; and Robyn Erkelens, Head, New Business Incubation Team, Verizon, spoke about defining digital twins in the physical world. Ms. Erkelens started by defining a digital twin as a virtual representation of an object or system with real-time, bidirectional data flow enabled by AI and ML. A digital twin has the ability to simulate outcomes and make decisions, she said. A user can create scenarios to model ecosystems or whole cities, Ms. Erkelens said, integrating data from many different sources. Over time, digital twins will get smarter.

Ms. Erkelens said one challenge with digital twins is the environment they are built to model. She said Verizon works in a lot of "brownfield" environments that are messy and have lots of manual processes that can create gaps in data. It is a challenge to model them

correctly, she said. But digital twins provide great value for decision-makers, she said. They can accelerate contextual understanding, de-risk process changes, and enable proactive and prescriptive adaptation instead of reactive management.

Mr. Kac said a digital twin is a virtual space that allows users to experiment without risk. It provides human-in-the-loop validation, which increases visibility and confidence, he said. In terms of the NAS, a digital twin could simulate thousands of flights and how those flights affect other flights (e.g., a flight that is diverted because of weather). The digital twin could run through thousands of simulations and provide options to an air traffic controller. Intelligent Agents can evolve through retrospection of human and automated decisions, he said, and as the model learns its outcomes will become more confident, leading to better and earlier decisions. Mr. Kac said the development process involves design-led, agile engineering that includes a team composed of different disciplines working together to identify problems; offer solutions; and then plan, build, and validate proposed solutions. A key to that process is the idea that everyone has a responsibility to listen, learn, and challenge each other throughout.

• Huntley Parker, Solutions Architect and Lean-Agile Coach, SAIC; and Phillip E. Holmer, Chief Engineer/Director, SAIC, spoke about agility as moving quickly and adapting to change while preserving quality and rigor. Mr. Holmer said that agile development is now the standard for information technology (IT) projects. Over 80 percent of major federal IT projects now use Agile, he said. Mr. Parker said Agile is a set of values and principles. In developing software and helping others do the same, SAIC has come to value: 1) individuals and interactions over processes and tools, 2) working software over comprehensive documentation, 3) customer collaboration over contract negotiation, and 4) responding to change over following a plan.

Mr. Parker said that with complex systems and shifting priorities and technologies, an iterative approach to development is best. Agile welcomes change requirements, delivers working software frequently, and organizes teams of highly motivated individuals that are empowered to get work done. By contrasts, waterfall development is a serial process with multiple handoffs between different groups. Components are developed separately and integrated later with testing deferred until the end. Agile should produce fully tested, production-ready code at each iteration, Mr. Parker said. Put another way, Mr. Parker said traditional waterfall development finds bugs, while Agile prevents bugs.

Mr. Parker said organizational culture is the biggest barrier to adoption of agile practices. V&V has to be involved in testing and validating the system as it is being developed, he said. V&V works with the product owner and team in writing acceptance criteria and validating the definition of "done." The majority of testing is automated, he said, with manual tests reserved for critical or exploratory elements. It becomes much more important that the right tests are written and conducted, he said.

The speakers at this year's summit addressed the theme of "Enabling Dynamic Innovation with Rigor" in many different ways. Many of the presentations touched on agile practices and processes. The main takeaways are:

- 1. The need to adopt agile principles and practices is driven by the speed of technological development and the velocity of obsolescence. Agile seeks to narrow the cone of uncertainty by first recognizing that the early stages of an acquisition represent the Point of Maximum Ignorance. Agile then continually performs V&V to support dynamic development and deliver what is really needed (versus what was thought to be needed at the early stages of the acquisition).
- 2. Organizational culture is the biggest barrier to the adoption of agile practices. Traditional development methods and organizational silos may prevent an environment where ideas and people are free to fail, learn, adjust, and repeat without fear from punishment or other negative outcomes.
- 3. The challenge for future AI is to move from pure logic to more intuition. Training AI may be more like training an animal—based on performance and trust. Continual V&V through deployment and sustainment will be needed to verify AI performance and build trust.
- 4. V&V faces significant challenges in concurrent technology advances, complexity, scale, interconnections, and uncertainty. With complex systems and shifting priorities and technologies, an iterative approach to development is best. Stakeholders need to be involved and integrated into development early and often.

All FAA participants who attended both days of this year's summit received FAA electronic Learning Management System (eLMS) credits. V&V Summit feedback forms will be assessed to improve future summits. The 17th Annual V&V Summit presentations, agenda, video, speaker biographies, feedback link, interactive poll results, and more information are located at <u>https://www.faa.gov/about/office_org/headquarters_offices/ang/library/events/v_vsummits/v_vs</u> ummit2022.

Technical Interchange Meeting

An in-person Technical Interchange Meeting (TIM) was conducted on the afternoon of Summit Day 1. The V&V Summit TIM included four brief presentations addressing agile principles and practices, followed by a roundtable dialogue and discussion around the challenges, best practices, useful methods, and lessons learned presented. The V&V Summit polling application tool (previously mentioned) was used during the TIM to spawn interaction, explore key concepts, and gather perceptions of the TIM participants. The V&V Strategies and Practices Branch will publish a white paper detailing presentations, discussions, and findings from the TIM.