18th Annual Verification and Validation Summit

"Convergence: Maximize and Manage"

2023 Event Record

The 18th Annual Verification and Validation (V&V) Summit was held September 27–28 with more than 187 industry, aviation, government, and academia professionals in attendance across both days. The V&V Strategies and Practices Branch (ANG-E5A) conducted the event at Resorts Casino Hotel in Atlantic City, NJ. V&V Strategies and Practices Branch Manager John Frederick organized the summit along with summit coordinator Wanda Lopez-LaBarbera. Speakers and presentations sought to spawn knowledge convergence while fostering divergent thinking with new concepts and improved perceptions and understanding. This was the first in-person V&V Summit since 2019.

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, interactive experiments, and surveys addressed the summit's theme, "Convergence: Maximize and Manage," and the importance of divergence and convergence in the innovation process. The two modes of thinking work together: divergent thinking without convergent thinking isn't actionable, and convergent thinking without divergent thinking is limiting. There were 15 speakers from:

- FAA
- National Aeronautics and Space Administration (NASA)
- Department of Homeland Security (DHS)
- Department of Transportation (DOT)
- U.S. Navy
- U.S. Air Force
- Software Engineering Institute (SEI) Carnegie Mellon University (CMU)
- MITRE
- U.S. National Science Foundation for the Directorate for Technology, Innovation and Partnerships
- Air Academy Associates
- Tavarene Analytics LLC

The V&V Summit presentations addressed topics that included:

- How V&V makes space travel possible
- Changing Test and Evaluation (T&E) paradigms for automatic threat detection
- Delivery of advanced capabilities with tight feedback loops
- V&V of the Joint Simulation Environment (JSE)
- Pitfalls and promise of convergence and innovation
- Safe Machine Learning (ML)
- Convergence of air and surface transportation
- Emerging strategies to identify and resolve cyber vulnerabilities in development
- Urban Air Mobility (UAM) airspace research
- Info-Centric National Airspace System (NAS) validation implications
- Accelerating technology, innovation, and partnerships
- Design of experiments (DOE)

To provide additional insight and foster understanding, the following videos were shown: *Creative Ideas & Divergent Thinking* (Dr. Andrew Huberman), *Agility Prime: The Third Revolution in Aerospace* (U.S. Air Force), and *NSF Convergence Accelerator* (National Science Foundation). Throughout the summit, Angela Moore of the V&V Strategies and Practices Branch and John Frederick moderated several interactive surveys to capture participants' perspectives on the summit theme relating to convergence and divergence.

The following lists the 15 distinguished speakers and a summary of their presentation:

Day 1 —

- John Frederick, Manager, V&V Strategies and Practices Branch, FAA, welcomed attendees to the 18th Annual V&V Summit and introduced the theme of "Convergence: Maximize and Manage." He said this was the first in-person summit since 2019. He reviewed the summit agenda, presentations, and surveys, and said that presentations and videos will be made available on the summit website.

  Mr. Frederick said that convergence is both beneficial and onerous. It is a difficult process, especially when dealing with systems or teams that do not normally work together. The challenge is to find the right balance that maximizes the benefits of convergence—collaboration of people and systems, integration of systems, combined operations and services, unified policies and strategies, new and diverse technologies for new and diverse capabilities—while managing the obstacles.

  Mr. Frederick said that any discussion of convergence must also include divergence. Both are needed for innovation. He likened it to the complementary principles of yin and yang found in ancient Chinese philosophy. He displayed the Double Diamond Model developed by the United Kingdom's Design Council in

2005, which shows the process of exploring an issue more widely or deeply (divergence) and then taking focused action (convergence). The double diamond is a visual representation of the dance between divergence and convergence, similar to yin and yang (see Figure 1).

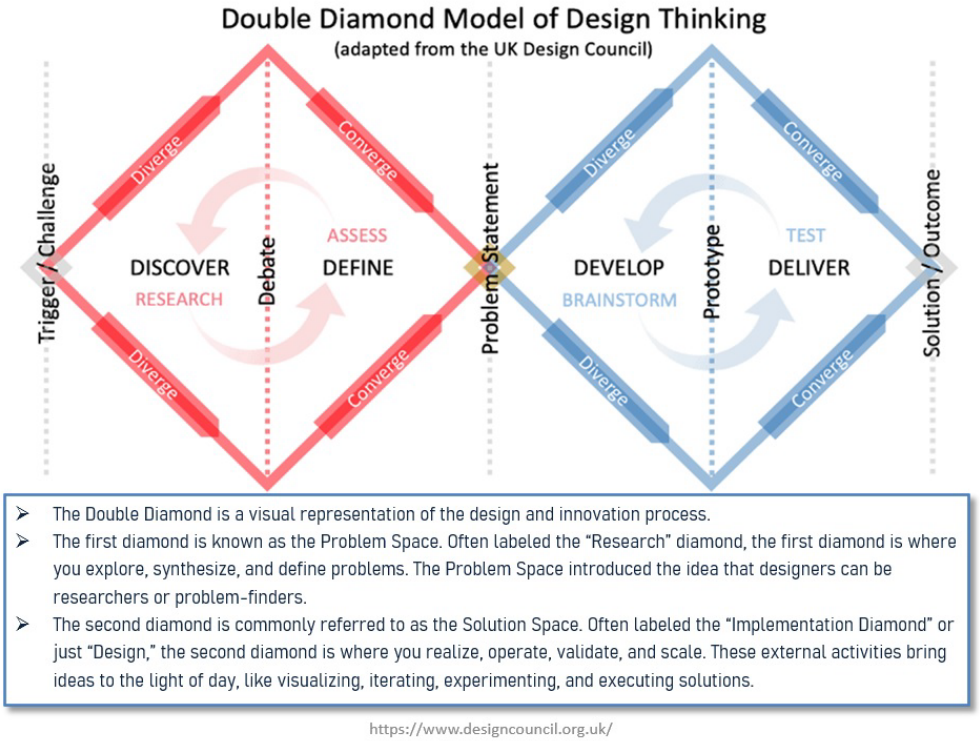

Figure 1. Double Diamond Model (UK Design Council, 2005)

Mr. Frederick said V&V summits are about knowledge convergence with a focus on new concepts and improved perceptions—divergence. He welcomed attendees to open their minds to divergent possibilities and look for opportunities to converge on new concepts and innovative solutions

- Paula Nouragas, Chief Scientist and Technical Advisor, Office of Science and Technology Integration, FAA, thanked Mr. Frederick and the V&V Strategies and Practices Branch for organizing the summit. She welcomed attendees on behalf of Shelley Yak, Director, WJHTC, and Eric Neiderman, Deputy Director, WJHTC.

  Paraphrasing Mihail C. Roco of the National Science Foundation, Ms. Nouragas described convergence as an integration of knowledge, tools, and all relevant human activities toward a common goal. She said employees of the WJHTC have a common goal of building a more robust and safe aviation system. Technologies, systems, and applications are converging to create advancements such as smart planes, new flight documentation and management tasks, NAS modernization, safe integration of unmanned aerial vehicles [e.g., UAM and Advanced Air Mobility (AAM)], electric vertical takeoff and landing vehicles, Artificial Intelligence (AI), and

ML. Convergence in practice at the WJHTC spurs innovation, consolidates function, helps reduces costs, presents solutions, and advances its mission to sustain the safest, most efficient NAS in the world.

Ms. Nouragas said divergent thinking—the yang to convergence's yin—helps as well. Convergence often works best in concert with divergence: its more spontaneous, free-flowing, non-linear complement. Divergence explores many possible solutions in a short amount of time, and often draws out unexpected connections. Together, convergence and divergence lead to extraordinary outcomes.

- Scott "Scooter" Altman, Senior Vice President, Civil Operations, ASRC Federal Engineering, Aerospace and Missions Systems, is a former NASA astronaut and retired U.S. Navy captain. He said he began his flying career in 1979, so he has been a long time user of the NAS. Mr. Altman has logged more than 7,000 flight hours in over 40 types of aircraft and is a veteran of four space flights, spending more than 51 days in space and commanding the final two servicing missions to the Hubble Space Telescope.

  Mr. Altman said he was inspired to fly by the television series "Sky King." But when he tried to become a pilot in the Air Force, he was told he was too tall. He decided to study aeronautical engineering and only later learned that the Navy's height standards allowed for a taller pilot than the Air Force, so he decided to fly for the Navy. He said there is always another way to get where you want to go.

  Mr. Altman became a test pilot and worked as an advisor and stunt pilot on the movie "Top Gun." He later joined NASA and was a space shuttle commander during missions to the Hubble Space Telescope. He described the process of repairing the telescope while in space: developing plans and training on custom-built tools while reacting to unexpected obstacles. There were many challenges and emergencies along the way. He said it took a team of diverse people coming together (i.e., convergence) to accomplish the mission. There was a commitment to a common goal, teamwork and support, communication, preparation, and imagination. Working together, he said, we can reach for the stars.

- Angela Moore, Program Analyst, V&V Strategies and Practices Branch, LS Technologies, conducted two interactive activities on Day 1. Using the Zoom application, she polled participants on topics and offered analysis of results with John Frederick. Approximately 100 people took part in the activities.

  Attendees were asked where they would place themselves on a scale of 1 to 5 measuring creativity and logic when problem solving and/or innovating. Almost 50 percent of attendees defined convergence as "combining knowledge and understanding to create a new capability for innovation." When asked what type of convergence they mainly encounter at work, 32 percent of attendees said Organizational (i.e., integrating employees from organizations to optimally their skills and experience) while 24 percent said Intellectual (i.e., utilizing knowledge from different fields to innovate). A large majority of attendees defined the synergy

between convergent and divergent processes as a mixture of discovering an issue, defining the issue, developing a solution, and delivering the solution; and knowing when to stop being divergent and start moving toward convergent solutions.

Almost 50 percent of attendees said the biggest roadblock to group convergence for problem solving and innovation is "a lack of trust or communication." Approximately 17 percent voted for "staying focused on project scope" and another 17 percent voted for "differing perspectives." Forty percent said the greatest accelerator for group convergence is a "well organized and managed cohort and collaborative groups."

- Christopher Smith, PhD, Director, Transportation Security Laboratory, Science and Technology Directorate, DHS, discussed the security of aviation and the T&E of automatic threat detection systems. He said a lot of work is being done to develop ML algorithms, which outperform basic heuristic algorithms. These ML algorithms require orders of magnitude more data, however.

  Currently, the Transportation Security Administration (TSA) uses X-rays and millimeter wave systems to detect threats in passenger bags and passengers, respectively. Millimeter wave scans are never viewed by TSA officers. Instead, Automatic Threat Recognition (ATR) software uses a cartoon figure to show where undivested items are located on a passenger's body. Transportation Security Officers (TSOs) only examine computerized tomography (CT) scans for prohibited items. Dr. Smith said the TSA aims to have ATR take over the screening function entirely so that TSO's responsibility becomes exclusively alarm resolution.

  In order to train ML algorithms to detect existing and potential threats, however, developers will need an abundance of high-quality data. Dr. Smith said it is a challenge to find enough representative threat data. Developers cannot afford hundreds of thousands of data points, he said, so synthetic data is being considered. But how do you trust synthetic data? How will it be validated so that new software can be certified?

  Dr. Smith said the traditional, sequential development process in which the vendor develops and the test team performs testing until requirements are met may not work for ML algorithms. He said the TSA needs to be integrated with the vendor, Research and Development (R&D), and T&E from the start so that they can work as a group to build requirements, characterize systems, and develop and assess tools.

- Robin Yeman, Space Domain Lead, SEI CMU, discussed the importance of tight feedback loops and iterative processes for digital engineering. She said Agile, DevOps, and ML tools have to come together to build systems quicker with improved quality. Agile development, as opposed to traditional waterfall development, does not mean steps can be skipped. All the work is still being done; it is just being done differently. She referenced computer scientist Winston Royce's definition of the "waterfall model," noting that he did not recommend it for

any program longer than 3 months if 100 percent of the requirements are not understood. Anything longer likely requires an iterative approach, she said.

Ms. Yeman discussed the Digital Engineering Value Stream and the importance of several actions that add value:

- Applying multiple horizons of planning with regular feedback points
- Architecting for change and speed with Model-Based Systems Engineering (MBSE)
- Shifting left and beginning with test to build executable requirements
- Chaos engineering—injecting faults into the system to build resilience
- Integrating early and often
- Instrumenting the system for observability
- Digital twins to validate the product
- Bringing in manufacturing early to ensure the product can be assembled at scale
- Applying a growth mindset; every data point is an opportunity to learn

Ms. Yeman said that the benefit of tight feedback loops in iterative development is that developers can do a little bit of work and then validate, then repeat the process. It is difficult to build good requirements at the start because nobody has the same mental model. Tight feedback loops allow developers to learn fast and fail fast. She said convergence most often occurs in liminal spaces.

- Taylor W.P. Lochrane, PhD, Deputy Director of Science and Technology, Chief Scientist for the Highly Automated Systems Safety (HASS) Center of Excellence (COE), DOT, discussed how automation is fueling the convergence of air and surface transportation. He said the future of transportation is not just one mode of transportation. Technology is integrating pedestrian and bicycle traffic, trains and automobiles, passenger flights and AAM.

  Dr. Lochrane said the HASS COE mission is to ensure federal capacity to review, assess, and validate the safety of automated technologies while enabling cross-sector collaboration for the safe integration of automation in transportation. He said the nation must prepare for new automation technologies and vehicles in the transportation system. We must understand how technology is going to enter the airspace and certify technologies that have never been certified. To do this, we will have to network, share ideas, and innovate.

  Dr. Lochrane said the future of transportation is multimodal. Innovation will require data sharing and federated systems for traffic management and guidance. He said AAM vehicles will rely on other modes of transportation to complete trips so there will need to be seamless information sharing across a complex system of systems. Projected traffic for automated surface and air transportation is greater than

anything currently managed with today's systems. A whole-of-community approach involving government, industry, and academia is required to develop a safe and sustainable transportation system for the future.

- Hector Morales, Acting Manager, Air Traffic Organization (ATO) Cybersecurity Group, FAA, discussed emerging strategies to identify and resolve cyber vulnerabilities early in the development cycle. He outlined the V&V process and V model and asked whether we are shifting left enough when it comes to cybersecurity of the ATO. Traditionally, code is reviewed for security as the last phase before release. He said this leaves little time to ensure the code is secure. If vulnerabilities are exposed, there can be impacts on schedule, cost, and trust. Mr. Morales said he has been advocating for cybersecurity to be a part of testing from the start. He said instead of DevSecOps, it should be SecDevOps. This requires convergence to work together so requirements and cybersecurity are met.

  Mr. Morales described mitigation activities used to minimize risk in development and operational environments. He said segmented operating environments are being built to protect Mission Critical and Mission Essential systems and services. Segmentation is being used as a defense-in-depth strategy for the NAS, much like an aircraft's systems are segmented. It might be possible to hack into the entertainment system, he said, but a safety-critical system would still be secure.

  Mr. Morales shifting left on cybersecurity will ensure security issues are anticipated and remediated early. Delivery speed will be increased and costs will be reduced. Shifting left will also require convergence of policies and standards. He said he is working with the FAA's Joint Resources Council (JRC) to set aside funding for cybersecurity requirements that might come up.

- Annie Cheng, Deputy Principal Engineer, UAM Airspace Subproject, NASA, spoke about engaging stakeholders for UAM airspace research. She reviewed UAM missions such as cargo delivery, regional passenger travel, on-demand airport transfers, and air ambulances. Integrating those systems means talking to people first. It's about technology and people. Stakeholders each have their own perspectives and concept of operations so it is important everyone be engaged. People convergence must come before processes and technologies.

  Ms. Cheng said research organizations like NASA have the capability to bring people together. Stakeholders include current NAS users, local governments, vehicle manufacturers, infrastructure, federal agencies, and others. This creates challenges because each stakeholder looks at the problem differently, and they have their own timelines and priorities. Industry traditionally wants to move faster than regulatory bodies. Even the definition of UAM is not consistent among different stakeholders.

  Ms. Cheng said NASA has used workshops, integrated testing with FAA automation and industry prototypes, and human-in-the-loop simulators to create a common reference framework for UAM. Each of those processes are iterative, so participants are learning, updating, and repeating. The common reference

framework continually updates and helps inform requirements, prototypes, community-based rules, and operations moving forward.

- Jeremy Smith, JSE V&V Lead/Verification, Validation and Accreditation (VV&A) Technical Director, Naval Air Warfare Center Aircraft Division, presented lessons learned and converging opportunities from the V&V of the JSE. The JSE is a simulated battlespace environment that enables high-fidelity testing and tactics training for fifth-generation fighter jets. Mr. Smith said the JSE is comprised of a convergence of government owned, operated, and developed simulation products. It contains a massive amount of complexity, which makes validating the simulation a challenge.

  Mr. Smith said V&V skills with the appropriate subject matter expertise are a rare combination. Many projects require similar expertise so personnel are not always available. Other complications include network connectivity and robustness; the availability, validity, and usability of data; contract language and specifications; and syncing with program schedules. But there is great value in a government-led V&V process.

  Mr. Smith said a government V&V process ensures that developers are not validating their own product and provides separation even for government-developed models. The government also has better access to information and can provide proprietary safeguards. Importantly, lessons learned can directly benefit future V&V efforts by establishing tools and processes, creating a robust team of SMEs, and growing complex organizational connections.

Day 2 —

- Carla Hackworth, PhD, Manager, Aerospace Human Factors Research Division, Civil Aerospace Medical Institute (CAMI), spoke about the pitfalls, progress, and promise of convergence and innovation. She defined convergence as technologies, information, and processes coming together to create a new approach or utility. She highlighted the yin and yang of convergence: innovation but change; opportunity but disruption.

  Dr. Hackworth said that convergence must consider human capabilities and limitations; it must optimize capabilities and protect limitations. She referenced a 2002 report, “Converging Technologies for Improving Human Performance: Nanotechnology, Biotechnology, Information Technology, and Cognitive Science,” sponsored by the National Science Foundation and the Department of Commerce. She asked how we can ethically assure new capabilities do not target or leave out specific groups. Convergence for whom? It is essential that we ask potential users and enable them early in the process. She said we need to include as many people as we can when converging.

  Dr. Hackworth said the 2002 report was optimistic about the potential for technology to improve human performance, but experience has shown technology can create further divides between the haves and the have nots. There are also

ethical concerns about genetic modification and other emerging technologies. She said science often gathers more than we can handle. We have to design for the optimal but consider possible perturbations and human factors. How do we make sure converging technologies don't leave out the human?

- Kerianne Hobbs, PhD, Safe Autonomy and Space Lead, Autonomy Capability Team, Air Force Research Laboratory, spoke about safe ML-based aerospace autonomy. She described autonomy as the "third offset," after nuclear and stealth, with the potential for revolutionary military applications. She asked how we know an autonomous system will do what we want and won't do what we don't want. She reviewed different types of ML—supervised, unsupervised, and reinforcement learning. She said reinforcement learning has shown superhuman performance in several big "human versus machine" competitions such as high-dimensional state spaces, partial observability, and complex strategy. However, ML is stochastic. Changing the random seed or input at the start of reinforcement learning can drastically change the result.

  Dr. Hobbs discussed the Safe, Trusted Autonomy for Responsible Spacecraft (STARS) program, which is studying what it would take to put a neural network control system on a spacecraft. She said the space domain is very risk averse. Referencing Scott Altman's presentation on Day 1, she asked how engineers would design a robot to do the Hubble Space Telescope repair. Space missions require humans, but how will humans and autonomous systems team up? STARS is looking at developing flexible human-autonomy interfaces and run-time assurance to mitigate hazards and allow autonomous systems to stay on mission for longer.

  Dr. Hobbs said autonomous systems are not going to fail predictably. She said developers need to mitigate the hazards. Human Factors research must determine the balance needed between autonomous systems and humans. She said neural networks could also be broken up between the sensing and actions sides to provide multiple checks.

- Stéphane Mondoloni, PhD, Outcome Leader for NAS Concepts and Architecture, MITRE, discussed the Info-Centric NAS. He said the transportation ecosystem, including the NAS, has undergone a digital transformation. Not long ago, we would use paper maps or call a hotel to make reservations when traveling. Now, we can do all of that from our phone. He said distinct players from across industry and government have converged to create this digital transformation and ecosystem evolution. An aim of the Info-Centric NAS is to to obtain, connect, secure, manage, and display information to improve existing, and enable new, operations. He said the Info-Centric NAS has to be an open space able to accommodate new operations.

  Dr. Mondolini said the Info-Centric NAS has audacious goals, including accommodating Unmanned Aircraft Systems (UAS) and AAM vehicles that have not yet been defined let alone built, as well as high-altitude vehicles and space

launch vehicles. Air Traffic Control (ATC) may not necessarily control these new operations. There may be other entities controlling traffic, or a federated system interacting together.

Today, NAS operations create terabytes of data per flight. In the future, there will be orders of magnitude more data as the Internet of Things (IoT) fully takes shape. Information will be a lynchpin of managing the NAS. He said ubiquitous information will make ML and digital twins possible. There will be roadblocks overcoming legacy systems, proprietary data, and security needs. Dr. Mondoloni said we are not trying to converge on a single solution yet, but the Info-Centric NAS should allow for an ecosystem that can evolve over time. Information is the key to make all these things possible.

- Carleen Adams, NAS Chief Architect, Manager, NAS Enterprise Planning and Analysis Division, FAA, spoke about convergence in the NAS Enterprise Architecture (EA). She described the NAS EA as a set of models and views that document the NAS in the current state, the desired future state, and the transition strategy between the two.

  Ms. Adams said NAS Infrastructure Roadmaps play a big role in convergence by creating a high-level, integrated, and holistic view. She said integrated views help create an understanding of the complex interrelationships necessary for effective planning, analysis, and decision-making, across the enterprise, portfolio, and specific investments.

  Ms. Adams said the Info-Centric NAS operations will include diverse traffic management services enabling an array of new vehicles, missions, and operations. New infrastructure will increasingly leverage commercial assets, services, and new technologies in support of operations across diverse traffic management services. Safety assurance will be tailored to achieve acceptable safety based on operational characteristics. With big data, real-time safety will be assured through continuous monitoring, modeling, and verification to detect anomalies and correct for real-time spikes in risk.

- Mark Kiemele, PhD, President and CEO, Air Academy Associates; and Charles McKee, President and CEO, Taverene Analytics LLC, presented an interactive exercise in the Design of Experiments (DOE). Summit attendees formed four teams to launch balls from a miniature statapult. Teams were given certain procedural requirements and a set time for data collection, and then each team measured the distance balls traveled. The range between the minimum and maximum distances were recorded. Teams were then asked to narrow that range by creating a Standard Operating Procedure (SOP).

  Teams used process flow diagrams and fishbone diagrams to identify variables and address them through the SOP. Dr. Kiemele said DOE is a process, and that process has to be baselined in an SOP. Test team members need to work together to create the SOP and to set practices that reduce variation. The SOP is a living document and can change over time.

The speakers at this year's summit addressed the theme of "Convergence: Maximize and Manage" in many different ways. Many of the presentations touched on the benefits and obstacles inherent in divergence and convergence. The main takeaways are as follows:

1. Divergence and convergence are both needed for innovation. Divergence explores possible solutions and draws out unexpected connections. Convergence is an integration of knowledge, tools, and activities toward a common goal. The challenge is finding the right balance that maximizes the benefits of convergence while managing the obstacles of divergence.
2. Technologies, systems, and applications are converging to create advancements and evolve the transportation system. The transportation system of the future will rely on a convergence of information systems to operate safely and efficiently. The future is automated and multimodal. We will have to network, share ideas, and innovate to certify these new technologies.
3. Data convergence will be critical to train ML algorithms but developers will need an abundance of high-quality data. Sequential development processes in which vendors develop and test teams perform testing until requirements are met may not work for ML algorithms. Stakeholders need to be integrated from the start so that they can work as a group to build requirements, characterize systems, and develop and assess tools.
4. Convergence most often occurs in liminal spaces. Iterative development and tight feedback loops allow stakeholders to learn fast and fail fast. People don't have the same mental models so it is important they converge to establish good requirements.
5. Integrating systems means talking to people first. Stakeholders each have their own perspectives and concept of operations, so it is critical that everyone be engaged. People convergence must come before processes and technologies.

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 18th Annual V&V Summit presentations, agenda, video, speaker biographies, feedback link, and more information are located at Verification and Validation Summits | Federal Aviation Administration (faa.gov).