16th Annual Verification and Validation Summit — 2021 Virtual Event

"***The Fusion of Art and Science***"

Event Record

The 16th Annual Verification and Validation (V&V) Summit was conducted virtually September 29–30, 2021, with 316 people in attendance across both days. The event was sponsored by the Federal Aviation Administration (FAA) William J. Hughes Technical Center and hosted by the V&V Strategies and Practices Branch (ANG-E5A) under the direction of Branch Manager John Frederick. Wanda Lopez-LaBarbera was the summit coordinator. Presentations, discussions, informational videos, and interactive surveys addressed the summit's theme, "The Fusion of Art and Science," and how V&V professionals will have to be more than scientists and engineers as they develop innovative and creative solutions for the future of aviation. The goal was to foster new perspectives, increase awareness, and inspire notions of curiosity and discovery for projects and organizations. There were 14 speakers from:

- FAA
- Leidos
- Verizon
- Carnegie Mellon University
- The MITRE Corporation
- Serco Inc.

Topics addressed V&V practices and the intersection of art and science. Presentations addressed topics that included

- Artificial Intelligence (AI) and Machine Learning
- Big data analytics
- Humanizing AI and associated trust factors
- Creating realistic, interactive simulations
- Digital twin modeling
- Virtual environments
- Innovation at the nexus of art and science
- Future of software engineering
- Continuous assurance
- Measuring mission impact
- Shift-left approach
- Trajectory Based Operations
- Mental models and system design

To provide additional insight and foster understanding, the following videos were shown: *The Genius of Leonardo da Vinci* (CBS Sunday Morning), *John Cleese on Creativity* (Content Marketing World 2015), and *Robots of the future at Boston Dynamics* (60 Minutes on CBS News). Throughout the summit, Angela Moore of the V&V Strategies and Practices Branch moderated several virtual interactive surveys to gauge how participants viewed the fusion of art and science.

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

- John Frederick, FAA, Manager, V&V Strategies and Practices Branch, welcomed attendees to the 16th Annual V&V Summit and introduced the theme of "The Fusion of Art and Science" and how it relates to V&V. He said the summit was being held virtually for the second consecutive year due to the COVID-19 pandemic, but that has not stopped it from being a successful place to interchange and socialize new concepts, look for innovations, and foster new ways of thinking. He reviewed the summit agenda, presentations and surveys, and solicited feedback at the summit website.

  Mr. Frederick challenged the audience to "Think like Leonardo," saying Leonardo da Vinci embodied this year's theme and saw the value in the fusion of art and science. He said V&V professionals should take time to step back and think creatively. Innovation lies at the intersection of art and science; that is where "the magic" occurs. There is a great opportunity to create and innovate in the modern world, but it will require us to be more than scientists and engineers.

- Shelley J. Yak, FAA, Director, William J. Hughes Technical Center, greeted attendees and thanked Mr. Frederick and the V&V Strategies and Practices Branch for organizing the summit around another interesting theme. Ms. Yak said the William J. Hughes Technical Center is the FAA's premier air transportation laboratory and serves as its scientific test base. The Technical Center's mission is to sustain a full spectrum of aviation systems, and foster and advance both science and art disciplines for the Next Generation Air Transportation System (NextGen) and the aviation industry as a whole. The division of labor is much more complex than left and right brain: art endorses science while science upholds art.

  As examples of promoting the "what if and what is," Ms. Yak highlighted the Technical Center's internship program; employee engagement team and mentoring; Aviation Science, Technology, Engineering, and Mathematics (AvSTEM) outreach efforts; and the Innovation and Technology Advisory Council (ITAC). She said there is constant cross-pollination of ideas and cooperative research agreements between FAA, Department of Defense (DOD), and Department of Homeland Security (DHS); and added the Technical Center works with private industry through events like the recent Cyber Rodeo, conferences, podcasts, YouTube, and the Tech Center Showcase. Ms. Yak asked attendees to consider the subjective and intuitive to tap the fullest of their abilities.

- Ronald C. Keesing, Vice President for Artificial Intelligence, Leidos Technical Fellow, Leidos, presented *Artificial Intelligence: Challenges and Opportunities in the Art and Science of V&V*. He said that Artificial Intelligence (AI) and Machine Learning (ML) can be leveraged to improve the art and science of V&V, but that cannot happen without humans' trust of AI. He said building that trust is more of an art than a science.

  Mr. Keesing said more data will be collected over the next 2–3 years than ever before. AI is capable of processing much more data than humans, can now produce synthetic data that is indistinguishable from the real thing, and has made advances in natural language understanding and scientific discoveries such as predicting protein structures. He said autonomous AIs will be used in the near future for driving cars and providing virus

detection. Lower costs and increasing complexity in ML systems (up to 175 billion free parameters) will allow researchers to apply ML to problems much faster and cheaper than the traditional human approach. But that will not be possible without trust in AI.

Mr. Keesing said that without trust, AI will not be effectively used. Without trust, mission owners will not provide enough resources for AI to be successful, or will not allow it to be used outside the lab. According to surveys, 85% of AI projects eventually fail to bring their intended results to the business. Through successful trust building, however, AI can be used to review massive amounts of data, creating opportunities in V&V to document missing requirements, develop test strategies, and automate assessment and the testing process. He said humans would no longer have to look at overwhelming amounts of data — important data would be highlighted for them — and AI would prevent teams from losing organizational memory when Subject Matter Experts (SMEs) retire or leave. Mr. Keesing said there is also a real art to designing AI solutions that can be verified. Such systems need to be built to adapt as the world changes. It will not be possible to take a model offline for a 2-year or 6-month V&V process. He said there will have to be a continuous certification process.

- Angela Moore, LSSMBB, Engineering Information Technology (EIT), Inc., conducted four rounds of interactive surveys (two each day) that asked participants their professional background, what art and science meant to them, and how they could "think like Leonardo." She used the Poll Everywhere website to show real-time responses in the forms of word clouds and graphics.

- Daniela Kratchounova, Ph.D., FAA, Research Scientist, Civil Aerospace Medical Institute, presented *Simulators as Theatre*. Dr. Kratchounova first worked as a sound engineer on a production of the Samuel Beckett play "Krapp's Last Tape." The experience taught her that effective interface design, just like effective drama, must engage the user directly in an immersive experience. The simulated experience should be as close to the real thing as possible. For flight simulators, this means increasing stimuli to maintain an element of surprise. Engagement in action makes all the "stage" elements disappear from conscious awareness.

  Dr. Kratchounova said there must be attention to detail, everyone must know their part, and a coordination of content and process in order for a simulation to be successful. Failure at any of these and the magic is gone. The notion of theater should not simply be a metaphor, but a way to conceptualize the pilot-simulator interaction. Scene design, lighting, movement, and visuals should all contribute seamlessly. A perfect example is trash cans at Disney World: they are thematic to their location in the parks. Attention to detail is why it is called the "Magic" Kingdom. "The Universe is made of stories, not of atoms." Magic is created by both people and machines. One example for flight simulators: delivering Air Traffic Control (ATC) clearance with the correct voice intonation. She said numbers, statistical analysis, etc., are only a small part of the story told from the sim as a stage. What matters most at the end is the story told about the real-life applications of these numbers.

- Jeffrey Schweitzer, 5G/Multi-Access Edge Computing (MEC) Solutions Innovation Architect, Verizon, presented *Digital Twin Futurescape*. Mr. Schweitzer said digital twins are an effective approach to predict desired outcomes. The National Airspace System (NAS), one of the most complicated system of systems, would be a prime opportunity for use of a digital twin. He said digital twins can model how behaviors unfold in real time. The model can be tested and evaluated. For instance, in airspace modeling, a digital twin can model how the network would adjust if an antenna array fails.

  Mr. Schweitzer recently led a team in Quantico, VA, where refugees from Afghanistan are being moved into temporary housing. His team was able to help federal agencies model and build infrastructure to intake people there. He said similar work has been done to provide shelter for hurricane victims with a quick turnaround. Digital twins can provide digital blueprints for projects or entire cities, inclusive of physical and digital infrastructure. Virtual command centers can be built, allowing stakeholders to step into a virtual environment to communicate or use interactive 3D holographic models. ML can also be used to evolve digital twin systems. Mr. Schweitzer said ML can assess as-is capabilities and feed back to a digital twin to refine them.

- Pamela D. Whitley, FAA, Assistant Administrator for NextGen, welcomed attendees to the second day of the summit. She challenged the audience to think about the relationship between art and science; artists thinking intuitively and scientists thinking logically; the unstructured versus the methodical. That intersection is where innovation occurs. Ms. Whitley said advances in communication technology are a good example of "the art of the possible." It wasn't long ago that phones were in a fixed physical location. Users had to stay near it and hold it to their ear. She said smartphones have removed those boundaries. Similarly, Ms. Whitley asked attendees to think how many V&V activities had to happen for the virtual summit to take place and allow her to speak in a virtual environment to them in their home. She said the FAA has focused on developing systems, but is now developing an information-centric environment in which information and data become decision-making mechanisms for everything in the system.

- Anita Carleton, Division Director, Software Engineering Institute (SEI), Carnegie Mellon University; and John Robert, Deputy Director, Software Solutions Division, Carnegie Mellon University, presented *Research Agenda for Software Engineering: Architecting the Systems of the Future*. Ms. Carleton started by saying the future of software engineering is vital to the United States' national security, innovation, and competitiveness. SEI led a study to reevaluate and redefine how software should be designed. How will software be developed, assured, analyzed, and deployed? What role should government, academia, and industry play? Due to software's ubiquity, Ms. Carleton said we must learn to develop and assure software continuously and insert new capabilities as quickly as possible. Improving software quality and productivity requires a community effort to identify future challenges in engineering software-reliant systems; developing a research roadmap that will drive advances in foundational software engineering principles across system types; raise the visibility of software so it receives sustained recognition commensurate with its importance to security and competitiveness; and enable strategic partnerships and collaborations to drive innovation. Humans and AI must be trusted partners to develop software systems

together. AI will play a big role in future software development. Ms. Carleton said SEI is working with the White House's Office of Science and Technology Policy (OSTP) to make software a major agenda item.

Mr. Robert added that new software systems will require new research and development (R&D) advances. V&V will be very important as new types of systems are developed. How are we assuring the system? How does change affect other parts of the system? Continuous assurance will be needed because software continues to evolve quickly. He said there also needs to be a paradigm shift in software development, especially for societal-scale systems. Software developers should incorporate the social sciences, which have mechanisms to apply predictability to societal-scale systems. Outcomes can be better predicted. Such systems have large impacts on people, and software engineers and users have to ask whether or how their behavior is being manipulated. Do they have a right to know? Mr. Robert said these questions go to ethics and social sciences. He said AI will be an important factor in software development, working with human engineers. At some point AI may be able to detect a lack of experience in a new software developer.

During the Q&A session following the presentation, John Frederick asked about agile acquisition and rapid deployment of systems, and how to get V&V into that process. Ms. Carleton said new acquisition pathways are being developed and software needs to be considered much earlier in the development process. She said she would be interested in collaborating with the V&V Branch to that end.

- Justin F. Brunelle, Ph.D., Principle Researcher, Software Engineering Innovation Center, The MITRE Corporation, presented *Measuring the Impact of Innovation Activities in Government*. Dr. Brunelle said government innovation organizations focus on the fusion of art and science and are increasingly open to using external innovations to meet issue needs. External innovation can complement or accelerate innovation in government. The MITRE Innovation Program (MIP) published a report, *Measuring the Impact of Innovation Activities in Government*, in October 2020, asking what roles do government innovation organizations serve? What activities are they performing to advance innovation? How do they measure their results?

  Using a data set of 39 organizations, MIP found that most are relatively young and small. The industry is a highly collaborative space, with most organizations partnering to accomplish their mission. He said almost all of the organizations had a parent organization. The MIP report measured four categories of innovation metrics: workload, engagement, output, and outcomes. Interestingly, although all the organizations said their purpose was to deliver mission impact, less than half collected mission impact measurements. Dr. Brunelle said there was a misalignment in measuring workload and output metrics instead of outcome metrics. He said innovation organizations should clearly establish their innovation role, identify and collect appropriate metrics, collect metrics as part of regular operations, make metrics transparent, and coordinate across the organization to build and maintain a directory. Dr. Brunelle said science is quantifying; art is understanding. He said it requires intuition to determine what organizations need and how to deliver that. Be deliberate — and *quantitative* — in your innovation framing!

- Wendy O'Connor, FAA, Air Traffic Services Lead, Trajectory Based Operations Air Traffic Services; and Almira Ramadani, FAA, Integration and Analysis Manager, Trajectory Based Operations Air Traffic Services, presented the *Art and Science of Implementing Trajectory Based Operations (TBO)*. Ms. O'Connor started by saying TBO is a collection of systems, capabilities, processes, and people working to achieve operational objectives. Time-Based Management (TBM) helps manage trajectories by scheduling and metering aircraft through constraint points. Performance Based Navigation (PBN) enables aircraft to more accurately navigate along their trajectory. Other enabling technologies expand and automate sharing of common information about aircraft trajectories. She said the synergy between TBM and PBN will improve the predictability of where aircraft will be at what time, and reduce the need for ATC intervention. Field implementation teams and open lines of communication will be needed to successfully incorporate TBO. An implementation strategy will rely on people to plan and implement TBO. Ultimately, the success of TBO depends on people.

  Ms. Ramadani spoke about data-driven decision making and TBO communications. She said TBO will try to improve predictability, flight efficiency, throughput, and operator flexibility. A TBO Dashboard prototype will be used to evaluate outcomes from TBO deployment and use at airports in Atlanta, Denver, Newark, Philadelphia, and Los Angeles. Developers will be able to fine tune real-world operations using lessons learned in these parts of the NAS. She said there are many moving parts and dependencies. A synergy between art and science will help synthesize all contributing factors to accomplish TBO's objectives. Ms. Ramadani said people are critical, and TBO deployment will involve facilitators giving feedback earlier to minimize risk and achieve end goals.

- John Bradley, FAA, Air Traffic Control Specialist, Air to Ground Communications Branch, presented *Atlantic City Advanced Air Mobility (AAM) Ecosystem*. Mr. Bradley has worked in ATC in various roles starting in 1986 and said that while there are specific procedures and phraseology, there is also a certain amount of flexibility on how to provide services. Listening to ATC operators, you can appreciate how it is like art, or an aerial ballet.

  Mr. Bradley spoke about the importance of using a shift-left approach in system development, including testing and evaluation in concept and design phases. It becomes very expensive to eliminate faults the further development goes through verification and validation. Costs can be 40 times as large if faults are found in Operational Testing (OT), or 110 times as large if found in deployment and site acceptance. He said part of the art in the shift-left approach is determining what elements to shift left. Finding faults early on will reduce the costs of the program.

  Mr. Bradley said FAA has been working with MITRE and National Aeronautics and Space Administration (NASA) as it develops the Atlantic City AAM Ecosystem, testing tools they want to develop in real airspace. Engineers are using Atlantic City airspace as a Live Virtual Constructive Environment (LVCE) to conduct research and development, creating an environment that encompasses complete integration of people, processes, and tools. Using FAA High-Fidelity NAS labs and NASA Urban Air Mobility (UAM) assets,

developers can simulate limited functionality expected from fleet operators and service providers who will use UAM vehicles to transport passengers from Atlantic City International Airport to the Atlantic City Convention Center. A "Jitney Route," taking passengers from the Convention Center to casinos and hotels on Pacific Avenue, regional aerodrome/vertiport access, and small Unmanned Aircraft Systems (sUAS) are also included in the ecosystem. As a demonstration, he showed a video simulation of an UAM vehicle flying from the Atlantic City Convention Center to a landing pad atop a casino/hotel parking garage.

Mr. Bradley said future AAM ecosystems will rely on operational integration and information sharing between public and private service providers. He said public acceptance will be a critical part of integration. To foster that acceptance, all the potential routes in the Atlantic City AAM Ecosystem avoid residential neighborhoods even though the UAM vehicles will be electric and should be very quiet. He said there are a lot of challenges, but shifting left will help researchers identify faults early on.

- George Emilio, Director, Aviation Business Development, Serco Inc., presented *Analysis vs. Intuition*. He spoke about the Two Systems Model of the human brain, a focus of psychologist Daniel Kahneman's book *Thinking, Fast and Slow*. The System 1 brain is our primitive, animal brain. It is highly connected to our senses, capable of parallel processing (e.g., watching video and listening to music simultaneously), and has frugal calorie demands. The System 2 brain is our evolved scientific brain. It is isolated from our senses, uses serial processing (e.g., cannot do two math problems at the same time), and has intense calorie demands.

  Mr. Emilio said cognitive biases often occur when System 1 fails to wake up System 2 for help. But both systems can be fooled, and developers should remember that designing a system that appeals to System 2 might shut out System 1. They should ask themselves to which brain are they appealing? How do we show data? He used an example of pilots landing an aircraft. Experienced pilots develop mental models, heuristics, and muscle memory they use when flying on approach; in other words, System 1. New pilots are more erratic and not as well coordinated; they are using System 2 and becoming "task saturated." Likewise, how we show data can help us communicate to our audience. The meaning of graphics and charts can often be picked up immediately because System 1 is very good at visual interpretation. The same data shown in a spreadsheet can look incomprehensible because System 1 cannot interpret it. He said an overemphasis on System 2 can make us miss intuitive clues. System 1 is very good at assessing risk. System 1 is quick, automatic, and has been doing it for millennia.

  Mr. Emilio said we should take the intuitive camp hypothesis seriously, including in V&V activities. He said V&V can be analytical and intuitive.

The speakers at this year's summit addressed the fusion of art and science by highlighting the importance of curiosity, intuition, creativity, and "thinking like Leonardo." The main takeaways are

1. The modern world provides a great opportunity to create and innovate, but it will require us to be more than scientists and engineers.

2. Building trust between humans and AI — a subjective undertaking — will be necessary to realize the potential AI offers in V&V, software development, data analysis, and other areas.
3. Humans have a magical ability to weave information into narratives. The best simulators and system design take this into account.
4. Continuous assurance will be needed for constantly evolving software. Social science SMEs will be needed as societal-scale software continues to develop.
5. The success of program planning and implementation relies on people.

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 16th Annual V&V Summit presentations, agenda, video links, speaker bios, and more information on art and science are located at https://www.faa.gov/about/office_org/headquarters_offices/ang/library/events/v_vsummits/v_vsummit2021/.