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ADVANCING INNOVATION AND COLLABORATION ACROSS THE SPACE ENTERPRISE

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The space domain is undergoing an unprecedented era of change, and this rapid transformation presents an exciting future with new possibilities for innovation. However, these opportunities also create new challenges and emerging adversaries that must be anticipated and addressed. Outpacing the threat requires more collaboration across the national security space enterprise—and next-generation space technologies will facilitate the integrated, multi-domain operations necessary to foster this collaboration.

Executive Summary

The Aerospace Corporation hosted the 5th Annual Innovation Summit in November 2020, which brought together key technology experts from Federally Funded Research and Development Centers (FFRDCs), University Affiliated Research Centers (UARCs), government agencies, academia, nonprofit organizations, and industry to share insight and ideas on tackling some of the nation's most challenging problems. The theme of this year's virtual event: *Increased Collaboration to Address the Rapidly Changing Landscape Across the Space Enterprise, and the Multi-Domain Operations It Supports.*

The three-day summit included discussions covering significant theme areas, including the role of space-based sensors for combating climate change and catastrophic threats; ensuring supply chain resilience against disruptive shocks (such as cyber, physical, or economic); and enabling collaboration to build the future digital engineering threads for a genuinely multi-domain joint force.

FFRDCs, UARCs, and nonprofit organizations play a critical role as trusted partners supporting government customers in innovating, developing, and integrating technology that advances the interests and security of the United States and its allies. Fostering more strategic collaboration and partnerships throughout this unique community is essential to the nation's continued success in staying ahead of the threat.

Some of the central calls to action for a unified FFRDC/UARC collaboration that were identified include:

- Formally agree upon a unified and shared vision for the Global Climate Observing System (GCOS)
- As unbiased brokers, strive for better communication with the government and the public about the scientific findings related to climate
- Collaborate to create digital engineering standards that will enhance model development and integration, as well as enable external collaborations
- Consider open-source collaboration on digital engineering environments that enable more effective sharing, analysis, and visualization of data and models
- Collaborate on a national strategy for access to strategic/critical materials (i.e., semiconductors, biopharmaceuticals, rare-earth materials) and processing capabilities. This plan may include a supply chain investment center that would provide for a common funding mechanism to support the development of critical technologies and their supply chains, as well as international cooperation among allies to increase processing resiliency.

Earth Science Enterprise Track

Description

The Earth Science Enterprise day's theme was how FFRDCs and UARCs are responding to, and their role in devising solutions for, the impacts of abrupt climate change. The exercise began with a keynote presentation from Dr. Gavin Schmitt from NASA Goddard Institute of Space Studies. Following the topic-framing keynote, the participants presented a complex but plausible scenario of catastrophic impacts of climate change. The scenario addressed the domino effect of multiple climate threats, beginning with the impact on the United States, which would likely lead to strains in the global economy and result in world leaders becoming desperate for alternatives. A panel of climate-oriented space-based sensor experts further framed the discussion and was followed by breakout sessions of small working groups who were tasked to offer innovative ideas to mitigate these "unanticipated" consequences. These small groups focused on prediction, assessment, mitigation, and prevention of the harmful impacts of the scenario on the United States. The goal was to outline plans of action, leveraging space-based sensing solutions. Overall, the exercise attempted to challenge longstanding assumptions about the inherent resilience of the U.S. economy and the security of the nation's food and water supplies, and to seek out unique approaches counter to our traditional thinking.

Several common themes surfaced from the expert panel and the breakout discussions. More specifically, the panelists agreed that both climate science and the needed space-based sensing technologies are very mature, but are limited primarily by political will and financial constraints. In the United States, a substantial segment of the public is skeptical of climate science and climate change. Human nature tends to focus on recent events, personal experiences, and immediate dangers and deemphasizes perceived distant threats. Furthermore, the financial investment required for a large-scale, space-based sensing architecture is even more difficult to afford with a $3 trillion federal deficit. Economic choices tend to be focused on short-term gains as opposed to long-term investments. As organizations that are not driven by profit, UARCs and FFRDCs can provide unbiased technical advice and maintain a long-term view of threats to national security.

This role of honest broker sets UARCs and FFRDCs apart from political groups and for-profit companies. An unbiased reputation is a starting point for engaging in these discussions, but insufficient alone. To date, climate scientists have failed to provide clearly articulated scientific evidence and projecting how the information might impact individuals. The climate change narrative should be shifted to tell a story of the personal impact on American citizens. Also, improved data presentations and visualizations are a powerful tool for educating the non-scientific portion of the population. Lastly, the narrative around climate change should not be limited to science, technology, and the public good. It should also incorporate the perspective of economics to describe the concrete benefits of investment by U.S. taxpayers. This will help the public connect to space-based technology investments more personally and emphasize the business case for acting on climate change *now*. A GCOS could, in principle, provide greater data resolution for more clarity of results.

The final central theme is that climate change is a global problem and thus will require a whole-of-government approach and international cooperation, backed by enforceable agreements and accountability. It is essential to foster inter-organizational and international relationships and engage as a collective community. This global community will include the private sector, non-governmental Organizations (NGOs), academia, and citizen scientists. Creating an open data-sharing model across these international organizations will be vital to combatting climate change. Also, we must work to remove existing barriers to international research.

It should be noted that tackling climate change is a multi-disciplinary problem that will require technological progress that extends far beyond space-based sensing. Other necessary advancements are needed in areas including essential data and analytics, advanced computation, artificial intelligence (AI), improved decision-

support tools, and novel remediation techniques. The need extends even to counter-influence operations to filter dishonesty in social media. Several of these necessary advances are captured under one common architectural concept: The Global Climate Observing System (GCOS).

The Need for a GCOS

Throughout the summit's first day, significant discussion centered on the need for a GCOS. We currently have no fully integrated climate-centric system analogous to the weather service that provides a global, unbiased, full-spectrum resource for predicting, assessing, and monitoring climate disruption impacts on U.S. citizens. A GCOS should enable full climate change processing and long-term change observations (conducted via satellite, in situ, and field experiments). This would include independent global observations of essential climate variables, analysis of these climate variables, algorithms, data storage and archival, data distribution, climate modeling (process and global), data/model comparisons, model development and refinement, and sufficient processing power.

Economic research using the latest models, such as the Dynamic Integrated Climate-Economy (DICE) model, suggest a return on the investment system as roughly 50 to one.[1] The need for a GCOS is growing; as more nations (especially China) consider and undertake geoengineering activities to lessen the effects of climate change; the economic impact of those individual nations' efforts on other countries must be assessed and understood.

The panelist Dr. Bruce Wielicki framed the discussion for how UARCs and FFRDCs could collaborate to address the issue of climate change:

> *The idea of the DOE and other agency FFRDCs as a trusted source vs. government labs is an interesting one. On the one hand, I don't see any essential difference: all government-funded scientific research is [sic] for the public good. On the other hand, the public might indeed perceive it differently, so it is worth pursuing. There are certainly many skills at the FFRDCs that could improve climate science and its communication to the public. In some sense, this is like the Manhattan Project or Apollo Project: all hands on deck [are] needed to solve the crisis.*

Earth Science Enterprise UARC/FFRDC — Calls to Action

Based on the discussion in the Earth Science Track, the following calls to action were developed:

- *Formally agree upon a unified and shared vision for the GCOS.* We must formally document the system requirements for a GCOS in a format that is readily accessible to scientist, policy makers, and the public. With this in place, FFRDCs and UARCs could work toward a common and unified goal for global climate observation.
- *Start investing our energy on this vision.* With a common vision in place, UARCs and FFRDCs could work toward a common objective and apply our financial and cognitive resources in an organized way, including other interested stakeholders.
- *Increase collaboration and data sharing.* We must continue to foster relations across domestic organizations, including the private sector, government agencies, academia, and the national labs. We must address the barriers to international collaboration, including data and model sharing, sharing infrastructure, and conducting cooperative research projects. FFRDCs and UARCs must define our range of roles across the spectrum: trusted resource, developer, provider, and disseminator — relative to a GCOS. We must also learn to interface with the existing resource base: GCOS is co-sponsored by the World Meteorological Organization, NOAA, and Climate Central.
- Strive for better communication with the government and the public and, as always, be the trusted advisor to the government on contentious issues. As unbiased brokers, UARCs and FFRDCs also have a special ability to undertake research and provide hard data for materials that can be used to educate and challenge skeptics in all domains about the benefits of addressing climate disruption before the catastrophic impacts are evident to all.

Digital Engineering (DE) Track

Description

Maj. Gen. Kimberly Crider, the mobilization assistant to the Chief of Space Operations, opened the final day of the summit with a message on the theme of *Enabling Collaboration through Digital Engineering: Combining Models to Tackle Challenging Problems* and the need to embrace DE to modernize the space enterprise. Acknowledging the recent first anniversary of the United States Space Force on December 20, 2020, she discussed how the scale, scope, complexity, and pace of today's space domain operations require the ability to work faster, smarter, and more connected to outpace the threat. As a small service with limited funding, the Space Force must advocate for a position and adapt to a continually and rapidly changing environment. General Crider shared a vision where the Space Force must work in a complete digital thread including design, architecture, development, production, test, deployment, operations, and sustainment.

Intuiting that DE will be more easily adopted if its value can be proven, the panel discussed capitalizing on DE opportunities and DE results by leveraging innovation—as well as the complexity of modern systems, which cannot be adequately validated and verified without DE approaches. The large, complex systems are often poorly architected, overly brittle, difficult to test, and difficult to maintain. Knowledge is lost during phase transitions, as well as insights gained from previous phases at lifecycle changes. We also lose knowledge between projects on what can be passed from one project to another. The technical and programmatic portions of programs are seldom well integrated. DE may be able to bridge the gap by creating an accurate analytical framework. The importance of standards for collaboration between organizations, and the cultural barriers to DE were also debated.

Breakout Session 1: Innovation Collaboration

In this session, the breakout participants agreed that there isn't enough emphasis on DE tools for the collaboration process. Currently, the application of DE methodologies is typically considered after the design selection and does not incorporate enough of the initial design process. There are also cultural issues between newly hired engineers and existing seasoned engineers at companies. One major problem facing the industry is model maintenance. Many legacy models are difficult to keep up to date and integrate and would benefit from application of the latest industry standards.

Breakout Session 2: Benchmarking Collaboration

This breakout addressed what type of DE benchmarking activities and data would be most valuable to share innovations across the community. Organizations will offer innovations that they believe would be useful if shared. The breakout addressed how to share information. Organizations can start by conducting digital domain assessments and separate benchmarks for different model domains. Organizations can leverage frameworks such as the INCOSE Model-Based Capability Assessment (MBCA). Also, organizations can share their data and information across the community through users' groups and communities of interest.

Breakout Session 3: Collaborative Integrated Data Environments

The discussion started with suggestions for policies fostering collaboration and interoperability that would enable the highest number of use cases to facilitate the "natural" adoption of DE practices in a common, integrated environment. The consensus among the breakout participants was that the environment needs to promote a balance of modernization and operability to maintain near-term relevance and smooth transition, leverage best practices and industry standards through a digital concept of operations, and address issues and challenges with data classification and multi-level security.

Breakout Session 4: Shared DE Elements

Here, the discussion focused on where the community would benefit from a shared DE lexicon, ontologies, methods, and tools. Recommendations included using open-source collaboration tools such as OpenMBEE and the CAESAR Framework, collaboratively developing recommended modeling patterns and standards, sharing success stories and positive customer feedback, establishing more open channels for communication among FFRDCs, and leveraging professional societies and collecting best practices among them.

Digital Engineering UARC/FFRDC — Calls to Action

Based on the discussion in the Digital Engineering track, the following calls to action were developed and could include government and industry partners as appropriate:

- Play a lead role in exercising DE and thereby finding solutions to gaps in tractability and commonality leading to developing best practices.
- *Collect best practices* through professional societies to draw from when applying DE.
- *Collaborate to create DE standards* that will enhance model development and integration, as well as enable external collaborations, and also can be used as a recipe for smaller organizations to follow.
- *Consider open-source collaboration* on DE environments that enable more effective sharing, analysis, and visualization of data and models; e.g., OpenMBEE, CAESAR Framework.
- *Collaborate on a CubeSat pilot demonstration project* to demonstrate full DE features, such as digital thread and digital twin, that are difficult to fund/perform on large programs.
- *Collaborate on a common DE training curriculum* and share DE success stories to overcome the cultural barriers.

Supply Chain Resilience Track

Description

On Day 2, the discussion centered on developing a resilient supply chain, balancing a global supply chain with a more domestically controlled one, and understanding the vulnerability of the supply chain, particularly in the face of a world pandemic with resulting political and regulatory issues. A panel explored failure indicators that could determine the likelihood of future supplier success to identify needed changes in the workforce to accommodate.

The featured keynote was delivered by Dr. Jason Matheny, director of Georgetown's Center for Security and Emerging Technology, on the theme of *Ensuring the Resilient Supply Chains: Essential Connections Between Talent and Technology*. His presentation was mainly based on the insight found from the recent white paper he co-authored, *Mitigating Economic Impacts of the COVID-19 Pandemic and Preserving U.S. Strategic Competitiveness in A.I.*, which included recommendations to better understand vulnerabilities and strengthen the defense industrial base. Dr. Matheny outlined several key steps, including establishing a supply chain investment center that would 1) provide for a joint funding mechanism to support the development and adoption of secure microelectronics and other critical technologies and their supply chains, and 2) sustain a skilled workforce and leadership capabilities. Other steps included screening for adversary investment, ensuring the production of critical goods, protecting small and medium suppliers, and establishing trusted partners in the supply chain.

The panel focused on supply chain resiliency. The COVID-19 pandemic has exposed fragility and vulnerability in the supply chain. The establishment of a Security Manufacturing Council to advise the government could help ensure that manufacturing is more resilient. Supply chain data across the space enterprise should be digitized, standardized, and communicated across the network of suppliers and to government organizations to help them better understand vulnerabilities. Current processes do not capture real-time inventory data, but this data would be valuable in enabling effective assessment of a course of action in response to or in anticipation of disruptions to the supply chain. Capturing and communicating this data would also enable a more resilient supply chain with the potential to forecast possible vulnerabilities, as well as offer the flexibility to respond to natural disasters and other disruptions.

Breakout Session 1: Talent and Technology Collaboration

The session explored talent and technology collaboration, focusing on the role of vocational/trade schools in the future workforce, retraining the workforce to address supply chain issues, and methods for verifying new skills.

Breakout Session 2: Methods and Tools Collaboration

The session focused on methods and tools collaboration barriers and incentives for cooperation, the role of the government and industry, the lack of reporting infrastructure and supply chain performance indicators/metrics/standards, and the role of policies to get the right information at the right time to the organizations that need it.

Breakout Session 3: Innovation Collaboration

In this session, the discussion focused on providing the infrastructure and technologies to enable collaborations, including breaking down stovepipes and the ability to merge different types of data sets. Innovations mentioned included homomorphic encryption, post-quantum encryption, as well as nongovernment organization (NGO) data management and infrastructure. Robust investment is also needed to ensure proper leverage of AI by tagging data appropriately.

Breakout Session 4: Information Sharing

in this session, the discussion focused on how to achieve and maintain an accurate knowledge of the supply chain network, policies to enable sharing, supply chain modeling, and information sharing risks and benefits.

Supply Chain Resilience UARC/FFRDC — Calls to Action

Based on the discussion in the Supply Chain Resilience Track, the following calls to action were developed:

- *Collaborate on a national strategy* for access to strategic/critical materials (e.g., semiconductors, biopharmaceuticals, and rare-earth materials) and processing capabilities. This plan may include creating a supply chain investment center that would provide for a common funding mechanism to support the development of critical technologies and their supply chains, as well as international cooperation among allies to increase processing resiliency.
  - For example, the processing capability for rare earth materials resides almost exclusively in China, which presents major challenges. Alternate access would involve forging alliances with countries like Australia and Canada that are further along in developing capabilities that the United States lost back in the 1990s. Without access to processed rare earth materials, we lack the ability to miniaturize microelectronics, finely polish optics, or make permanent magnets that are used in countless applications.
- *Develop common tools and processes* to screen for adversarial investments.
- *Collaborate on strategies to share data more effectively*, such as addressing manufacturing capacity and gaps in capabilities (ranging from development and innovation to risk management) of the supply chain and industrial base.
- *Develop strategies to better manage human resources.* Treat talent as a supply chain and partner with universities to strengthen the workforce. Diversify the pipeline entry points to broaden the potential talent pool. Provide resources and accessibility at the earliest possible opportunity so that innovative solutions may increase. Create or support a contingent and flexible talent pool in the face of economic reshaping.

Concluding Remarks

This year's Innovation Summit successfully brought together some of the nation's leading technical minds to discuss significant current and future challenges, such as climate change and supply chain vulnerability, which can only be addressed through increased innovation and collaboration. Embracing new concepts and approaches, such as digital engineering and multi-domain integration, creates new opportunities to advance the space enterprise to improve resilience, agility, and velocity in tackling these challenging problems. The calls to action discussed in the summit offer myriad paths along the roadmap to collaboration on these exciting concepts and approaches in the near future.

For more information about the 5th Innovation Summit, please reach out to contact@aerospace.org.

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