U.S. Department of Defense
Office of Economic Adjustment

Project Profile: Utah

Impact Statement

The University of Utah developed a network of researchers and manufacturers across Utah and Colorado to facilitate applied research into carbon composites and additive manufacturing (AM). This research accelerates innovation, new product development, and faster production through collaboration among defense suppliers, OEMs, and academic experts working in a network of 25 additive manufacturing entities and over 200 businesses. The grantee is conducting foundational R&D to inform additive manufacturing processes, materials, and applications that will lead to a stronger, nimbler, and more technologically sophisticated defense industrial base and better assets for the warfighter.

Key Project Takeaways

Leveraging work done through the Phase 1 grant by Utah's Advanced Materials and Manufacturing Initiative (UAMMI) to map the Mountain West region's advanced materials manufacturing community, the grantee developed a community of AM manufacturers and researchers to advance applied research in AM and develop best practices for using the technology. This results in both short- and long-term benefits to national security. Through its OEA Industry Resiliency Grant, the University of Utah and its sub-awardee at the Colorado School of Mines (CSM) demonstrate the technical and cost effectiveness of metal additive manufacturing, and leverage a cloud-based artificially intelligent database of additive materials properties to drastically reduce the time required to adopt and deploy new AM technologies and processes. Facilitating the basic research undertaken by the grantee will benefit the DoD's resiliency, lethality, and readiness through increasing the speed by which AM research is integrated into defense suppliers' designs, materials, and production processes. Certified and proven AM processes and materials provide the DoD with a more responsive defense industrial base, innovative designs with more desirable properties, and streamlined logistics both domestically and in the field.

Project Description

Rationale

The DoD is a major contributor to the economies of Colorado and Utah. The two states host more than fifteen military installations combined. In Utah, a concentration of manufacturing, repair, and non-destructive inspection companies service A-10, F-22, and F-35 sustainment operations based at Hill Air Force Base, the largest single site employer in the state. Defense contractors servicing military installations comprise one of Utah's most important manufacturing ecosystems – advanced materials/carbon composites. With Utah's workforce in this sector labeled as in "crisis mode," defense contractors servicing the A10, F-22, and F-35 supply chain are faced with a shortage of qualified machinists and repair technicians. In Colorado, the defense sector is the third largest industry with 170,000 jobs attributed to defense expenditures. Prime contracts and military installations in Colorado support 450 businesses, of which 70% employ less than 10 people. Most of these firms service the DoD's cluster of aerospace and satellite installations. With an unemployment rate below 4%, advanced manufacturing firms supporting the DoD mission report an inability to find qualified workers. With a scarce supply of qualified workers to support the DoD operations located at Mountain West military installations, local businesses will have to adopt new technologies that require an agile workforce and enable flexible options in production. In response to this demand, the University of Utah received an OEA Industry Resiliency grant to develop the Mountain West region's advanced manufacturing capabilities in composites and metals and enhance the ability of defense suppliers to rapidly deploy new materials and new technologies such as additive manufacturing. The Phase 2 award enables foundational research to accelerate deployment of AM using innovative materials across a wide range of applications with implications for the entire defense supply chain.

Program Activities

The Industry Resiliency grant enabled the University of Utah to develop connections and empower research between industry and academia in the fields of composites and metals manufacturing, respectively. There were two phases of IR grants provided to the University of Utah: Phase 1 addressed the Mountain West region's advanced materials supply chain. Only a select number of activities undertaken by Phase 1 of the grant impacted activities undertaken during Phase 2. In each Phase, Utah's Manufacturing Extension Partnership center played a key role to convene industry, academia, government, and education resources to support the project. The outcome of Phase I was the founding of the Utah Advanced Materials and Manufacturing Initiative (UAMMI), to manage and maintain the supply-chain database, and ensure the results of this project will sustain and advance beyond the duration of the grant.

In Phase 1, the University of Utah developed a directory of all entities associated with the advanced composites' supply chain and support ecosystem. The directory includes the entity's capabilities, capacities, equipment, workforce resources, research & development activities, and business connections. This work identified 120 defense-related, carbon composite entities in Utah, a composites researcher network and over 1500 customer-supplier relationships, providing a clearer picture of the region's DoD supply chain. UAMMI then hosted two events to convene industry, academia, government, and educators working in composite materials. These events established and strengthened partnerships to facilitate and advance research in composites materials. Finally, UAMMI identified commercial and DoD opportunities for more than 100 businesses in the composites sector and established a Workforce Commission to grow the talent base prepared to operate in advanced manufacturing.

Phase 2 is leveraging this work, facilitating and advancing research in materials science, focusing on the additive manufacturing of metals. Activities include contributing to the development of the Alliance for the Development of Additive Processing Technologies (ADAPT), an industry-academia consortium that advances data informatics and advanced characterization technologies to optimize additive processes, materials, and parts, as well advancing educational and capacity-building activities with companies, workers, and students. ADAPT supports a machine-learning powered, curated database of materials characterization for additive manufacturing accessible from the cloud. This database, curated with and hosted by Citrine Informatics, leverages testing research from materials scientists and information from manufacturers' 3D printers to document and predict materials' properties and their variation according to design, printer, and feedstock. This mapping of materials properties enables companies to identify promising AM processes through a shared pool of materials characterization data while expanding applications and reducing trial and error, risk, and costs.

Resiliency Impacts

Increasing Awareness of the Defense Industrial Base

Growing the advanced composites and metals additive manufacturing ecosystems in the Mountain West region required mapping the scale and scope of the DoD's impact on businesses and researchers in the states. An improved understanding of the advanced materials ecosystem in Utah allows officials to identify the roles and actions of the current pool of DoD suppliers and identify assets and businesses that can be employed to support the DoD mission. The supply chain and asset mapping tool developed in Phase 1 includes 198 businesses and services providers, 24 workforce training assets, and 30 R&D projects relating to advanced carbon composites in Utah. This tool enables businesses and researchers in Utah's composites industry to identify potential collaborations, sources of talent, and opportunities to commercialize technology. Direct outreach to more than 500 businesses, training assets, and researchers enabled this work. In culmination, UAMMI hosted two "Crosstalks" involving industry, academia, government, and educators to share advances and best practices in materials science. These events attracted more than 500 attendees and 75 exhibitors. UAMMI continues to share advancements in materials research through a monthly newsletter that reaches 1200+ subscribers.

Outreach to the metals AM community in Phase 2 consisted of growing the ADAPT network, offering educational and awareness sessions, and developing businesses' and workers' understanding of AM processes and benefits. The University of Utah MEP Center provided 14 workshops explaining the technical and financial benefits of AM to their business, training more than 200 individuals. Additionally, University of Utah officials provided 8 courses through technical colleges on AM to 81 companies and 6 private courses for companies in the DoD supply chain. Building on this success, officials provided an online course resulting in a badge and continuing education credits for participants. The program plans to develop a follow-on course that provides more technical information on AM and introduces participants to the ADAPT network. Outreach activities went beyond businesses seeking to better understand AM. The OEA grant enabled ADAPT to grow from 12 members to 25, leveraging $35 million in private investment over 22 months. The OEA grant achieved a 8x return-on-investment from ADAPT's growth alone. The growth and development of industry clusters in advanced materials benefits the DoD mission by strengthening their ability to take advantage of innovations in materials science and meet changing demand with innovative designs enabled by AM and materials characterization. Outreach by the Colorado School of Mines and the ADAPT network is described in more detail below.

Enhancing Force Multipliers to Support the Defense Industrial Base

The cluster development achieved by the University of Utah, Colorado School of Mines, and the ADAPT network enabled AM businesses to form research partnerships, learn from the AM data in the Citrine database, enhance existing and develop new products, and accelerate the rate of progress due to the collaborative effort. Many participating companies, including Elementum 3D, Moog, and GE Additive, provided examples described below, illustrating the value of ADAPT and the multi-disciplinary research that broadened what they could accomplish working alone.

Commercial Diversification of Defense Companies to Sustain the Industrial Base

Defense suppliers must be prepared to service legacy weapons systems requiring only a few replacement parts a year; however, the parts have high unit costs and causes high overhead in the companies. AM obviates the need for maintaining a complex separate process for small DoD procurement requests, so suppliers can print legacy system parts as needed while maintaining the same workflows used for commercial production. Moreover, among defense suppliers, AM increases agility and decreases costs associated with new production lines. For example, Elementum 3D is using aluminum alloys developed through ADAPT for flight hardware parts with commercial applications in automotive racing. AM companies' machines across the country could be quickly repurposed during wartime to support the DoD mission and handle any surge orders.

Cost Savings to DoD through Business Diversification or New Products/Customers

Work done by UAMMI as part of Phase 1 of the grant resulted in over 100 business consultations to defense suppliers in the composites industry. Some examples of these consultations included connecting a large company with several small composites companies for specific parts manufacturing support. UAMMI also connected companies with Hill AFB and Air Force Research Laboratories (AFRL) for contracting opportunities. Additionally, UAMMI partnered with the World Trade Center Utah who provided SBA STEP grants for four rural Utah composites companies to attend important trade shows for the first time and assisted companies with certification processes, such as NADCAP. As part of the OEA project, the University of Utah leveraged $5.5 million in funding to support composites research, including the development of a process to weave coal into carbon fiber with the University of Kentucky and Oak Ridge National Laboratory. If successful, this process can drastically reduce the price of carbon composites by reducing input materials costs.

As noted elsewhere, the collaborative effort supported by this OEA grant through the ADAPT network has far-reaching benefits. Among those include yielding cost savings to defense suppliers looking to test innovative materials and new production processes. Elementum 3D, Moog, and GE Additive all provided examples, described below, illustrating the value of ADAPT and the multi-disciplinary research to reducing the need for trial and error when testing new materials and production specifications; this directly leads to cost savings for defense suppliers. Moreover, participation in this network speeds the production process and delivery of critical components to the warfighter.

Lethality Impacts

Innovation through the Development of New Intellectual Property or New Technologies

The ADAPT network empowers basic research in AM materials characterization, both by convening AM specialists and providing a database that informs research in the field. ADAPT's combination of multi-disciplinary researcher teams and experience and shared testing data significantly amplifies ongoing R&D in AM and advances the use of this new technology to support innovation.

To actualize this potential, companies need scientists, engineers, and technicians who understand AM. Trainings and workshops provided by the University of Utah and Colorado School of Mines helped businesses understand how AM provides manufacturing solutions beyond traditional processes. For example, the trainings aided the integration of AM processes into Parker Hannifin's production of flight controls for the V-22, F-15, and F-35, with AM processes drastically reducing the weight and improving the performance of hydraulic controls. With many manufacturers unwilling or unable to invest in materials characterization research, ADAPT's network helps companies identify promising material and design combinations for testing.

AM materials and designs informed by ADAPT will contribute to new IP supporting the next generation of military aircraft. For instance, Moog and GE Additive found that participating in ADAPT helped them to innovate faster. Reaction Systems, a hypersonic engine manufacturer based in Golden, Colorado, developed a new panel for endothermic fuel systems that facilitates the cooling of aircraft engines. Officials at Wright Patterson Air Force Base approved the material for on-the-ground engine testing after computed tomography (CT) scanning of the material at the Colorado School of Mines raised the materials' technology readiness level. Improved cooling in hypersonic engines could enable an aircraft's speed from Mach 6 to Mach 8 for longer periods of time. Reaction Systems is now working with an OEM to produce these panels for testing on a flight-based system. Materials-testing machines like a CT scanner or fatigue machine are not an investment priority for companies, making the access ADAPT provides to researchers crucial for manufacturers.

Improving 'Force Overmatch'

This IR award provides numerous benefits supporting DOD's goals regarding force overmatch. AM delivers logistical and customized production advantages as well as lower unit costs for small production runs and speed—faster delivery of equipment and replacement components to the warfighter.

For instance, ADAPT member Big Metal Additive (BMA) in Wheat Ridge, Colorado is advancing capabilities using metal AM (MAM) to build at industrial scale, incorporating new machines and processes. This brings DOD a capability currently not available, the ability to make product quickly on demand. The placement of BMA MAM machines at forward operating locations simplifies DoD supply chains by only requiring the transport of interchangeable feedstock, as opposed to many small parts that all require tracking. And the ability to make big component parts in small batches as needed, with superior design (one piece), without the time required to stand up a new production facility, constitutes a significant advantage. Recently, the Navy engaged BMA to 3D print a 40-foot landing craft; BMA received an SBIR award and partnered with ADAPT to address this challenge. BMA has sold 3 industrial scale machines, one to the Marine Corps and two to the Navy. It is feasible to envision hundreds of industrial-scale metals additive manufacturing machines positioned across the US to support surges when product is needed quickly on site, and there are similar opportunities to put the machines on the front lines to directly and immediately serve the needs of the warfighter.

Readiness Impacts

Training and People Support

A key component across both phases of OEA funding is the outreach to and engagement of the current and future workforce to educate about carbon composites and additive manufacturing technologies. These efforts had multiple components.

UAMMI formed a private-public Workforce Committee to address the composite industry's shortage of production and engineering talent. Solutions include an Aerospace Pathways Program for high school students that provides for technical training and apprenticeships with composite manufacturers, and a Master of Engineering program at Utah State University.

In Utah, only one metal additive manufacturing services firm existed before the University of Utah awareness program, with low state-wide awareness and maturity around AM technologies. A training module developed with Qualified Rapid Products (in West Jordan, Utah) and EmergenTek showed how to incorporate AM processes into their suite of manufacturing solutions. It helped machinists in Utah understand how AM shortens product development, expands their product mix to help them enter non-defense markets, diversify, and strengthens the supply chain. Moreover, it can help grow the pool of companies able to benefit from the ADAPT network. The training will be transitioned to the Utah MEP Center. Next phases of the training plan to target rural regions, focus on the benefits of the ADAPT network, cybersecurity, and provide deeper information on AM. Companies reported the trainings helped build confidence among staff in AM processes to pursue the technology.

Activities by the ADAPT network spurred the development of additive manufacturing programs offered by the Colorado School of Mines. The recently developed Masters in Additive Manufacturing graduated between 12-15 students last year, and the University plans to provide an online graduate certificate in AM for industry. The programs focus on the intersection between materials science, design, and data, teaching students how to identify advanced manufacturing solutions and their use cases, while considering business factors such as operational and capital expenditures. And CSM recently unveiled a Graduate Certificate and Master of Engineering programs in Additive Manufacturing and is working with Red Rocks Community College to revise their AM technician program. Without the necessary talent across education levels to implement AM technologies, the DoD cannot benefit from the improved designs and reduced costs facilitated by AM processes.

Individual companies working in the ADAPT network also contribute to training advances. For example, Citrine hires undergraduate fellows to accelerate their learning about AM. MOOG, an aerospace manufacturer, plans to fund student research projects in AM after several student presentations to ADAPT members. And Big Metal Additive provides AM equipment and training to help organizations identify the materials and properties to develop their desired designs. Recently, BMA trained Marine Corps' maintenance battalions to produce, repair, and design AM replacement parts for ground and sea vehicles. The training included how to use CAD and CAM to print designs and troubleshoot and recover any faulty builds. They teach machinists to run software and operate large metal additive manufacturing machines so they can produce replacement parts for their own needs locally. The Marine Corps plans to integrate AM into their front-line operations, working with BMA to design an AM machine that can be deployed in a shipping container. Also, they have trained maintenance battalions for the Navy and Marine Corps at Camp Lejeune, Camp Pendleton, and Carter Rock.

Improved Capability and/or Production Adjustments

A key benefit of the training modules provided by the University of Utah is helping companies match AM processes to manufacturing use-cases. While AM does eliminate the need for some processes, companies still will need to rely on traditional machining and need to understand the business cases for which AM is optimal. AM processes are specifically relevant when considering rapid changes to production. AM reduces the 12-month lead time and associated costs required to prepare a traditional machining process, because a printer can be quickly reconfigured, in tandem with the cloud-based artificially intelligent database developed during this project. AM technologies can enable the warfighter to replace parts and implement new designs without a traditional manufacturing infrastructure.

Additive manufacturing technology benefits the warfighter's lethality both in its improved design possibilities and its ability to enable flexible responses to shifting parameters on the front line. Soldiers in Iraq reinforced the doors of the International MaxxPro MRAP vehicle with 400 pounds of additional metal to protect against the impact of IEDs. Unfortunately, the extra weight added caused door hinges to sag and break, forcing soldiers to drive without doors and wait 6-18 months for replacement hinges.

In response, TARDEC commissioned engineers from Elementum 3D and the Colorado School of Mines ADAPT center to develop an additively manufactured door hinge. ADAPT researchers tested the effect of different build parameters, such as laser density, on the material's roughness and fatigue life. AM processes enabled researchers to now produce the hinge as one part, increasing the design's strength ten-fold. Design changes such as reducing the hinge to one part reduce the complexity of DoD logistics by reducing the number of moving parts to track. The AM design can maintain integrity even when driving full-speed and the doors wide-open. The testing parameters for this material and design are now available across the ADAPT network, allowing other network-members to build upon this research. The research support and testing data provided by the ADAPT network develop and provide confidence in new design-material combinations enabled by AM processes.

Elementum 3D planned on forming cooperative agreements with AM companies to share research around materials characterization and identify best practice in powder bed fusion additive manufacturing. ADAPT served as a pre-existing network for these collaborations, with a shared database of materials characterization curated by AM researchers from the CSM and Citrine. ADAPT's relationship with the DoD and prime contractors helped Elementum 3D pursue contracts with the Army and Navy, resulting in a contract with the U.S. Army's Tank Automotive Research, Development and Engineering Center (TARDEC) to develop a 3D printed door hinge for Mine-Resistant Ambush-Protected (MRAP) vehicles. The ADAPT network proved key in this research, with the Colorado School of Mines stress-testing the hinge to certify its performance, with testing data re-input into the ADAPT database to inform future research.

A key challenge facing the integration of AM into current manufacturing processes is that AM parts have a highly variable range of properties as a result of the wide range of possible design, material, and manufacturing combinations. Additive manufacturers face the possibility of high research costs when exploring a new material, design, or AM process. ADAPT's Citrine powered database shares and predictively analyzes test data for material-process-design combinations across the network, in a manner that is readable across machines and secures any intellectual property, using data reported by network members' testing and AM machines. The Army awarded Elementum 3D a SSTR to develop an easy-to-use, adaptable raw steel feedstock that can service numerous parts. With the Army requiring the feedstock to remain serviceable under a range of conditions, Elementum 3D relied on test data in the ADAPT database to analyze how different designs impact the material's properties, narrowing the scope of the required materials testing. Manufacturers can capitalize upon the network's research to speed the process by which new materials and designs are brought to market.

Lifetime Extension or "Insurance" Efforts

A major limiting factor across any field of research is the loss of knowledge associated with the loss of an organization or researcher from the field. ADAPT's Citrine database seriously reduces this risk by acting as a cloud-based repository for AM research, while also producing new knowledge by leveraging state-of-the-art technology. The Citrine database uses machine learning to organize and curate materials characterization data and predictively identify untested properties through associated test data. The database can predictively analyze how a specific AM process and design impact a material's properties. The ADAPT database begins to certify AM materials by predicting more robust test data using available test results. Certified AM materials reduce the amount of application, or destructive, testing necessary to integrate an AM material into DoD designs, reducing costs and product-to-market times for manufacturers. Certified AM materials allow research funded by this project to become available industry-wide, raising the fields' capacity, and insulating the research from risk of disappearing.

Another concern for the DoD is a loss of manufacturers willing to provide costly-to-produce replacement parts for legacy systems, such as the F-18, F-16, Blackhawk, and Apache, entering service life extension programs. Using AM, a manufacturer can rapidly switch from a commercial process to meet a DoD order at low cost. The ADAPT database provides the necessary data to help integrate AM parts into these systems and enables network members' entrance into this market. The shared availability of the ADAPT network's materials characterization research ensures that new manufacturers can provide AM solutions to legacy systems with limited suppliers benefitting from prior research.

Lessons Learned

Greatest Challenge and Most Important Lessons Learned

The project has faced several challenges and learned important lessons from each. These include:

The grantee had to overcome hurdles in communication, specifically bridging the gap between sciences and across industry and academia. AM requires highly specialized experts across physics and engineering. Facilitating communication across niche researchers proved difficult because of the differences in nomenclature, even within a field; these difficulties only multiplied when providing AM research to industry partners, especially information that is digestible and valid across specialties. Citrine quickly shifted its database to facilitate *teams* of researchers, with persons able to understand, explain, and integrate their niche knowledge into a team's AM project.

It was critical to build a network around a stable platform like Citrine that could collect and curate data from multiple sources. This enabled the team to mine, assemble, and organize information from academic research and industry practice to create a resource with a value proposition that was clear to potential users.

Businesses faced challenges integrating the ADAPT database into their existing processes and databases due to its complexity. Some businesses were cautious about providing data to the ADAPT network because of proprietary considerations. But as the database grew, the value proposition became clearer since the ROI for engaging the network was vastly superior to trial and error methods previously used.