New Mexico Research Center for Distributed Resilient and Emergent-Intelligence-Based Additive Manufacturing (DREAM)

Annual Report – Year 1

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Overview:

The Center for Distributed Resilient and Emergent-intelligence-based Additive Manufacturing (DREAM) is a collaborative initiative bringing together four minority-serving research institutions of New Mexico: New Mexico State University (NMSU), University of New Mexico (UNM), New Mexico Institute of Mining and Technology (NMT), and Navajo Technical University (NTU). Led by NMSU, the DREAM Research Center is pioneering the cyberinfrastructure necessary for jumpstarting the nascent distributed intelligent additive manufacturing (DIAM) industry in the state of New Mexico, with the vision of becoming a world-class hub for the nation and beyond in both technical frameworks and in developing the next-generation workforce that will support this industry.

Through research goals in advanced distributed networking, cybersecurity, testbed-based validation, and digital twin design for the additive manufacturing (AM) industry, the DREAM Research Center seeks to overcome challenges of DIAM including maintaining resilient connectivity between geographically dispersed facilities, meeting data demands for global and local coordination amongst various human and digital systems, and secure and trustworthy computing with safeguards for supply chain networks and intellectual property protection. Concurrently, the DREAM Research Center will supplement these research goals by building workforce capacity through integrated educational resources for skill-development in a broad campaign connecting secondary schools, universities, national laboratories, and industry partners.

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Executive Summary:

Progress in Year 1 for the DREAM Research Center has been on schedule and aligned with the strategic plan. Engagement from graduate students and faculty has enabled significant momentum in collaborative partnerships, communication of findings through outreach and publications, and impactful cross-functional involvement within meetings and with the community. All research tasks are on or ahead of schedule and only one activity within EWD.2.3 was delayed after reconsideration of priorities and interdependent task alignment. Advanced progress was made on Objective 1.3, Objective 4.3, and EWD.2.4 wherein major accomplishments include delivering a preliminary network architecture testbed, an *in-situ* product quality assessment machine learning model, and a successful professional development workshop for 10 K-12 teachers from a local school district in Gadsden, NM.

Project spending is estimated at upwards of 31% of this year's budget, on account of the delay from an institutional moratorium in early 2025, complications with onboarding of personnel, and the need for multiple project-wide deliberations for equipment selection to ensure integration within a connected testbed. Across the project, 18 publications and 3 patents have been generated as output from this grant. Year 1 external engagements included outreach to K-12 students and teachers, various conference presentations, and collaborative partnerships with the Aggie Innovation Space (AIS) at NMSU. AIS has helped to collect data and conduct functional testing within their student-led environment, as well as helping provide practical presentations to K-12 teachers for learning about 3D printers.

Within each goal, the key accomplishments are listed in Table 1 alongside novel opportunities and challenges identified through Year 1 progress. Research Goal 1 is progressing on or ahead of schedule in Year 1. This includes development of iMPROVE, a novel system for addressing Quality of Service (QoS) standards across all stages of data transmission; formulation of network slicing approaches for additive manufacturing (AM) setups; the creation of network architecture for microservices to begin outlining the interaction between services, agents, and SDN components; and definition of a semantic data structure for building of ontologies based on AM domain knowledge. Within this research goal, key knowledge in additive manufacturing was communicated informally between computer science experts and manufacturing experts which could be improved with better cross-functional alignment presentations.

Objectives for Research Goal 2 have advanced on schedule despite minor personnel onboarding hurdles. In Year 1, the team delivered on identifying hardware side channel attack approaches, creating authentication protocols addressing computational efficiency, and graphical representations of intrusion detection models from collected data. Amongst the key accomplishments in this goal are the development of experimental setups for identifying side channel attack access points, proposal of novel credentialing systems shared in various conferences which tackle gaps in peer-to-peer payment channel networks, and data collection with AIS for supervisory intrusion detection models using graphical representations of network connectivity.

Research Goal 3 has progressed as planned with a thorough survey of zero-knowledge proof systems yielding an upcoming review publication, designing a self-adaptive pseudo-labeling model for quality monitoring through collaboration with the teams responsible for Research Goal 4, and identifying 2 blockchain platforms for performance testing to address needs by implementing in a secure testbed network that simulates the organizational matrix of distributed intelligent additive manufacturing (DIAM) scenarios. Collaborative work from faculty at NMSU not formally affiliated with DREAM has yielded expert insight and direction while also spurring more interconnection between teams at UNM and NMSU. Efforts in this goal reach across to Research Goal 4, which relies on information that was disclosed after a provisional patent application was complete, causing a slight delay in effective sharing.

For Research Goal 4, progress on the testbed environment and digital twin simulation was conducted on schedule and with key accomplishments in alignment of instrumentation requirements and the development of a functional layer-by-layer product quality assessment model. Within this goal, the team delivered test coupon design and alignment efforts, model training approaches, a provisional patent for a working product quality assessment model in real time using layer segmentation and comparison with the corresponding G-code layer for visual comparison, and gathered simulation requirements within various functions of each research goal for introduction into digital twin environments. Collaborative engagement between various research groups were essential to advancement on this research goal since decisions made within each objective had implications on testbed configurations, data collection methods, network connectivity, and more.

For EWD Goal 1, the team focused on activities concurrently worked on by members of RIO-NM to design and deploy workshops for early career researchers and science communication for limited cohorts which include members of the DREAM project. For EWD Goal 2, the team is working to complete curriculum submission at NTU while overcoming significant hurdles in administrative constraints and budgetary reconciliation and has delivered a K-12 teacher professional development workshop at NMSU 1 year in advance. The team contacted responsible authorities for development of progression maps to map the associates degree at NTU with the BS in Cybersecurity at NMSU and the BS degree creation at NTU. We are working with the stakeholders to get a clear understanding of the curriculum needed at the state level, which will be deployed as micro-credentials for greater access.

Lastly, the Core Leadership Team comprised of institutional leads and the DREAM Research Center Project Manager have been executing on behalf of this project through regular meetings; completion of reporting documentation including: the project's strategic plan, evaluation, and annual report; and onboarding of industrial advisory board members. Initially, biweekly meetings were held for subsections of the project to have more detailed conversations and now have begun to be more inclusive of other DREAM personnel to accommodate more cross-functional decision-making and alignment. Providing project updates and regular due diligence on communications will be improved as the team continues to establish consistency and routine amongst themselves. Overall, engagement from personnel at all levels has fueled positive morale and maintained an atmosphere of expansive thinking punctuated by lively in-person meetings and passionate discussions of future potential.

Table 1: Key Accomplishments, Opportunities, and Challenges for DREAM Research Center Project at Y1 Progress

DREAM Research Center Goals	Year 1 Key Accomplishments	Novel Opportunities	Challenges
Research Goal 1: Build a Cloud-Edge Continuum Architecture	Developed a core network architecture and testbed, new methods for data transmission and slicing, and semantic data structures for efficient future query and automation.	Architecture build-out progressed ahead of schedule to allow for equipment testbed decision-making to happen	Additive Manufacturing knowledge could have been communicated to computer science researchers with more structure
Research Goal 2: Build A Secure and Trustworthy Environment for Distributed Manufacturing	Advancements made in security through identifying hardware signal protections, authentication protocols for computational limitations, and graphical representation of network activity for intrusion detection.	Significant publications were disseminated across conferences and equipment communications data collection was enabled by the involvement of AIS	Onboarding personnel and equipment was delayed due to HR issues and decision-making
Research Goal 3: Ensure Verifiability and Auditability of DIAM	Coordinated strategies for verifiable computing and auditable systems relevant to DIAM such as zero-knowledge proofs and blockchain technologies for supply chain provenance.	Work on Supply Chain provenance technologies gained collaborative momentum from contacts at NMSU which motivated the team	Model training using pseudo-labeling required collaborative disclosure which was delayed due to provisional patent processing
Research Goal 4: Perform Validation using Testbeds and Digital Twins	Developed a platform for layer-by-layer product quality assessment, onboarded equipment for interconnected printing of test coupon, and formulated approach for digital twin design.	Collaboration between teams helped gather real-world data and expertise to help build out functional prototypes.	Testbed deployment requires decision-making from all parts of the DREAM Research Center, which delayed equipment onboarding
EWD Goal 1: Increase Research Capacity	Workshops developed by RIO-NM for early research career skills and science communication to the pubic with plans to execute over the summer and fall.	Connections with RIO-NM enabled mutually beneficial progress and sharing of efforts	Workshop size limitations limited the involvement of DREAM personnel
EWD Goal 2: Engage, train, and retain students in STEM to create a STEM Workforce	Completed curriculum submission at NTU while overcoming significant hurdles in administrative constraints and budgetary reconciliation and developed K-12 teacher professional development workshop at NMSU 1 year in advance with marketing video and resources.	Collaborative efforts in communicating science through workshop marketing videos enabled advanced progress and boosted morale amongst students	Budgetary and admin limits at NTU can be overcome and tele-workshop events for associate degree students deferring to Y2 enabled advanced progress of EWD.2.4
Project Management, Evaluation, and Administration (PMEA) Goals	Executing through regular meetings, completion of reporting documentation including: strategic plan, evaluation, and annual report; and onboarding of industrial advisory board members.	Biweekly meetings were conducted in subsections, allowing for more detailed conversations and alignment at project start.	Maintaining momentum with structured reporting of progress updates is key to enabling streamlined compilation efforts like the annual report.

Jurisdiction-Wide Network to Develop High-Quality Research

- All research objectives progressing within schedule of Strategic Plan, with 3 objectives advancing beyond expectations: Objective 1.3, Objective 4.3, and Objective EWD.2.4
- 18 peer-reviewed publications, 3 patents, and 2 submitted IRB's in Year 1
- The team of researchers across the involved universities have been meeting on a biweekly basis. Additionally, there have been several cross-institutional team visits. This has built an interactive team and has aided positive progress. The leads are also interfacing with companies and other institutions in the region.

Incorporation of Diversity, Equity, Access, and Culture of Inclusion

- Under the auspices of the DREAM Center New Mexico Tech. is partnering with AIS at NMSU to collect instrument and user data for building intrusion detection models.
- Cross-institution testbed alignment efforts with onsite visits to all participating institutions to onboard 3D printers in preparation for creating the cross-institutional testbed to study challenges and opportunities in deploying the novel architectures, protocols and algorithms.

Development of Skilled Workforce

- Teacher professional development event on 3D printing with co-design of student engagement activities in Fall 2025.
- Progress on BS in Cybersecurity degree program at Navajo Technical University with the aim for seeking approval in FY2026.
- Outreach event in December 2024 to kickstart relationship building within community and spur engagement with 3D printing companies to build needed workforce.

Incorporation of Use-Inspired Perspectives and Societal Impact

- Discussions and facility tour with Roadrunner 3D to initiate industry partnership on challenges and future potential.
- Equipment alignment efforts surveyed many possible options, priority was given to domestic manufacturing and future-proof design elements.
- The center is making headway in creating a blueprint for deploying distributed, intelligent AM in rural communities.

Research Activities in Year 1

Research Goal 1 : Build a Cloud-Edge Continuum Architecture

Leads: Professor Jay Misra Ph.D. (PI), Professor Michael Devetsikiotis Ph.D. (Co-PI), and Asst. Professor Xiang Sun Ph.D. (Sr. Personnel)

Researchers: 2 Post-doctoral Researchers Dr. Petro M. Tshakwanda and Dr. Henok B. Tsegaye from the Electrical and Computer Engineering Department at UNM; 4 Ph.D. Students Ashok Karukutla, Raddad Almaayn, Abid Mohammad Ali, and Jin Zhang from the Electrical and Computer Engineering Department at UNM; 2 Ph.D. students Sharad Shrestha and George Torres from the Computer Science Department at NMSU.

3 of 3 tasks completed on schedule
6 of 6 active Y1 tasks advancing as planned or ahead of schedule, no tasks behind schedule

Table 2: Research Goal 1 at Y1 Progress

Research Goal 1: Build a Cloud-Edge Continuum Architecture	Expected Year 1 Progress	Year 1 Accomplishments	Responsibility
			Sun, Misra, Devetsikiotis
Objective 1.1: Design a Scalable Network Architecture	Definition of requirements of baseline network for SDN + NFV and identify edge services.	SDN + NFV requirements and edge services outlined, with developed system for QoS and publication.	Misra, Sun
Objective 1.2: Implement Dynamic Network Slicing for 5G and Beyond	Built functional prototype of network slicing solution from defined constraints.	Literature review and publishing functional network slicing prototype for multiple scenarios using reinforcement learning	Sun
Objective 1.3: Multi-agent SDN based Core Network for Intelligent Manufacturing	Establish macroservice framework architecture for MaaS and beginning to design agents.	Designed and deployed multi-agent SDN-based cloud-edge testbed with microservice architecture and service interfaces outlined and 3 publications underway.	Devetsikiotis
Objective 1.4: Integrate Semantic IoT for Intelligent AM	Data structure defined and begun building of ontologies based on AM domain knowledge.	Data structure defined and begun building of ontologies based on AM domain knowledge.	Sun

Research Goal 1 is progressing on or ahead of schedule in Year 1, having developed a core network architecture and testbed, new methods for data transmission and slicing, and semantic data structures for efficient future query and automation.

The Objective 1.1 team has been defining baseline requirements for Software Defined Networks (SDN) and Network Functions Virtualizations (NFV) (Task 1.1.1A) and identifying edge services (Task 1.1.1B) with near-term plans to begin chaining of components for atomizing services. During the year, the team developed iMPROVE, a novel system for addressing Quality of Service (QoS) standards across all stages of data transmission. The result has been submitted to *IEEE MILCOM 2025*.

The team for Objective 1.2 conducted literature review (Task 1.2.1A) and prepared a functional network slicing prototype from defined constraints (Task 1.2.1B). They formulated an approach for two scenarios: additive manufacturing and air-to-ground (A2G) channels, the latter of which was published in the *IEEE Transactions on Mobile Computing*, *2025*. The approach included optimization of parameters using Reinforcement Learning (RL) in a novel way.

Work for Objective 1.3 has enabled DREAM's mission through robust design and preliminary deployment of a multi-agent SDN-based cloud-edge testbed for demonstrating real-time flow control and microservice-based orchestration for intelligent Manufacturing as a Service (MaaS). Leveraging recent work accepted in *IEEE CCWC* and *IEEE VCC*, the team established the architecture for microservices (Task 1.3.1A) before May 2025 and began outlining the interaction between services, agents, and SDN components (Task 1.3.2A) ahead of schedule with three conference publications underway to *IEEE CCNC 2025*, *MeMeA 2025*, and *MDPI Smart Cities.*

Objective 1.4, Task 1.4.1A was complete in March of 2025, wherein the team defined a semantic data structure for building of ontologies based on AM domain knowledge. While the team has developed a structure for assembling semantic data, future work will rely on building out the ontological modules for eventual query and automation.

Objective 1.1: Design a Scalable Network Architecture

Researchers responsible: Professor Jay Misra Ph.D. (PI), 2 Ph.D. students Sharad Shrestha and George Torres, from the Computer Science Department at NMSU

2 active tasks (1A and 2A) on schedule for Y1

Objective 1.1: Design a Scalable Network Architecture			Year 1				Year 2				Year 3				Year 4				Responsibility
1: Aug-Oct; 2: Nov-Jan; 3: Feb-Apr; 4: May-Jul			1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	Misra, Sun
1		Build SDN and NFV network architecture				A		B											Misra, Devetisikiotis, Sun
Tasks	A	Identify requirements of the NFV+SDN compatible baseline architecture				A													
	B	Baseline framework is selected and formalized						B											
2		Chain components and atomize services					A			B		C							Sun, Misra
Tasks	A	Define chain components to begin atomizing					A												
	B	Atomize components								B									
	C	Complete chaining of services (communication, message ontology, security…)										C							
3		Edge service discovery, deployment, and secure data transfer				A					B			C		D			Misra, Sun, Panwar
Tasks	A	Define edge services				A													
	B	Deploy edge service solutions									B								
	C	Test deployment with test data												C					
	D	Deliver edge services														D			

Table 3: Objective 1.1 Gantt Chart at Y1 Progress

In collaboration with tasks in Objective 1.3, researchers advanced on Objective 1.1 Tasks 1 and 3 by outlining network architecture and edge service challenges specific to AM. From this approach, the team defined priorities for the network and developed a novel network design that uses network statistics to ensure Quality-of-Service (QoS) standards across all stages of data transmission, along with a new system designed to adapt to changing network conditions.

Previous solutions for bandwidth treatment using multicast routing were limited by static allocation of network interfaces. The team developed iMPROVE, a forwarding strategy that adapts to real-time changes in network conditions. iMPROVE evaluates current network performance metrics per interface at a node before deciding how to route each packet. Upon receiving a packet, iMPROVE's dynamic selection process at the forwarding node determines how many interfaces to use and which ones to choose based on the packet's traffic-class requirements and each interface's score. The score combines six metrics: bandwidth, success probability, queue fill rate, number of packets sent, jitter, and throughput. The team began implementing and testing of iMPROVE in a simulated environment. The results demonstrated significant improvements over previous QoS-aware design and traditional network architectures at helping prevent both over-utilization of congested links and under-utilization of available bandwidth; balancing load across the network and reducing the likelihood of packet loss or excessive latency.

The team submitted the results to IEEE MILCOM conference and plans to extend iMPROVE by integrating application-specific requirements and statistics—such as those relevant for advanced manufacturing infrastructure: per-job print duration estimates, current machine workload, and priority levels assigned by scheduler—into our scoring and selection framework. By aligning network forwarding decisions even more closely with the operational context of the factory floor, future work aims to operationalize these responses for improved efficiency.

Objective 1.2: Implement Dynamic Network Slicing for 5G and Beyond

Researchers responsible: Asst. Professor Xiang Sun Ph.D. (Sr. Personnel), and Ph.D. Student Abid Mohammad Ali, from the Electrical and Computer Engineering Department at UNM

1 complete task (1A) and 1 active task (1B) on schedule for Y1

Table 4: Objective 1.2 Gantt Chart at Y1 Progress

Objective 1.2: Implement Dynamic Network Slicing for 5G and Beyond			**Year 1**				**Year 2**				**Year 3**				**Year 4**				**Responsibility**
1: Aug-Oct; 2: Nov-Jan; 3: Feb-Apr; 4: May-Jul			1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	**Sun**
1		Design a flexible and efficient network slicing solution	A			B													Sun
Tasks	A	Define constraints for slicing solution	A																
	B	Build functional prototype of network slicing solution				B													
2		Enhance network slicing with resource efficiency						A						B					Sun
Tasks	A	Define the resource management constraints in wireless access networks						A											
	B	Build deep reinforcement learning (DRL) algorithm for efficient wireless resource allocation												B					
3		Simulate/emulate multi-communication technologies											A					B	Sun, Misra
Tasks	A	Build simulated environment for network slicing											A						
	B	Train and test output from DRL algorithm (1.2.2b) with baseline performance																B	

The work began with surveying the constraints of the problem through identifying published challenges in 5G connectivity, network architecture and topology, and methods for addressing complex scenarios including Air to Ground Channels (A2G) and Additive Manufacturing (AM). From this literature review Task 1A (completed by November 2024), the team formulated a novel approach which included optimization methods and parameters using Reinforcement Learning (RL).

Approaching the A2G scenario, the team developed a complete architecture that when implemented, fully established wireless connectivity within an A2G model with a single agent UAV working as a base station. Actor-Critic-based deep reinforcement learning optimization is used for efficient dynamic resource allocation. Preliminary results are satisfactory, and the RL optimization technique indeed proved to be effective to establish a strong wireless channel to serve a maximum number of users. The team's results were published in IEEE Transactions on Mobile Computing, January 2025 and further work is being prepared for dissemination.

Leveraging the learning from the above setup, the team has worked on the second wireless scenario pertaining to modeling of wireless connectivity for AM factory floors. The setup consists of a stationary base station with IoT devices (printers, cameras, etc.) assumed to have fixed demands for resources including power, latency, throughput, and bandwidth. Ensuring Quality of Service (QoS) is the main objective here while handling the packets arriving at the queues. Queueing models, such asM/G/1 are being evaluated in this scenario to represent packet arrival process and service time. At the same time traditional optimization techniques are going to be used to minimize latency while allocating optimal powers to the entities while ensuring low overall interference. We anticipate progress on this in the summer of 2025 leading to publications in the fall of 2025.

Objective 1.3: Multi-agent SDN based Core Network for Intelligent Manufacturing

Researchers responsible: Professor Michael Devetsikiotis Ph.D. (Co-PI), 2 Post-doctoral Researchers Dr. Petro M. Tshakwanda and Dr. Henok B. Tsegaye, and 2 Ph.D. Students Ashok Karukutla and Raddad Almaayn, from the Electrical and Computer Engineering Department at UNM

1 complete task (1A) and 2 active tasks (1B, 2A) ahead of schedule for Y1

Table 5: Objective 1.3 Gantt Chart at Y1 Progress

		Objective 1.3: Multi-agent SDN based Core Network for Intelligent Manufacturing	Year 1				Year 2				Year 3				Year 4				Responsibility
		1: Aug-Oct; 2: Nov-Jan; 3: Feb-Apr; 4: May-Jul	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	**Devetsikiotis**
1		Develop the macroservice framework in the context of SDN to achieve MaaS			A					B									Devetsikiotis, Misra
Tasks	A	Establish macroservice architecture for MaaS			A														
	B	Define interaction between services, agents, and SDN components								B									
2		Design multi-agent systems based on the proposed microservice framework						A		B									Devetsikiotis, Misra
Tasks	A	Define agent framework specifications						A											
	B	Implement agent functionality								B									
3		Optimize the SDN configurations for dynamic microservice deployment												A					Devetsikiotis, Misra
4		Develop efficient inter-agent communications								A				B					Devetsikiotis, Misra
Tasks	A	Create API's for agents to communication with SDN controller and other network elements								A									
	B	Implement inter-agent communications												B					
5		Testing and Validation																A	Devetsikiotis, Misra

The team is designing a novel Multi-Agent Software-Defined Networking (SDN)-based core network architecture to support scalable, intelligent, and resilient cloud-edge continuum infrastructures for Manufacturing-as-a-Service (MaaS). The architecture specifically targets DIAM environments by addressing the orchestration, network programmability, and real-time responsiveness requirements needed to enable decentralized and on-demand manufacturing. In Year 1, the team was able to establish the preliminary architectural design for microservices (by May 2025) and has begun outlining the interaction between services, agents, and SDN components ahead of schedule with three publications underway: 1) *Fortifying Multi-Agent Architectures in Smart Manufacturing – IEEE CCNC 2025* (In Press), 2) *SDN-Based cloud-edge microservices deployment for smart healthcare equipment manufacturing– MeMeA 2025* (Under Review), and 3) *Requirements Analysis of Multi-Agent Microservices in AM – MDPI Smart Cities* (Ongoing).

The team designed and deployed a functional microservice-SDN architecture testbed for DIAM using a three-node Kubernetes cluster comprising a master node, a cloud node hosting SDN agents and applications, and an edge node orchestrated with KubeEdge. The system, shown in Figure 1 below, incorporates ONOS as the SDN controller and Open vSwitch (OVS) at the edge to enable programmable flow control. Multi-agent microservices are deployed as Kubernetes pods to provide local intelligence and network reconfiguration capabilities. Recent work published in *IEEE Virtual Conference on Communications (VCC)* related to network resource management demonstrated the value of predicting computational utilization using neural networks to increase network resiliency. Leveraging this work, the testbed architecture enables MaaS by exposing manufacturing resources, such as 3D printers, computer network control (CNC) machines, and robotic arms, as services over a programmable network. Microservice-based orchestration enables dynamic agent deployment, service registration, and policy-driven routing, supporting flexible, location-transparent manufacturing tasks in real-time.

The team also demonstrated real-time policy enforcement and flow management across cloud and edge nodes using ONOS intents and agent-to-agent messaging for demonstrating integration into the cloud-edge continuum. Similar methodology to this work was recently shared at *IEEE 15th annual Computing and Communications Workshop and Conference (CCWC)* addressing control strategies necessary for enabling resource transmission across a distributed network. The edge node, decoupled from traditional container network interface (CNI) plugins, operates with a lightweight bridge configuration to accommodate custom SDN paths without disrupting KubeEdge's device orchestration.

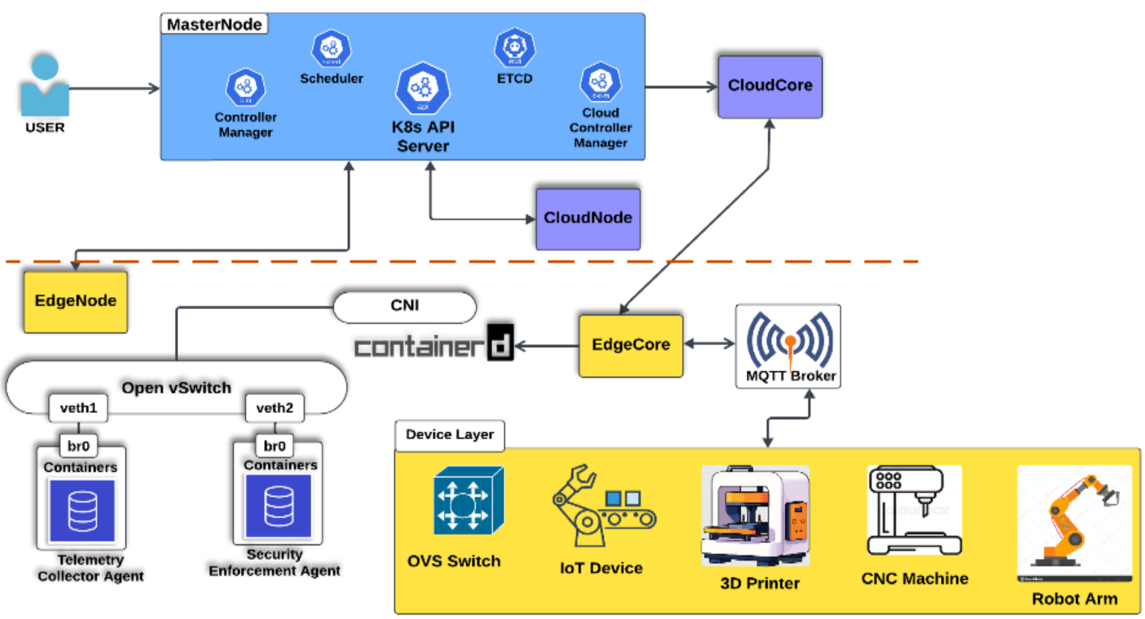

Figure 1: Three Node Hybrid Kubernetes cluster for SDN based core network

Overall, ongoing work on Objective 1.3 has leveraged recent accomplishments to enable advancement of the DREAM Research Center's mission of building a robust microservice and multi-agent based SDN core network for intelligent manufacturing network design. Using ONOS, OVS, and KubeEdge, the team deployed this preliminary version of a multi-agent SDN-based cloud-edge testbed. This work will lead to the eventual demonstration of the real-time flow control and microservice-based orchestration for MaaS.

Objective 1.4: Integrate Semantic IoT for Intelligent AM

Researchers responsible: Asst. Professor Xiang Sun Ph.D. (Sr. Personnel), Ph.D. Student Jin Zhang, from the Electrical and Computer Engineering Department at UNM

1 complete task (1A) and 1 active task (1B) ahead of schedule for Y1

Table 6: Objective 1.4 Gantt Chart at Y1 Progress

Objective 1.4: Integrate Semantic IoT for Intelligent AM			Year 1				Year 2				Year 3				Year 4				Responsibility
1: Aug-Oct; 2: Nov-Jan; 3: Feb-Apr; 4: May-Jul			1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	Sun
Tasks	1	Design lightweight ontologies			A				B											Sun
	A	Define data structure of ontologies for efficiency and light-weight			A															
	B	Build ontologies based on the domain knowledge of additive manufacturing							B											
Tasks	2	Design and develop efficient semantic query and semantic mashup									A				B					Sun
	A	Build semantic query processes based on the designed ontologies									A									
	B	Finalize the mashup system based on semantic query results													B					

For this objective, the team approached integrating semantic technologies to improve the information exchange needed within AM environments. Semantic web tech is widely used in industries to improve machine-accessibility and interoperability due to the adding of machine-readable semantic encoding. In the intelligent additive manufacturing field, this addresses heterogeneity of IoT devices and data, as traditional data or information exchange becomes increasingly difficult to handle in environments with a large diversity in devices and data encoding methods.

The team designed a lightweight AM ontology by using the package Owlready2 to define modules, such as material, process, device, printing methods, and device standards/parameters for query with SPARQL language. After the creation of these ontological modules, the team deployed the ontologies along with specific information for a preliminary range of devices into one central machine acting as server. This specific information is communicated to the server when a 3D printing device is initialized at first usage, which then allows the server to answer queries from edge IoT devices such as associated peripheral computers.

The creation of AM ontology requires a thorough knowledge of IoT devices, such as 3D printers and affiliated downstream processing instrumentation, as well as the data and information shared within the whole system. Now that the team has developed a structure for assembling this required data, the ongoing challenge will be to build out the domain knowledge and advance to creating a distributed query system which can address automation of the AM ecosystem for process monitoring, process control, and error detection.

Research Goal 2: Build A Secure and Trustworthy Environment for Distributed Manufacturing

Leads: Asst. Professor Roopa Vishwanathan Ph.D. (Co-PI), Asst. Professor Krishna Roy Ph.D. (Co-PI), and Assc. Professor Abel-Hameed Badawy Ph.D. (Sr. Personnel)

Researchers responsible: 1 Ph.D. student Youssef Aly from the Electrical and Computer Engineering Department at NMSU; 2 Ph.D. students Kartick Kolachala and Santosh Adhikari, Master student Manuel Mares, from the Computer Science Department at NMSU; 2 Ph.D. Students Md. Mahbub Hasan and Sosmita Paul, and 1 Undergraduate student Marcus Sternhagen from the Electrical Engineering Department of New Mexico Institute of Mining & Technology.

2 of 2 due tasks completed on schedule
5 of 5 active Y1 tasks advancing as planned or ahead of schedule, no tasks behind schedule

Table 7: Research Goal 2 at Y1 Progress

Research Goal 2: Build A Secure and Trustworthy Environment for Distributed Manufacturing	Expected Year 1 Progress	Year 1 Accomplishments	Responsibility
			Badaway, Vishwanathan, Roy
Objective 2.1: Design Supervisory Techniques to Address Trojans and Side-Channel Attacks	Ready to define Segment Anything Model (SAM) for performance profile of AM operations.	Literature review, developing experimental setup, and ready to determine model for side-channel attack profiling.	Badawy
Objective 2.2: Develop Efficient Authentication Protocols and Access Control Models for DIAM	Credential system identified and ready for gap analysis.	Tackling challenges in computation for P2P authentication protocols using novel technology.	Vishwanathan
Objective 2.3: Design Graph-based DIAM Monitoring System for Intrusion Detection.	IRB approval for data collection, ready for identification of human factors and generation of data mapping model.	IRB approved, collaborations with student maker spaces to gather data, and draft of graph-based heuristics for intrusion detection.	Roy

Objectives for Research Goal 2 are reaching milestones within schedule. The three teams responsible for these objectives have made advancements in security through proposal of hardware protections, compute-efficient authentication protocols, and graphical representation of network activity for intrusion detection.

During the summer, the team for Objective 2.1 has been preparing for Task 2.1.1A by reviewing literature, developing experimental setups, and identifying side channel attack access points before defining a Segment Anything Model (SAM) for performance profiling of AM operations by the expected milestone in Q1 of Y2.

The team working on Objective 2.2 identified a credential system (Task 2.2.1A) that eliminates maintenance of the entire network topology and redundant computation by leveraging

Chronological Merkle trees and began tackling research challenges within payment channel networks during gap analysis in Task 2.2.1B to publish three conference papers.

For Objective 2.3, the NMT & NMSU teams are working together with AIS to collect device connectivity data from various AM instruments managed by their student workers. The team delivered on Task 2.3.1A by receiving IRB approval for data collection of human interface data within AM. Through this collaboration with AIS, the team identified data formatting and are identifying human factors relevant to Task 2.3.1B. Concurrently, the team generated a data mapping model in Task 2.3.2A for graph-based DIAM monitoring for intrusion detection which can incorporate both the device communication traffic and human-machine interactions.

Objective 2.1: Design Supervisory Techniques to Address Trojans and Side-Channel Attacks

Researchers responsible: Assc. Professor Abel-Hameed Badawy (Sr. Personnel), and Ph.D. student Youssef Aly from the Electrical and Computer Engineering Department at NMSU

1 active task (1A) on schedule for Y1

Table 8: Objective 2.1 Gantt Chart at Y1 Progress

Objective 2.1: Design Supervisory Techniques to Address Trojans and Side-Channel Attacks		Year 1				Year 2				Year 3				Year 4				Responsibility
1: Aug-Oct; 2: Nov-Jan; 3: Feb-Apr; 4: May-Jul		1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	
1 Tasks	Build a performance profile of AM operations					A	B											Badawy, Misra, Mahajan
A	Decide on Segment Anything Model (SAM)					A												
B	Deliver workable model algorithm						B											
2 Tasks	Build ML models to differentiate normal vs. abnormal behavior							A				B						Badawy, Mahajan
A	Build injection dataset to generate abnormal behavior							A										
B	Finalize tolerance limits used to distinguish abnormal/normal behaviors											B						
3 Tasks	Combine hardware acceleration of ML trained models on FPGAs									A					B			Badawy
A	Integrate model into FPGAs to be tested									A								
B	Finalized version of software model on hardware with profile of tolerance														B			
4 Tasks	Create Trusted ML models with resilient, accelerated inference													A	B			Badawy
A	Produce working platform and interface ready for augmentation													A				
B	Verified Proof of Concept ready for practical use														B			
5	Augment supervisory model with feedback from model-based tests																A	Badawy

The team has reviewed research publications, surveying experimental conditions for detection of electromagnetic side-channel attacks, and developed antennae setups for monitoring unintentional broadcast channels. Using machine learning, monitoring of unprotected channels can be exploited to obtain sensitive information by detection of signal patterns. The team is preparing to design a Segment Anything Model (SAM) to detect and prevent side-channel and hardware Trojan attacks by monitoring hardware signals used within AM operations.

Current summer research will begin monitoring AM-relevant side channels through experimental setups to detect possible weak points for exploitation, after which a machine learning model will be designed and built to interpret signals and suggest signal protection methods. By October 2025, the team hopes to have identified relevant machine learning parameters for side-channel protection in Task 1A to later complete Task 1B by delivering a workable model by January 2026.

Objective 2.2: Develop Efficient Authentication Protocols and Access Control Models for DIAM

Researchers responsible: Asst. Professor Roopa Vishwanathan (Co-PI), Asst. Professor Gaurav Panwar (Sr. Personnel), Ph.D. students Kartick Kolachala and Santosh Adhikari, Master student Manuel Mares from the Computer Science Department at NMSU

1 complete task (1A) and 1 active Y1 task (1B) on schedule

Table 9: Objective 2.2 Gantt Chart at Y1 Progress

Objective 2.2: Develop Efficient Authentication Protocols and Access Control Models for DIAM			Year 1				Year 2				Year 3				Year 4				Responsibility
1: Aug-Oct; 2: Nov-Jan; 3: Feb-Apr; 4: May-Jul			1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	
1		Develop authentication systems using decentralized, anonymous credentials (DAC)			A		B			C									Vishwanathan, Panwar
Tasks	A	Identified credential system			A														
	B	Generate gap analysis and list of requirements for access control					B												
	C	Deliver sequential delegatable anonymous credentailing in decentalized systems using mercurial signatures								C									
2		Design novel revocable credentialing systems, and explore their applications											A		B			C	Vishwanathan, Panwar
Tasks	A	Define revocability constraints for novel anonymous credentialing											A						
	B	Build a revocable, decentralized, anonymous credentialing system													B				
	C	Explore use case to DIAM ecosystem, among other applications and use-cases																C	

Distributed networking enables DIAM goals of decentralization of computing resources and scalability when introducing new agents or nodes to the network. The team is working on creating a peer-to-peer (P2P) payment channel network-based ecosystem for distributed manufacturing. The team envisions a distributed economy at the edge to enable greater participation of myriad stakeholders (designers, slice designers, and manufacturers), especially in rural areas. For this objective, the team has begun addressing how to authenticate nodes and node connections when using a distributed peer-to-peer (P2P) network. While working on the Tasks

1A and 1B in this objective, the team has demonstrated research progress at three conferences: 6th Workshop on the Coordination of Decentralized Finance, 2025; IEEE BuildSec, 2024; IEEE Percom, 2025.

Figure 2 shown below is an example of a payment channel network (PCN), which is a distributed P2P network wherein nodes can transfer resources, typically funds, between each other along established node connections. Within PCNs, it is important for nodes to authenticate others within the network before sending sensitive data, such as funds, along the payment path to the desired recipient. The team has begun development of a payment channel verification process for authenticating nodes and node connections such that nodes will not be required to 1) maintain the entire network topology, 2) access the blockchain, or 3) perform redundant steps. This verification process is generalizable to other distributed systems, including those in DIAM scenarios.

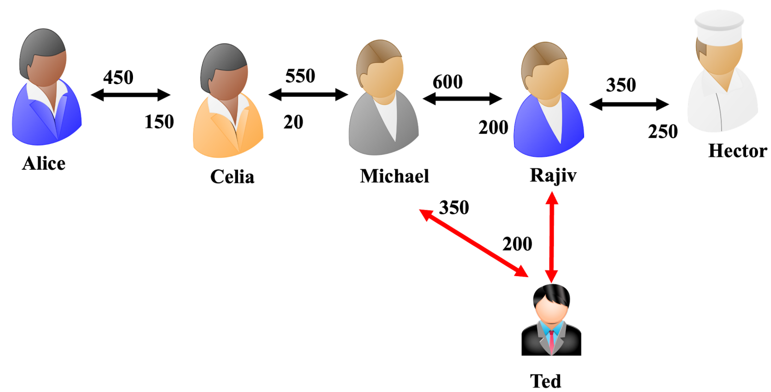

Figure 2: Snapshot of a PCN

Each node is capable of forwarding payments to its immediate neighbor along established payment channel node connections. For instance, Alice can forward payments to Celia, and Celia can send payments to both Alice and Michael. Consider a situation where Alice wants to send a payment to Hector, the payment path is Alice → Celia → Michael → Rajiv → Hector. Before sending, Alice needs to verify that each channel along the payment path is legitimate and that each node is who it claims to be. As an attack, Michael could insert the node named Ted as an additional Sybil node (a fake node) in the routing path to act as an intermediary and collect extra routing fees, resulting in the extended payment path Alice → Celia → Michael → Ted → Rajiv → Hector.

The team's proposed solution leverages chronological Merkle trees to store the necessary and deterministic information pertaining to a payment-channel transactions, enabling nodes to locate and verify them efficiently. This solution addresses storage constraints, eliminates redundant processes, and comes with a proof of validity for the existence and non-existence of a transaction which can also be verified cryptographically. The team is working to translate these solutions to the distributed AM scenarios involving security and intellectual property preservation.

Objective 2.3: Design Graph-based DIAM Monitoring System for Intrusion Detection

Researchers responsible: Asst. Professor Krishna Roy Ph.D. (Co-PI), 2 Ph.D. Students Md. Mahbub Hasan and Sosmita Paul, and 1 Undergraduate student Marcus Sternhagen from the Electrical Engineering Department of New Mexico Institute of Mining & Technology.

1 complete task (1A), 2 active tasks (1B,2A) on schedule, and 1 task (1C) ahead of schedule

Table 10: Objective 2.3 Gantt Chart at Y1 Progress

Objective 2.3: Design Graph-based DIAM Monitoring System for Intrusion Detection.			Year 1				Year 2				Year 3				Year 4				Responsibility
1: Aug-Oct; 2: Nov-Jan; 3: Feb-Apr; 4: May-Jul			1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	
Tasks	1	Collect cyber and human behavioral data			A		B				C								Roy
	A	IRB Approval			A														
	B	Identify human factors to analyze					B												
	C	Collect new and publicly available datasets									C								
Tasks	2	Construct a heterogeneous information network (HIN)					A						B						Roy
	A	Generate a heterogeneous data mapping model					A												
	B	Visualize HetG-CH graphed											B						
	3	Develop HetG-CH graph model abstraction using GNN													A				Roy
	4	AI intrusion detection model using cyber-human graph semantics																A	Roy

The team has completed an IRB submission and has been given approval for the collection of network log data and human behavioral data of individuals interfacing with 3D printing instruments. Before approval of the IRB in Spring of 2025, the team began working with IoT datasets that included network logs from publicly available sources. Subsequently, the team collaborated alongside researchers from Objective 4.1 and the Aggie Innovation Space (AIS) at NMSU to collect 20 minutes of benign data collected from interactions within the student maker space. AIS collected network logs, specifically capturing interactions from a controller PC to a 3D printer using Wireshark, outputting data which could be analyzed extensively.

The team is currently extending methodologies from their collaboration with AIS to gather similar data from the New Mexico Tech (NMT) fabrication lab, which includes a Creality K1 Max 3D printer onboarded in recent months. Lastly, the team has also begun documenting various strategies to introduce intentional attacks and anomalies to generate relevant attack datasets for future evaluation.

For this objective, researchers developed a detailed graph-based intrusion detection system, employing a combination of Graph Attention Networks (GAT), feature aggregation via Bidirectional Long Short-Term Memory (BiLSTM), and a preliminary classification mechanism to distinguish normal and anomalous activities.

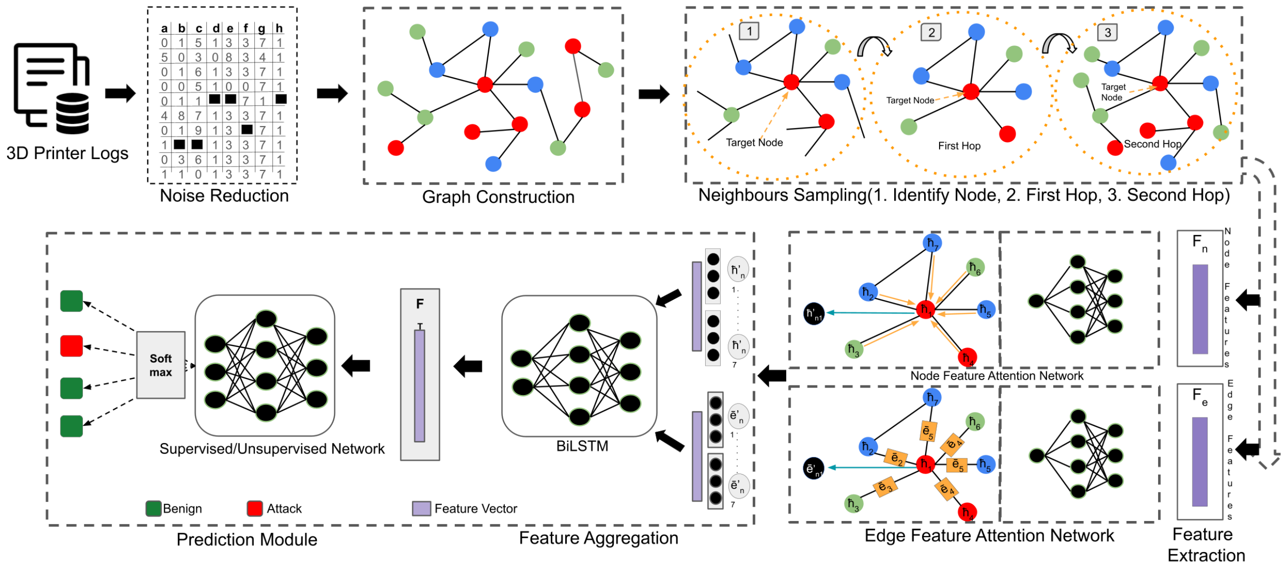

Figure 3: Graph-based DIAM monitoring system architecture.

The graph-based DIAM monitoring system produces an aggregate graph for supervision and malicious activity prediction from processing network log data, as shown in Figure 3. Temporal data and event attributes from the network logs undergo noise reduction, directed graph formulation from event source nodes and node edge interactions, feature extraction and aggregation, and generation of intrusion probabilities for detection. Implemented using PyTorch Geometric and NetworkX frameworks on IoT data, preliminary results demonstrate accurate differentiation between benign and anomalous activities. Metrics, such as accuracy, confusion matrices, and ROC curves validate system efficacy, supporting future extensions to 3D printer datasets and the team plans to share details through upcoming publications to identified conferences or journals.

Research Goal 3: Ensure Verifiability and Auditability of DIAM

Leads: Asst. Professor Xiang Sun Ph.D. (Sr. Personnel), Asst. Professor Gaurav Panwar Ph.D. (Sr. Personnel), and Professor Michael Devetsikiotis Ph.D. (Co-PI)

Researchers responsible: Collaborative contributions from Assc. Professor Raja Jayaraman Ph.D. and Asst. Professor Venkata Sirimuvva Chirala Ph.D. from the Industrial Engineering Department of NMSU, 2 Post-doctoral Researchers Dr. Petro M. Tshakwanda and Dr. Henok B. Tsegaye from the Electrical and Computer Engineering Department of UNM, 1 Ph.D. student Tianjie Chen from the Computer Science Department of NMSU, 3 Ph.D. students Yie Sheng Chen, Raddad Almaayn, and Ashok Karukutla and from the Electrical and Computer Engineering Department of UNM

2 of 2 due tasks completed on schedule
5 of 5 active Y1 tasks advancing as planned or ahead of schedule

Table 11: Research Goal 3 at Y1 Progress

Research Goal 3: Ensure Verifiability and Auditability of DIAM	Expected Year 1 Progress	Year 1 Accomplishments	Responsibility
			Panwar, Sun
Objective 3.1: Implement Verifiable Edge Computing	Zero-knowledge proof systems reviewed, begun evaluation for applicability to DIAM.	Thorough survey and review publication of verifiable computing strategies including zero-knowledge proof systems for DIAM.	Panwar
Objective 3.2: Verifiable and Efficient Distributed Machine Learning for Quality Control and Process Improvements	Collected datasets applicable for self-adaptive pseudo-labeling.	Datasets aligned from public and DREAM testbed sources to develop strategy for self-adaptive pseudo-labeling.	Sun
Objective 3.3: Design Blockchains for Supply Chain Provenance, Visibility, and Auditability.	Blockchain platforms and consensus algorithms identified, beginning to build cross-platform reputation system.	2 identified blockchain platforms to address DIAM needs, ready for performance testing. Secure testbed network built for DIAM scenarios and published.	Panwar

The team working on Research Goal 3 has progressed as planned to coordinate strategies for verifiable computing and auditable systems relevant to DIAM.

For Objective 3.1, a thorough survey of zero-knowledge proof systems through Task 3.1.1A has yielded an upcoming review publication and relevant strategies for beginning to implement verifiable computing principles for DIAM applications (task 3.1.1B).

On Objective 3.2, the team is set to complete Task 3.2.1A by identifying datasets and novel methods applicable for designing a self-adaptive pseudo-labeling model for quality monitoring, both from aligning with collaborators working on Objective 4.1 and from publicly available sources. The team has pulled from relevant work conducted previously by PI Misra's lab regarding federated learning and will be developing a new strategy in alignment with the DREAM testbed development efforts using semantic segmentation.

Within work for Objective 3.3, the team has completed Task 3.3.1A, identifying two blockchain platforms that can address the needs for DIAM and began performance testing for active Task 3.3.1B. The team has concurrently made progress on Task 3.3.2A with the creation of a secure testbed network that simulates stakeholder interactions and multi-functional communication and supply chain networks in DIAM scenarios, with plans to share this work in a conference publication for MDPI Smart Cities 2025.

Objective 3.1: Implement Verifiable Edge Computing

Researchers responsible: Asst. Professor Gaurav Panwar Ph.D. (Sr. Personnel), 1 Ph.D. student Tianjie Chen from the Computer Science Department of NMSU

1 complete task (1A), 2 active tasks (1B,2A) on schedule

Table 12: Objective 3.1 Gantt Chart at Y1 Progress

Objective 3.1: Implement Verifiable Edge Computing			Year 1				Year 2				Year 3				Year 4				Responsibilty
1: Aug-Oct; 2: Nov-Jan; 3: Feb-Apr; 4: May-Jul			1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	
Tasks 1		Build a non-interactive zero-knowledge (zkSnark) based framework			A			B											Vishwanathan, Misra
	A	Identify and review ZKproof (zero-knowledge) systems			A														
	B	Evaluated ZKproof systems for applicability to DIAM						B											
Tasks 2		Build a platform integrating Trusted Execution Environments for verifiable computation at the network edge						A			B			C					Panwar, Misra
	A	Integrating trusted execution environments with cryptographic mechanisms to scale the proving operations						A											
	B	Incorporate access control, provisioning, and attestation of secure enclaves in edge ecosystems.									B								
	C	Testbed will be deployed for testing, benchmarking of frameworks.												C					

The team completed Task 3.1.1A by collecting around 130 papers on existing verifiable computation (VC) systems, categorized by a range of relevant topics such as bugs / vulnerabilities with existing systems, compilers for VC systems, hardware-related VC methods, incremental adoption of VC and related methods, succinct non-interactive arguments of knowledge (SNARK) and zero-knowledge SNARK (zkSNARK) proof systems, zero-knowledge virtual machines (zkVM) for VC, and other miscellaneous VC strategies (e.g. VC outsourcing, VC on data stream, VC pipeline). The team plans to publish an extensive survey by the end of Year 1 to share the insights from this literature review.

The team also explored several compilers and zkVMs available outside of academic literature. Most zkVMs are written in Rust and use either proprietary or off-the-shelf zero-knowledge Scalable Transparent Argument of Knowledge (zk-STARK) proof systems. This reliance on Rust may cause problems when adopting VC into existing code written in other languages, such as Python or C++, identifying considerations for the team as they begin integrating trusted execution environments for VC in active Task 3.1.2A. In addition to reconciling strategies for zkVMs, the team noticed that there is an increasing trend in creating RISC-V-based accelerators for cryptography and VC. Current progress on Task 3.1.1B has yet to determine whether these accelerators can be used for DIAM systems.

Objective 3.2: Verifiable and Efficient Distributed Machine Learning for Quality Control and Process Improvements

Researchers responsible: Asst. Professor Xiang Sun Ph.D. (Sr. Personnel), 1 Ph.D. student Yie Sheng Chen from the Electrical and Computer Engineering Department of UNM, Asst. Professor Chaitanya Mahajan (Sr. Personnel), Prof. Satyajayant Misra (PI), Ph.D. students Jesus Diaz (IE Dept.) and Casey Tran (CS Dept.) from NMSU.

1 active task (1A) on schedule

Table 13: Objective 3.2 Gantt Chart at Y1 Progress

Objective 3.2: Verifiable and Efficient Distributed Machine Learning for Quality Control and Process Improvements			Year 1				Year 2				Year 3				Year 4				Responsibility
1: Aug-Oct; 2: Nov-Jan; 3: Feb-Apr; 4: May-Jul			1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	
1 Tasks		Self-adaptive pseudo labeling based on softmax probabilities				A		B		C									Mahajan, Sun
	A	Collect datasets that are publicly available and/or from the manufacturing prototypes from NMSU				A													
	B	Design a novel pesudo-labeling model						B											
	C	Train and test the pseudo-label model								C									
2 Tasks		Semi-supervised federated training over images									A			B					Sun
	A	Define a novel semi-supervised machine learning model for mixed labeled and pseudo labeled images									A								
	B	Apply classic federated learning to model for multi-site distributed training												B					
3 Tasks		Adjusting local weights based on freshness in async FL aggregation												A				B	Sun, Misra
	A	Design a staleness aware asynchronous FL for efficient distributive machine learning model training.												A					
	B	Compare performance of the proposed asynchronous FL with FedAvg and other baseline solutions																B	

The team's activity in Y1 focused on pseudo-labeling training operations for quality control models deployed within the DREAM testbed environment. Specifically, the team surveyed the current state of pseudo-labeling strategies that would enable refined training of machine learning models for process monitoring within DIAM and presented methods based on adoption of classic and novel approaches.

For quality monitoring, the team worked in collaboration with the team working on Objective 4.3, which had begun collecting quality assessment data within hardware setups. Significant alignment efforts helped defined the current state of training datasets, train-data collection, and details of the hardware monitoring setups which included 3D printers, web cameras, and corresponding interface software. Adopting a pseudo-labeling model within this testbed ecosystem would refine the usage of collected data and the team proposed converting a classifier found within Meta-Pseudo Labeling (MPL) approaches for pixel-wise semantic segmentation of monitoring data such as images. The teams at UNM and NMSU have been in close collaboration to enable UNM researchers with DIAM contextual information through knowledge transfer by NMSU experts.

The team continues progress on Task 3.2.1A through example pseudo-labeling training on a publicly available CIFAR10 dataset using an open-source PyTorch implementation of MPL. To begin developing a pseudo-labeling model design for a DIAM ecosystem, the team must implement inference code which appeared to be missing in the open-source PyTorch repository.

Objective 3.3: Design Blockchains for Supply Chain Provenance, Visibility, and Auditability

Researchers responsible: Asst. Professor Gaurav Panwar Ph.D. (Sr. Personnel) from the Computer Science Department at NMSU, Assc. Professor Raja Jayaraman Ph.D. from the Industrial Engineering Department of NMSU, and Professor Michael Devetsikiotis Ph.D. (Co-PI), 2 Post-doctoral Researchers Dr. Petro M. Tshakwanda and Dr. Henok B. Tsegaye, 2 Ph.D. Students Ashok Karukutla and Raddad Almaayn from the Electrical and Computer Engineering Department at UNM

1 completed task (1A) and 2 active tasks (1B, 2A) on schedule

Table 14: Objective 3.3 Gantt Chart at Y1 Progress

Objective 3.3: Design Blockchains for Supply Chain Provenance, Visibility, and Auditability.			**Year 1**				**Year 2**				**Year 3**				**Year 4**				**Responsibility**
1: Aug-Oct; 2: Nov-Jan; 3: Feb-Apr; 4: May-Jul			1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	
1		Design and building a global, permissioned blockchain			A			B			C								Panwar, Devetsikiotis, Jayaraman, Misra
Tasks	A	Identify relevant blockchain platforms, consensus algorithms			A														
	B	Compare the performance characteristics						B											
	C	Register stakeholders, develop smart contracts, deploy and test									C								
2		Build a privacy-aware reputation system					A			B			C						Misra, Panwar
Tasks	A	Cross-platform reputation access and anonymous ratings					A												
	B	Develop policies for Role-Based Access Control								B									
	C	Decentralized governance decision making of network participants											C						
3		Secure cloud software updates with blockchain											A			B		C	Panwar, Misra
Tasks	A	Define security of the proposed blockchain-based firmware updates											A						
	B	Deliver firmware integrity, malicious code resistance, and DDoS mitigation														B			
	C	Develop monitoring tools to track performance and security updates																C	

This objective focuses on designing and implementing a secure, scalable, and interoperable permissioned blockchain network to support distributed intelligent additive manufacturing (DIAM). As described in publications to *IEEE 22nd Consumer Communications & Networking Conference (CCNC)* and *IEEE 29th International Workshop on Computer Aided Modeling and Design of Communication Links and Networks (CAMAD)*, effective incorporation of blockchain to DIAM network environments can outperform centralized systems at scale and reduce vulnerability, especially when coupled with federated learning.

Accompanying incorporation into smart manufacturing and edge layers, the selected blockchain platform can also integrate end-to-end supply chain visibility, secure data provenance, and maintain trustworthy multi-stakeholder collaboration across manufacturing entities. To this end, the team completed Task 3.1.1A by identifying two viable blockchain platforms and is actively evaluating them. Both Hyperledger Fabric and Corda could serve as potential platforms for building the permissioned blockchain infrastructure for DIAM. Fabric's modular architecture allows for pluggable consensus mechanisms (e.g., Raft, Kafka, BFT), making it adaptable to different trust models across multi-agent environments. This flexibility is essential for supporting various stakeholders with diverse performance and governance needs. Parallel investigations on Corda's notary-based model help in assessing alternatives for privacy-preserving and legally binding inter-organization transactions.

For active Task 3.3.1B, the selected frameworks are being benchmarked using a combination of synthetic workloads and real-world DIAM workflows. Metrics, such as transaction throughput, endorsement latency, scalability across peers, and consensus finality time are being collected. These metrics inform the selection of optimal configurations and help tailor the network for manufacturing constraints like real-time data exchange and policy-enforced access control.

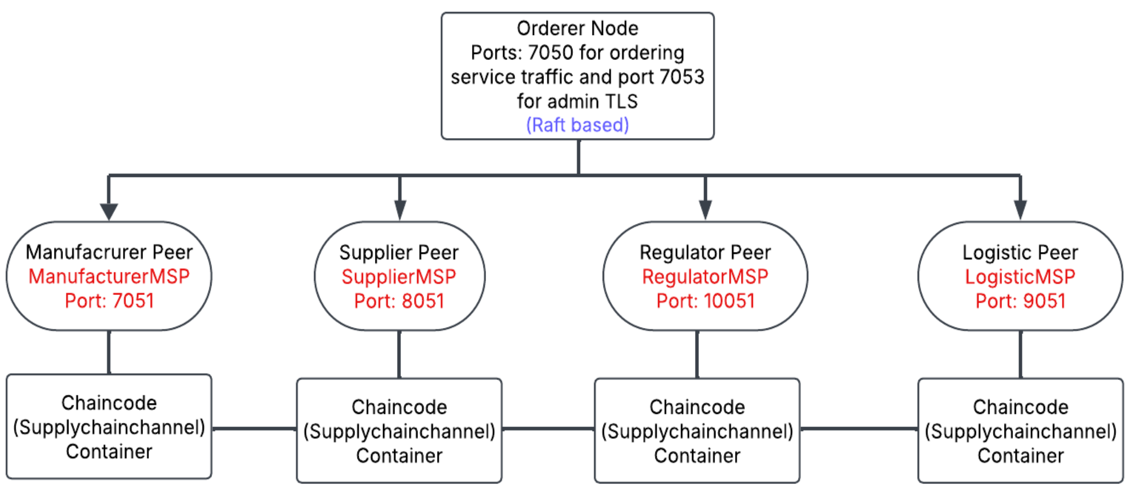

Figure 4: Hyperledger fabric-based supply chain network

Current efforts in configuring a primary testbed for Task 3.3.2A focused on developing a customized supply chain network targeting DIAM requirements using Hyperledger Fabric. The team developed a multi-org Hyperledger Fabric testbed with organizations representing Manufacturer, Supplier, Logistics, and Regulator. Chaincodes (Smart contracts) written in Golang have been deployed to manage digital asset lifecycle: asset registration, ownership transfer, design hash verification, and timestamped approvals. Transport Layer Security (TLS) and Membership Service Provider (MSP) configurations ensure authenticated access. Network policies were fine-tuned to satisfy Admin and Endorsement requirements. The network has been successfully instantiated, peers have joined the channel, and smart contract approvals have begun. Details on this testbed will be shared in an upcoming publication for the MDPI Smart Cities Conference. This testbed design will enable upcoming work for Task 3.3.1C concerning stakeholder onboarding, smart contract development, and network deployment.

Research Goal 4: Perform Validation using Testbeds and Digital Twins

Leads: Asst. Professor Chaitanya Mahajan (Sr. Personnel), Asst. Professor Gaurav Panwar (Sr. Personnel), Asst. Professor Xiang Sun (Sr. Personnel), and Professor Jay Misra (PI)

Researchers responsible: 2 Ph.D. Students Jesus Diaz and Huzaifa Hussain from the Industrial Engineering Department of NMSU, 2 Ph.D. Students Casey Tran and Syed Ziaul Bin Bashar from the Computer Science Department at NMSU, and 1 Ph.D. student Yie Sheng Chen from the Electrical and Computer Engineering Department of UNM

6 of 6 active Y1 tasks advancing as planned or ahead of schedule

Table 15: Research Goal 4 at Y1 Progress

Research Goal 4: Perform Validation using Testbeds and Digital Twins	Expected Year 1 Progress	Year 1 Accomplishments	Responsibility Mahajan, Sun, Panwar, Misra
Objective 4.1: Designing and Deploying a Distributed Cloud-Edge Continuum Testbed	CAD file for test coupon is finalized, ready for alignment of test sites with defined evaluation parameters.	**Collaborative CAD design of test coupon with alignment efforts between institutions, leading to growing familiarity with instruments for identifying evaluation parameters.**	**Mahajan, Sun**
Objective 4.2: Test Security Posture in Deployment	Awaiting collection of datasets for edge ML model.	**Awaiting setup of testbeds and model drafts with datasets before experimentation.**	**Panwar, Misra**
Objective 4.3: Demonstration of Real time In-situ Quality Control Using Testbed	Ongoing FL algorithm development while awaiting creation of edge ML model.	**Federated learning translation work to work in DIAM environments. Drafted working model for quality assessment of additive manufacturing products secured through provisional patent, with publication underway.**	**Mahajan, Sun**
Objective 4.4: Digital Twin Design	Determined enabling technology for digital twin system for DIAM and supply chain.	**Collecting relevant simulation data from all DREAM objectives before deciding on digital twin framework.**	**Misra, Panwar**

For Research Goal 4, the team focused on the testbed environment to develop a platform for validating the work from other research goals and incorporate their work into a simulated digital twin environment.

The team for Objective 4.1 coordinated CAD designing of test coupon options along with various outputs from other objectives to align research efforts around model configurations and hardware monitoring setup. This alignment work leads directly into upcoming work for evaluation parameters for print quality assessment at various sites.

While there were no active tasks for Objective 4.2, work from dependent objectives has been progressing to enable upcoming security testing.

Two publications enabled a foundation for the Objective 4.3 team in Task 4.3.1A to continue pursuing federated learning for decentralized DIAM environments. The team also made significant progress through Task 4.3.2A to develop a working model for quality assessment using layer segmentation of G-code content within extrusion 3D printing. This work will be disseminated through a publication with Journal of Additive Manufacturing (JoAM) and has been filed as a provisional patent. The team plans to write an NSF SBIR for this provisional patent to start a technology start up in this area.

The team for Objective 4.4 has focused on collecting relevant data on all DREAM Research Objectives before identifying an enabling technology to create a digital twin system for DIAM and supply chain. This work has depended on various pending decisions from other objectives, including network architecture, monitoring setup, additive manufacturing supply chain, and data transmission steps.

Objective 4.1: Designing and Deploying a Distributed Cloud-Edge Continuum Testbed

Researchers responsible: Asst. Professor Chaitanya Mahajan (Sr. Personnel), Prof. Satyajayant Misra (PI) and 2 Ph.D. Students Jesus Diaz and Huzaifa Hussain from the Industrial Engineering Department of NMSU, and 1 Ph.D. Students Casey Tran and Syed Ziaul Bin Bashar from Computer Science Department at NMSU

3 active tasks (1A, 1B, 2A) on schedule

Table 16: Objective 4.1 Gantt Chart at Y1 Progress

Objective 4.1: Designing and Deploying a Distributed Cloud-Edge Continuum Testbed			Year 1				Year 2				Year 3				Year 4				Responsibility
1: Aug-Oct; 2: Nov-Jan; 3: Feb-Apr; 4: May-Jul			1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	
1		Design and print test coupons				A	B			C									Mahajan, Halliday
Tasks	A	Finalize design the CAD file for the test coupon				A													
	B	Hardware alignment between NTU and NMSU					B												
	C	Print the test coupon with material extrusion (FFF) AM technique on multiple sites								C									
2		Evaluate print consistency across sites				A				B									Mahajan, Halliday
Tasks	A	Identify evaluation parameters and how they will be evaluated (acceptable deviations)				A													
	B	Identify process parameter optimization for successful print at each site and each process								B									
3		Confirming dimension consistency remotely for each printed test coupon											A	B				C	Mahajan, Halliday
Tasks	A	Network setup											A						
	B	Determine baseline deviations from networked remote connection process												B					
	C	Addressing deviations imparted by network																C	
4		Incorporate security and coordination framework in the network													A				Sun, Panwar, Misra
5		Deploy edge devices at manufacturing sites											A		B				Sun, Panwar, Misra
Tasks	A	Identifying edge devices											A						
	B	Deliver integrated edge devices in network													B				

With respect to Objective 4.1, the team responsible for designing and deploying a functional testbed has narrowed down requirements for processing monitoring strategies and onboarding equipment. Specifically, the team aims to deploy aligned hardware at each collaborating DREAM institution: NMSU, UNM, NTU, and NMT.

The team approached Task 4.1.1A through an initial CAD design proposal following design elements showcased in the textbook Standards, Quality Control, and Measurement

Sciences in 3D Printing and Additive Manufacturing. The design will be finalized and exported for slicing, which will require various hardware parameters to be defined as well. With onboarded equipment at New Mexico Tech, various printers available from the Aggie Innovation Space (AIS) and similar UNM facilities, further hardware alignment between NTU and NMSU continues to be explored in active Task 4.1.1B to narrow down a selection for research-grade 3D filament extrusion printers based on the following criteria: 1) compatibility with a web-based service for monitoring 3D printers called OctoPrint, 2) being a core XY or H printer, and 3) being easily modifiable to attach a camera to a fixed position on the extrusion head.

As part of Task 4.1.2A, the Objective 4.1 team has coordinated alignment needs with the teams for Objective 2.3, 3.2, and 4.3, each of which rely significantly on the process monitoring setup, formatted data collection, and/or instrument interfaces. Evaluation parameters will be addressed in future work as edge-devices are onboarded and assessed.

Objective 4.2: Test Security Posture in Deployment

Researchers responsible: Asst. Professor Gaurav Panwar (Sr. Personnel) from the Computer Science Department at NMSU

No active tasks on schedule until Q1 Y2

Table 17: Objective 4.2 Gantt Chart at Y1 Progress

Objective 4.2: Test Security Posture in Deployment			Year 1				Year 2				Year 3				Year 4				Responsibility
1: Aug-Oct; 2: Nov-Jan; 3: Feb-Apr; 4: May-Jul			1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	
Tasks	1	Test verifiable computing with an edge ML model								A				B					Panwar
	A	Deploy edge model in situ								A									
	B	Complete ML model verification												B					
Tasks	2	Ensure privacy with power metrics and audio signature morphing											A	B					Badawy, Misra
	A	Verify model security											A						
	B	Testing of privacy												B					
	3	Evaluate real-world scalability of cloud security solutions																A	Panwar, Misra, Roy

As shown in the DREAM Research Center Strategic Plan document, there are no active tasks for this objective. This work is dependent on Verifiable Computing output from Objective 3.1 and the team will be assembled once a Trusted Execution Environment has been built at the network edge.

Objective 4.3: Demonstration of Real Time In-situ Quality Control using Testbed

Researchers responsible: Professor Jay Misra (PI) from the Computer Science Department at NMSU and Asst. Professor Xiang Sun (Sr. Personnel), 2 Ph.D. Students Casey Tran and Syed Ziaul Bin Bashar from the Computer Science Department at NMSU and 1 Ph.D. student Yie Sheng Chen from the Electrical and Computer Engineering Department of UNM

2 active tasks (1A, 2A) on schedule

Table 18: Objective 4.3 Gantt Chart at Y1 Progress

Objective 4.3: Demonstration of Real time In-situ Quality Control Using Testbed		Year 1				Year 2				Year 3				Year 4				Responsibility
1: Aug-Oct; 2: Nov-Jan; 3: Feb-Apr; 4: May-Jul		1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	
Tasks 1	Investigate the proposed federated learning (FL) algorithm for scalability, resilience, etc.						A				B	C						Sun
A	Define FL algorithm						A											
B	Produce testable FL algorithm										B							
C	Deliver finalized model											C						
Tasks 2	Use ML for layer analysis to predict manufacturing quality								A				B				C	Misra, Mahajan, Sun
A	Deploy for extrusion process								A									
B	Deliver refined version												B					
C	Completed practical ML analysis																C	

For quality control in DIAM, work has been divided into two tasks that enable designing and deploying machine learning models. Proposed federated learning algorithms published by members of the UNM team are being evaluated through Task 4.3.1A to refine model training and data processing in a decentralized DIAM system.

The team for Objective 4.3 has also developed a promising in-situ layer-by-layer analysis model within Task 4.3.2A to assess quality within extrusion 3D printing. Using a scoring system for quality adherence comparing the sliced layer file to images captured after deposition of each layer during manufacturing. The model uses segmentation of each layer from G-code analysis to perform a statistical quality assessment similar to human quality grading. This work has been written for publication in Elsevier JoAM and filed for provisional patent in collaboration with the Arrowhead Center at NMSU.

Dependent work in other objectives of the DREAM project relies on various aspects of the data collected via the hardware monitoring setup, model configurations such as image segmentation, and file processing and training.

Objective 4.4: Digital Twin Design

Researchers responsible: Professor Jay Misra (PI), 2 Ph.D. Students Casey Tran and Syed Ziaul Bin Bashar from the Computer Science Department at NMSU

1 active tasks (1A) on schedule

Table 19: Objective 4.4 Gantt Chart at Y1 Progress

		Objective 4.4: Digital Twin Design	Year 1				Year 2				Year 3				Year 4				Responsibility
		1: Aug-Oct; 2: Nov-Jan; 3: Feb-Apr; 4: May-Jul	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	
1		Identify the enabling technologies for digital twin				A				B									Sun, Panwar, Roy, Misra
Tasks	A	Idenitfy enabling tech (simulator, emulator, co-sim, etc.)				A													
	B	Finalize selection of tech								B									
2		Design and implement a base digital twin for the DIAM system								A				B					Misra, Mahajan, Panwar
Tasks	A	Deliver version 1 tested against actual								A									
	B	Deliver verified version												B					
3		Deploy and test DIAM supply chain digital twin framework								A				B				C	Chirala, Jayaraman
Tasks	A	Develop conceptual model to integrate blockchain and Digital Twin (DT) technology for AM supply chains								A									
	B	Use simulation software to create a virtual representation of the AM supply chain using the DT framework												B					
	C	Extract data feeds for integration, apply ML for prediction capabilities, deliver visualizations for live insights																C	

Working on Objective 4.4 has involved collecting the work from various objectives and defining parameters to simulate activity in the network architecture, monitoring setup, additive manufacturing supply chain, and data transmission. Task 4.4.1A has revolved around determining the emulation platform used to deploy this digital twin environment, however evaluating options requires deeper understanding of input constraints. Through the summer, the team aims to deliver initial options that can be configured for initial testbed environments to enable evaluation during Y2.

EWD Goal 1: Increase Research Capacity

Leads: Asst. Professor Marcilene Netongo (Co-PI), Asst. Professor Suparna Chatterjee, Ph.D. (Sr. Personnel), Communication and Outreach Manager Brittney Van Der Werff, MS (Collaborator) and Professor Jay Misra (PI)

Researchers responsible: None

1 of 1 due tasks completed on schedule
3 of 3 active Y1 tasks advancing as planned or ahead of schedule

Table 20: Education and Workforce Development (EWD) Goal 1 at Y1 Progress

EWD Goal 1: Increase Research Capacity	Expected Year 1 Progress	Year 1 Accomplishments	Responsibility
			Netongo, Chatterjee, Misra, RIO-NM
Objective EWD.1.1. Fill key gaps in faculty research expertise	Awaiting administrative bandwidth for hiring processes.	**Awaiting administrative bandwidth and identifying applicant pool for hiring.**	**Netongo**
Objective EWD.1.2: Early Research Career Workshops	Designed early career leadership workshop, ready to be held.	**RIO-NM Early Career workshop designed and held in early June.**	**Misra, RIO-NM**
Objective EWD.1.3: Developing Science Communication to the Public	Designed Science Communication workshop, ready to be held.	**Science communication workshop designed and to be held in Fall of 2025.**	**Chatterjee, RIO-NM**

For EWD Goal 1, the team focused on activities concurrently worked on by members of RIO-NM to design and deploy workshops for early career researchers and science communication. Our collaborator point of contact, Brittney Van Der Werff was directly involved in planning and executing these workshops which plans to include members of DREAM. For hiring activities in Objective EWD1.1, the team has been awaiting administrative bandwidth in Year 2 before beginning in accordance with the strategic plan.

Objective EWD.1.1: Fill key gaps in faculty research expertise

Researchers responsible: Asst. Professor Marcilene Netongo (Co-PI) from the Cybersecurity department at Navajo Technical University

No active tasks on schedule

Table 21: Objective EWD.1.1 Gantt Chart at Y1 Progress

Objective EWD.1.1. Fill key gaps in faculty research expertise		Year 1				Year 2				Year 3				Year 4				Responsibility
1: Aug-Oct; 2: Nov-Jan; 3: Feb-Apr; 4: May-Jul		1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	
1	Hiring device security expert at NTU								A									Netongo
2	Hiring cloud and edge computing expert at UNM										A				B			Devetsikiotis
Tasks A	Evaluate need and post job										A							
Tasks B	Hired Personnel														B			

This objective is awaiting administrative bandwidth necessary for defining and initiating the hiring processes, alongside refining the applicant pool of potential device security experts willing to serve in this capacity at NTU.

Objective EWD.1.2: Early Research Career Workshops

Researchers responsible: Asst. Professor Marcilene Netongo (Co-PI) from the Cybersecurity department at Navajo Technical University

2 active tasks (1A and 1B) on schedule

Table 22: Objective EWD.1.2 Gantt Chart at Y1 Progress

Objective EWD.1.2: Early Research Career Workshops		Year 1				Year 2				Year 3				Year 4				Responsibility
1: Aug-Oct; 2: Nov-Jan; 3: Feb-Apr; 4: May-Jul		1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	
1	Workshops enhancing leadership, grant/proposal writing for early career faculty and post-docs				A	B				B				B				RIO-NM
Tasks A	Leverage existing material to design workshop through RIO-NM				A													
Tasks B	Hold workshop for DREAM participants and affiliated					B				B				B				

Within this objective, Task 1.A was worked on through the EPSCoR E-CORE RIO-NM project (#OIA-2435071), which sent out for applicant registration in March 2025 and planned to be conducted in early June. Objective EWD.1.2 Task 1.B was completed when the workshop was held on June 03 - 04, 2025 with up to 16 participants after applications received by April 25th. One member of DREAM was involved with this workshop and signed up for training this summer.

The workshop was developed by instructors: William K. Michener, Ph.D., former NSF program officer, statewide EPSCoR project director, and researcher; Selena Connealy, Ph.D., NM EPSCoR Associate Director; and Brittney Van Der Werff, MS, NM EPSCoR Communication and Outreach Manager. The RIO-NM Early Career Workshop is a two-day intensive program for up to 16 NM postdoc and faculty participants in STEM research and education disciplines. This practical, hands-on workshop addresses ideation, proposal writing, project management, and effective public communication, empowering participants to increase their research productivity, funding, and impact.

Objective EWD.1.3: Developing Science Communication to the Public

Researchers responsible: Asst. Professor Suparna Chatterjee, Ph.D. (Sr. Personnel) from the Health, Education, and Social Transformation (HEST) department at NMSU and Communication and Outreach Manager Brittney Van Der Werff, MS (Collaborator) from the New Mexico EPSCoR Office.

1 completed task (1A) and 1 active task (1B) on schedule

Table 23: Objective EWD.1.3 Gantt Chart at Y1 Progress

Objective EWD.1.3: Developing Science Communication to the Public		Year 1				Year 2				Year 3				Year 4				Responsibility
1: Aug-Oct; 2: Nov-Jan; 3: Feb-Apr; 4: May-Jul		1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	
1	Communicate concepts of Advanced Manufacturing identified from K-12 Pathways to the public via workshops/online content			A				B		C				C			C	Chatterjee, RIO-NM
Tasks A	Identify topic areas from K-12 pathways for public distribution			A														
B	Propose workshop and develop content							B										
C	Hold workshop									C				C			C	

Task 1.A was completed in tandem with progress for interdependent Task 2.A of Objective EWD 2.4. Task 1.B has begun with submission of Workshop Award proposals to the EPSCoR E-CORE RIO-NM project (#OIA-2435071) on April 16th, 2025. Once reviewed, Dr. Chatterjee and Dr. Netongo will begin development in coordination with Brittney Van Der Werff. Concepts relevant to advanced manufacturing, 3D printing, and cybersecurity developed for K-12 public audiences in Task 2.A of objective EWD 2.4 were compiled within proposals to the RIO-NM Workshop Awards. Workshop Award support is aimed at convening working groups that emphasize collaborative development and advancement of important ideas and theories, cutting-edge analysis of recent or existing data and information, industry engagement in research, industry/academic partnerships for workforce development, or the use of science in policy or management decisions. By leveraging the developments in Objective EWD 2.4, the proposals affiliated with the DREAM Research Center will focus on catalyzing collaborations across participating disciplines, facilities, and/or institutions. As part of this award, a collaborative workshop for science communication is planned for 30 people to be held September 2025 at NMSU campus, combining efforts from RIO-NM and DREAM.

EWD Research Goal 2: Engage, train, and retain students in STEM to create a STEM Workforce

Leads: Asst. Professor Marcilene Netongo (Co-PI), Asst. Professor Suparna Chatterjee, Ph.D. (Sr. Personnel), Communication and Outreach Manager Brittney Van Der Werff, MS (Collaborator) and Professor Jay Misra (PI)

Researchers responsible: 2 Ph.D. Students Sumanth Reddy Nandhikonda and Rigesh Krishnaraj from the HEST department at NMSU, 2 undergraduate students Jonathan Dennison and Logan Boydjenson from the Cybersecurity Department at Navajo Technical University

2 of 3 due tasks completed on schedule, 1 deferred to Y2
8 of 9 active Y1 tasks advancing as planned or ahead of schedule, 1 deferred to Y2

Table 24: Education and Workforce Development (EWD) Goal 2 at Y1 Progress

EWD Goal 2: Engage, train, and retain diverse students in STEM to create a STEM Workforce	Expected Year 1 Progress	Year 1 Accomplishments	Responsibility Netongo, Chatterjee
Objective EWD.2.1. Support for cybersecurity at NTU	Defined curriculum requirements for bachelor's program at NTU, ready to submit for approval.	**Curriculum submission completed following NTU checklists, challenges overcome in budget reconciliation and creation of TCUP proposals.**	**Netongo**
Objective EWD.2.2. Creating a pipeline for students in NTU and other 2- and 4-year colleges in NM	Progression map for students in higher learning ready to be delivered with tele-workshop designed and held.	**Tele-workshop content and delivery deferred to Year 2, with progression map underway.**	**Chatterjee, Roy**
Objective EWD.2.3. Micro-credential in Cybersecurity for Manufacturing	Curriculum requirements ready to be finalized for micro-credential course.	**NMSU Global requirements outlined with subject matter experts identified and curriculum requirements discussed**	**Chatterjee**
Objective EWD.2.4. Creating K-12 Pathways for advanced manufacturing	Middle and high school partners identified with IRB submitted, identified topic areas for unit plans.	**IRB approved, K-12 teacher PD event ready 1 Year in advance with marketing materials developed for about 10 participants from Gadsden Independent School District (GISD)**	**Chatterjee**

For EWD Goal 2, the team worked diligently to execute on major accomplishments in Objective EWD.2.1 and EWD.2.4, completing curriculum submission at NTU while overcoming initial hurdles in administrative constraints and budgetary reconciliation and delivering a K-12 teacher professional development workshop at NMSU one year in advance, complete with marketing resources, such as an introduction video and flyers, on-site 3D printing activities, and subject matter expert presentations. For Objectives EWD.2.2 and EWD.2.3, the teams have concentrated on contacting administrative bodies, such as NMSU Global and institutional personnel affiliated with cybersecurity educational programs, to define possible resources for development of progression maps and micro-credential coursework. Tasks in EWD.2.2 affiliated with tele-workshops for associate degree students were deemed to be more relevant to be conducted with Year 2 activities and were therefore deferred.

Objective EWD.2.1. Support for cybersecurity at NTU

Researchers responsible: Asst. Professor Marcilene Netongo (Co-PI) and 2 undergraduate students Jonathan Dennison and Logan Boydjenson from the Cybersecurity department at Navajo Technical University

1 active task (1A) on schedule

Table 25: Objective EWD.2.1 Gantt Chart At Y1 Progress

Objective EWD.2.1. Support for cybersecurity at NTU		Year 1				Year 2				Year 3				Year 4				Responsibility
1: Aug-Oct; 2: Nov-Jan; 3: Feb-Apr; 4: May-Jul		1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	
1	Create undergraduate bachelor's program at NTU by enabling online coursework to supplement hands-on work at NTU				A				B				C				D	Netongo
Tasks A	Define curriculum requirements				A													
B	Submitted for approval upon review								B									
C	Deliver curriculum resources												C					
D	Deliver program																D	
2	Create an online course via NMSU Global.								A				B				C	Misra, Panwar, Netongo
Tasks A	Build the Course for DIAM								A									
B	Deliver and Refine Course Content												B					
C	Deliver Course Content																C	

Professor Netongo at the cybersecurity department at NTU has been executing on an existing associates degree while proposing the bachelor's program. The course curriculum for the BS degree program was developed by Dr. Netongo from November to February following an NTU Curriculum Development Checklist. This checklist contained additional line items for marketing and recruitment plans, budgets, syllabi, and assessment plans which were completed from February to March. The completed curriculum and degree plan was submitted for discussions and approval and is currently under consideration. Additional work included: 1) the defending of the program and its budget after submission in early April and 2) the creation of Tribal College and Universities Program (TCUP) cybersecurity infrastructure proposals to the Cyberinfrastructure Health, Assistance, and Improvements (CHAI) program, which was developed to provide Tribal Colleges/Universities funding to upgrade cybersecurity infrastructure. While administration at NTU is supportive of the creation of this program, deploying the proposed budget and establishing additional teaching support created challenges that can hopefully begin to be addressed through online coursework from NMSU Global created in Task 2 and continued work from the curriculum development process.

Objective EWD.2.2. Creating a pipeline for students in NTU and other 2- and 4-year colleges in NM

Researchers responsible: Asst. Professor Suparna Chatterjee, Ph.D. (Sr. Personnel) from the Health, Education, and Social Transformation (HEST) department at NMSU, Asst. Professor Marcilene Netongo from the Cybersecurity department at Navajo Technical University, and Communication and Outreach Manager Brittney Van Der Werff, MS (Collaborator) from the New Mexico EPSCoR Office.

1 active task (1A) on schedule and 2 tasks (2A and 2B) deferred to Y2

Table 26: Objective EWD.2.2 Gantt Chart at Y1 Progress

Objective EWD.2.2. Creating a pipeline for students in NTU and other 2- and 4-year colleges in NM			**Year 1**				**Year 2**				**Year 3**				**Year 4**				**Responsibility**
1: Aug-Oct; 2: Nov-Jan; 3: Feb-Apr; 4: May-Jul			1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	
Tasks	1	Creating a pipeline for students to start their higher education					A				B				C				Chatterjee, Netongo, Devetsikiotis, Misra
	A	Progression map from associates to bachelors to graduate studies					A												
	B	Create mechanism for upward progression									B								
	C	Approve curriculum													C				
Tasks	2	Connect researchers with students through tele-workshops research			A	B			A	B			B				B		RIO-NM (E-CORE), Chatterjee, Roy
	A	Design workshop for identified associates degree students (RIO-NM)			A				A										
	B	Hold Tele-workshop							-	B			B				B		

In Task EWD.2.2.1A, a progression map for students in higher learning is under development by STEM educators Dr. Chatterjee and Professor Netongo in collaboration with other faculty from NMSU and UNM. The tele-workshops for associates degree students defined by Tasks 2A and 2B of this objective has been delayed for initiation in Year 2, due to lack of faculty bandwidth and shifting priorities for RIO-NM. This delay aligns better with the interdependent Task 1A of this objective, as completion of the progression map will allow for a clearer outlook for students participating in this workshop. Holding the first workshop in Task 2B will also help refine the outcomes of Task 1B, which will be concurrent at the end of Year 2. Because of this change, the affected tasks have been highlighted in Table 26.

Objective EWD.2.3. Micro-credential in Cybersecurity for Manufacturing

Researchers responsible: Asst. Professor Suparna Chatterjee, Ph.D. (Sr. Personnel) from the Health, Education, and Social Transformation (HEST) department at NMSU, Assoc. Professor Roopa Vishwanathan, and Asst. Professor Gaurav Panwar (Sr. Personnel) from the Computer Science Department at NMSU.

1 completed task (2A) and 2 active tasks (1A, 2B) on schedule

Table 27: Objective EWD.2.3 Gantt Chart at Y1 Progress

Objective EWD.2.3. Micro-credential in Cybersecurity for Manufacturing			Year 1				Year 2				Year 3				Year 4				Responsibility
1: Aug-Oct; 2: Nov-Jan; 3: Feb-Apr; 4: May-Jul			1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	
Tasks	1	Build and deploy micro-credential course in cybersecurity in manufacturing					A				B								Chatterjee, Panwar
	A	Define curriculum requirements					A												
	B	Launch course									B								

Work on this objective began with Task 1A to define curriculum requirements for deployment within the NMSU Global ecosystem. The team focused on communicating with contacts from NMSU Global to outline the micro-credential process and course deployment. Initial discussions amongst content experts have been to plan course design and define course structure, which involves development of topics, learning objectives, activities, and outcomes, as well as determining the level of engagement required. Content experts have been identified from amongst the DREAM faculty to address the following concepts in DIAM: cybersecurity, advanced manufacturing, artificial intelligence, and decentralized networking.

Objective EWD.2.4. Creating K-12 Pathways for advanced manufacturing

Researchers responsible: Asst. Professor Suparna Chatterjee, Ph.D. (Sr. Personnel) and 2 Ph.D. Students Sumanth Reddy Nandhikonda and Rigesh Krishnaraj from the Health, Education, and Social Transformation (HEST) department at NMSU

1 completed task (2A) and 2 active tasks (1A, 2B) on schedule
2 tasks (2C and 2D) ahead of schedule

Table 28: Objective EWD.2.4 Gantt Chart at Y1 Progress

Objective EWD.2.4. Creating K-12 Pathways for advanced manufacturing			Year 1				Year 2				Year 3				Year 4				Responsibility
1: Aug-Oct; 2: Nov-Jan; 3: Feb-Apr; 4: May-Jul			1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	
1		Middle and high school relationship building		A		B		C											Chatterjee
Tasks	A	Submission of IRB for approval		A															
	B	Schools identified				B													
	C	Submission of IRB for participating schools with relationships made, upon conditional approval				C		C											
2		Cybersecurity and AM curriculum for middle and high schools		A				B	C					D					Chatterjee
Tasks	A	Identify topic areas for unit plans		A															
	B	Plan for teacher recruitment						B											
	C	Approved participant list of teachers							C										
	D	Professional development for middle and high school teachers (plan for codesign)												D					
3		Recruit teachers to create units for minority students						A	B	C		A	B	C					Chatterjee
Tasks	A	Onboarded teachers						A				A							
	B	Codesigned units							B				B						
	C	Implemented and received support								C				C					
4		Co-design, implement, and revise study units through Participatory Action Research (PAR)									A				A	B		C	Chatterjee
Tasks	A	Iterations of co-design with teachers									A				A				
	B	Collaborative assessment														B			
	C	Revised units																C	

Tasks 1A, 1B, and 1C were completed ahead of schedule with IRB submission currently in conditional approval for the identified collaboration with Gadsden Independent School District (GISD). Task 2.A was complete by March of 2025, with output of a conference publication for the Society of Information Technology and Teacher Education (SITE). Tasks 2B, 2C, and 2D are advanced: teacher recruitment happened for the Teacher Professional Development workshop hosted at NMSU in early June. Codesign plans are now targeting Fall of 2025, Q1-Q2 of Y2, for commencement instead of previous plans for Spring of 2026, Q4 of Y2.

During Fall of 2024, two graduate students were hired within the Chatterjee group for research support. In December 2024, two graduate students accompanied Dr. Chatterjee to GISD for a 3D printing showcase as part of an outreach event for K-12 students. Dr. Chatterjee and Dr. Mahajan were accepted for a publication for the SITE conference in March of 2025 in Orlando, Florida. For conducting research involving human subjects, an IRB application was submitted and revised by March 2025 alongside certification with CITI training for Social/Behavioral/Educational Researchers. After IRB submission, letters to school districts in southern New Mexico were sent with positive response from GISD administration. In April, relationship building activities with GISD Chief Academic Officer Maria Hernandez and GISD administrative team began with on-site visits and trust-building presentations which allowed for thorough discussion of school district expectations and alignment for program efficacy. After positive responses from GISD, the groups of Dr. Chatterjee and Dr. Mahajan began teacher recruitment activities including preparation of video resources and printed flyers that summarize PD workshop logistics, the DREAM mission and vision, and plans for teacher co-design through Participatory Action Research (PAR).

Teacher PD workshop event was held from June 2nd to 7th with 10 teachers participating online and in-person on NMSU campus. Presentations from Dr. Mahajan and the Aggie Innovation Space facilitated hands-on practice of 3D printing principles with opportunities to design, slice, and produce 3D printed goods. Surveys and focus group interviews were conducted as Pre-PD and Post-PD activities. Teachers were instructed to plan a 3D-printing related project within their classrooms in Fall 2025 for engaging students and gathering insights on their learning. The team plans to conduct monthly meetings to follow-up with these teachers to provide open communication about insights, challenges, or technical troubleshooting needs for which the DREAM Research Center can provide assistance.

Project Management, Evaluation and Assessment (PMEA)

Leads: Mat Martins (Program Manager) from NMSU College of Engineering and Professor Jay Misra, Ph.D. (PI) from the Computer Science Department at NMSU

Personnel responsible: Mat Martins (Program Manager) from NMSU College of Engineering and Professor Jay Misra, Ph.D. (PI) from the Computer Science Department at NMSU

5 of 5 due tasks completed on schedule
5 of 5 active Y1 tasks advancing as planned or ahead of schedule

Table 29: Education and Workforce Development (EWD) Goal 1 at Y1 Progress

Project Management, Evaluation and Assessment (PMEA)	Expected Year 1 Progress	Year 1 Accomplishments	Responsibility
			Misra, Martins
PMEA Objective 1.1: Administrative Activities	Completed strategic plan, conducting regular bimonthly meetings, and annual submissions completed	Strategic plan submitted and approved by NSF, biweekly meetings conducted with engagement from personnel, and annual submissions completed with feedback	Martins, Boren
PMEA Objective 1.2: Advisory Board	Expectations defined for IAB, nomination letters sent, member responses given for induction, ready for annual advisory board meeting in fall	IAB members sent expectations and nomination letters with positive responses from six leaders ready to meet. Additional board members identified to be sent nominations before end of summer.	Martins

The Core Leadership Team comprised of institutional leads and the DREAM Research Center Project Manager have been executing on this goal through regular meetings, completion of reporting documentation including the strategic plan, evaluation, and annual report, and onboarding of industrial advisory board members.

Objective PMEA.1.1: Administrative Activities

Personnel responsible: Mat Martins (Program Manager) from NMSU College of Engineering and Professor Jay Misra, Ph.D. (PI) from the Computer Science Department at NMSU

3 completed tasks (1A,1D, and 2A) and 3 active tasks (1B, 1C, and 2B) on schedule

Table 30: Objective PMEA.1.1 Gantt Chart at Y1 Progress

PMEA Objective 1.1: Administrative Activities		Year 1				Year 2				Year 3				Year 4				Responsibility
1: Aug-Oct; 2: Nov-Jan; 3: Feb-Apr; 4: May-Jul		1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	
1	Project Management	D	A	B,C	B	B,D	B	B	B,C	B	B	B	B,C,D	B	B	B	B,C	Martins
Tasks	A	Strategic Plan		A														
	B	Meetings: Quarterly Updates, Monthly Progress Check-ins, Biweekly Discussion Spaces			B	B	B	B	B	B	B	B	B	B	B	B	B	B
	C	Annual Update Submissions			C					C				C				C
	D	Kick-off and All-hands Meet-ups (3)	D				D							D				
2	Evaluation			A	B	C		A	B	C		A	B	C		A	B	Misra, Boren (Evaluator)
Tasks	A	Summative assessments			A				A				A				A	
	B	Reporting and Review				B				B				B				B
	C	Incorporation of Feedback					C				C				C			

For this objective, the team met for the project's strategic kick-off meeting, completed the project's strategic plan with NSF approval, and delivered on the project's evaluation. The team has been meeting biweekly as planned with engagement from researchers from each institution. Quarterly updates, monthly project updates via collaborative spreadsheets, and annual submission documentation has been progressing on schedule and has allowed for streamlining of project deliverables with clarity from all levels of project personnel. Biweekly meetings were held in 3 sections, with personnel from Research Goals 1 and 2 meeting one day, Research Goals 3 and 4 meeting later in the week, and EWD goals meeting at the end of the week. This division allowed for more close-knit conversations and enabled more time to be spent deliberating with detailed progress updates and information sharing. As the year progressed and tasks became more interconnected, the team decided to reintegrate the 3 meetings together, with in-person check-ins enabling more cross-functional alignment and motivation from diverse sets of research groups.

Objective PMEA.1.2: Advisory Board

Personnel responsible: Mat Martins (Program Manager) from NMSU College of Engineering and Professor Jay Misra, Ph.D. (PI) from the Computer Science Department at NMSU

2 completed tasks (1A and 1B) and 1 active task (1C) on schedule

Table 31: Objective PMEA.1.2 Gantt Chart at Y1 Progress

PMEA Objective 1.2: Advisory Board		**Year 1**				**Year 2**				**Year 3**				**Year 4**				**Responsibility**
1: Aug-Oct; 2: Nov-Jan; 3: Feb-Apr; 4: May-Jul		1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	
1	DREAM Center Industry Advisory Board from Private Companies and National Labs		A	B	C	D				D				D				Misra, Martins
Tasks: A	Create bylaws and documentation		A															
B	Nominate members			B														
C	Induct members				C													
D	Annual Advisory Board Meetings					D				D				D				

From discussions with the Core Leadership Team, bylaws for the industrial advisory board were developed from expectations for: annual meeting attendance, responses to semi-annual project snapshot updates, capturing industry perspectives, creating opportunities for internships and externships, and creating bridging opportunities for the future workforce. These expectations were compiled into a nomination letter to potential advisory board members, who were identified collaboratively from contacts suggested by faculty leadership within DREAM. The nomination letters were sent to 7 contacts from various national labs and private industry executive teams. Five of the invitees responded positively, one deferred until summer of 2026, and 1 declined with follow up suggestion of new contacts from within their company. A second cohort of potential advisors have also been identified, and invitations are planned to be sent this summer.

External Evaluation

The SOAR Evaluation and Policy Center at NMSU, which provides evaluation as an external entity to extramurally funded projects at NMSU, conducted a thorough assessment of strengths, challenges, and progress adherence for this award. Looking at graduate students' involvement and cross-institutional collaborations that took place in the first year, the evaluation used two sources of data: check-in conversations with key personnel and a completed survey from 17 student researchers. All respondents found the program to be progressing well, with engagement from graduate students and faculty leaders promoting focus and motivation, and collaborative activities inspiring future work, creating a "sense of camaraderie."

Recommendations from the evaluation report include 1) improving clarity to increase equipment spending, 2) ensuring Navajo Technical University has sufficient resources for supporting a BA program in Cybersecurity, and 3) improving avenues for graduate students to provide more focused feedback. In response to these recommendations, the DREAM Core Management Team formed by the institutional leads (PI and Co-PI's) and the Project Manager reflected, discussed, and aligned on strategies for moving forward.

To address these three recommendations the following actions were taken:

1. Firstly, shortly after this evaluation, the Core Management Team provided a synchronizing opportunity across two in-person conference room locations for researchers to meet, provide feedback via surveys, conduct any planning business for the summer months, and connect informally. This meeting also allowed for touring of labs, which aids in identifying equipment needed, and provided an exchange opportunity for a selection of members to travel across the state to share ideas face-to-face.
2. Leadership from labs across each institution have also met to align on testbed equipment requirements to interconnect using technology supported within the DREAM research environment, enabling future equipment purchases.
3. The team also produced a survey on meetings and feedback avenues. Feedback from this survey led to more goal-wise inclusive meeting scheduling and created another outlet for collaborative engagement through a Discord channel where students can more informally connect and express themselves.
4. Lastly, the Core Management Team plans to visit the faculty and administration at Navajo Tech to discuss how participating institutions can enable the emerging bachelor's degree program.

Expenditures and Unobligated Funds:

Upwards of 31% of the $1.829M Year 1 allocated funds are estimated as expenses through July 2025. The lower expenditure is due to a few factors: 1) spending began late due to the delayed kick-off and strategic plan meeting conducted in October causing many students to begin getting paid by this grant after January of 2025; 2) amidst federal administrative executive orders, NMSU instituted a moratorium on research spending for the months of February through April of 2025; 3) equipment spending on this grant has depended on group decision-making from research outputs for several specifications of the testbed build-out. Currently, equipment purchases have begun and will continue through the summer and into Year 2. Spending is expected to increase significantly through Year 2 due to ongoing equipment orders for lab-scale 3D printers, additional planned K-12 engagements, conference and engagement travel to related technical events, and onboarding of professional personnel. The team expects to reach within 20% of Year 2 budget at the next time of reporting.