NEW MEXICO DREAM RESEARCH CENTER: STRATEGIC PLAN

NSF E-RISE RII Award OIA-2417062

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

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New Mexico Jurisdiction

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TABLE OF CONTENTS

Executive Summary

Introduction

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 through an NSF EPSCoR Research Incubators for STEM Excellence Research Infrastructure Improvement (E-RISE RII) award effective August 15, 2024. Collaborators from 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 will pioneer a novel cyberinfrastructure for jumpstarting the nascent distributed intelligent additive manufacturing (DIAM) industry in the state of New Mexico.

Through research goals in advanced distributed networking, cybersecurity, testbed-based validation, and digital twin design for the additive manufacturing (AM) industry, this project aims to overcome challenges of the industry relevant to the state of NM and serve as a model for deployment of DIAM globally. Concurrently, the DREAM Research Center will supplement these research goals by building capacity through a broad campaign of onboarding experts and equipment, providing integrated educational resources for developing DIAM-related skillsets, and establishing academic pipelines that leverage workshops and innovative educational technologies for virtual career-enabling accreditations accessible in rural areas of NM and worldwide.

Vision

The DREAM Research Center envisions New Mexico as a world-class hub for the sustainable distributed intelligent additive manufacturing industry, founded by a resilient and secure distributed network aimed at prioritizing equity for rural and geographically diverse communities where small and medium-sized enterprises (SMEs) are leading economic growth for the state and are aided by a next-generation workforce representative of the state's demographics.

Mission

The DREAM Research Center seeks to address the challenges of DIAM which includes 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 by establishing a transformative and novel manufacturing cyberinfrastructure in New Mexico coupled with innovative educational resources to train a highly skilled and diverse workforce connected to university, national laboratories, and industry partners.

Preface

DIAM requires a framework for seamless and resilient connectivity between geographically dispersed manufacturing facilities, asset designers, and end-users. To this end, this framework must support the data, and communication demands of local and global inferencing, decision-making, and coordination among an array of interfaces: humans, machines, and virtual systems. In pursuit of safeguarding supply chains and protecting intellectual property (IP), effective DIAM infrastructure must operate under the umbrella of security, access control, and trustworthy computing. From the design to distribution, meeting the requirements for cyberinfrastructure in DIAM has been a high barrier to entry for small and medium enterprises (SMEs) in the state which will be the transformative contribution of the DREAM Research Center.

Aligned with the NM Economic Development Department (EDD) and accompanying New Mexico Science & Technology (S&T) Plan, the DREAM Research Center seeks to increase SME participation in the intelligent manufacturing (IM) industry through investing in key infrastructure, developing the workforce and innovative partnerships, accelerating commercialization of intellectual property, and building research capacity.

We foresee our Center as a crucial determinant for making NM a global leader in DIAM and enable SMEs to make an outsized impact on the state's gross domestic product. We believe the unique characteristics of NM: predictable and stable climate, scattered population, large expanses, low cost of labor, and existing investments in manufacturing, financing, and R&D capacity poise the state for becoming surprisingly competitive in DIAM; democratizing manufacturing via SME participation and spurring an epicenter for economic vibrancy in the American Southwest. Oil, natural gas, and agriculture have largely driven NM's economy, but with the focus shifting to renewable energy and the increased adversities of climate change, DREAM can propel manufacturing into a major economic driver for the state in a use-inspired manner. We will be the first such center in the Southwest region joining 14 manufacturing institutes established nationwide by the Departments of Defense (8), Energy (5), and Commerce (1).

NM has a strong presence of federal national labs and defense installations, who are supported in their mission by three major research universities and other four-year and two-year colleges. These federal and defense institutions in NM have cutting-edge advanced manufacturing capacities but are currently isolated from NM educational institutions. The state government has also been a champion for advanced manufacturing and has helped create an advanced manufacturing ecosystem localized to Albuquerque (18 companies) propelled by the S&T Plan. Nationally the federal government and the private sector lack the skilled workforce needed for advanced manufacturing facilities to fill open positions and sustainably grow. Together, the goals of the DREAM Research Center align to address the needs of connecting the industry to sustainable infrastructures for networking, cybersecurity, and skilled workers.

The DREAM Research Center Team

The NM educational institutions collaborating on the shared vision of the DREAM Research Center: NMSU, UNM, NMT, and NTU, each have distinguished capability in accomplishing innovative goals in computer science; electrical, computer, and industrial engineering; and STEM education. The research team members involved with this project and their areas of expertise are listed in the table below.

Name	Role	Title	Institution	Department	Expertise
Satyajayant Misra	PD	Professor	NMSU	Computer Science & Electrical & Computer Engineering	Cloud-edge continuum networking, distributed computing, cybersecurity in machine learning, & blockchains.
Roopa Vishwanathan	Co-PI	Asst. Professor	NMSU	Computer Science	Cryptographic protocols, applied cryptography, blockchains, & decentralized finance.
Michael Devetsikiotis	Co-PI	Professor	UNM	Electrical and Computer Engineering	Computer networking, blockchains, & software-defined networking.
Krishna Roy	Co-PI	Asst. Professor	NMT	Electrical Engineering	Cybersecurity, anomaly detection, security of intelligent transportation systems, & artificial intelligence.
Marceline Netongo	Co-PI	Asst. Professor	NTU	School of Engineering, Math & Technology	Cybersecurity, cybersecurity risk and vulnerability management, & cybersecurity education.
Gaurav Panwar	Sr. Personnel	Asst. Professor	NMSU	Computer Science	Distributed systems, edge computing, applied cryptography, & verifiable computing.
Abel-Hameed Badawy	Sr. Personnel	Assc. Professor	NMSU	Electrical and Computer Engineering	Hardware security using machine learning, hardware trojan detection, supervisory circuit design for side-channel attacks.
Chaitanya G. Mahajan	Sr. Personnel	Asst. Professor	NMSU	Industrial Engineering	Additive manufacturing, printed electronics, & quality assessment.
Suparna Chatterjee	Sr. Personnel	Asst. Professor	NMSU	Curriculum & Instruction	STEM education, design, and learning technology in K-12 and higher education.
Xiang Sun	Sr. Personnel	Asst. Professor	UNM	Electrical and Computer Engineering	Mobile edge computing, cloud computing, Internet of Things, wireless networks, & big-data-driven networking.
Harold Scott Halliday	Sr. Personnel	Director	NTU	Center for Digital Technology	Advanced manufacturing, additive manufacturing, quality control, & manufacturing education.

Table 1: Research Team Members and Expertise.

Partnering Institutions

NMSU: From NMSU there are 6 research members participating as Principal Investigator (PI), Co-Principal Investigator (Co-PI), and four Sr. Personnel and their teams within the DREAM Research Center. Alongside this project, there are fledgling efforts in advanced manufacturing at NMSU: 1) The Quality Control of Additive Manufacturing (QCAM) Consortium: A Department of Energy (DOE)-funded program to meet the needs of US Department of Energy's National Nuclear Security Agency (NNSA) national labs and production plants by laying the groundwork for a sustainable pipeline of underrepresented students in STEM from Minority Serving Institutions (MSIs). 2) NMSU hosts the Aggie Innovation Space (AIS) which is a student-managed makerspace with over ten AM machines, such as binder jet, direct energy deposition, and small polymer printers, established to give students, faculty, and community members access to state-of-the-art AM resources and training to help foster innovation and entrepreneurship in a semi-commercial setting. NMSU also has the largest cluster of expertise in NM for Computer Networking & Communications and Cybersecurity; with four faculty in the former and six in the latter, each assisted by their research groups.

UNM: University of New Mexico (UNM), the only R1-university in NM, has a breadth in physical sciences combined with an array of applied engineering and technology fields. These add to UNM's statewide crucial role in health sciences, social, and education fields. Prominent areas include quantum computing and information sciences, micro- and nano-electronics, materials science, and machine learning (ML). High visibility and high impact centers include the Air Force Research Lab (AFRL)-sponsored center for robotic manufacturing and repair of satellites; and COSMAIC, focusing on space-related research on antennas, satellites, and space communications. Recent efforts have converged on the Internet of Things (IoT), smart grid, smart cities, and intelligent manufacturing as focus areas of growth with new hires.

NMT: At NMT there is a strong focus on additive manufacturing with several federally funded research activities undertaken by four faculty researchers and their labs. The focus on distributed manufacturing is nascent and germinates out of this grant effort. This effort will broaden the interdisciplinary component of AM research at NMT.

NTU: At NTU, advanced manufacturing is a major area of student education and training, supported in large part by an NSF-supported $5.4M additive manufacturing research center. Faculty have been involved in various collaborative efforts, representing the sovereignty of the Navajo Tribe as a Tribal University with unique technological perspective.

PROJECT IMPLEMENTATION

We envision a future-proof, cloud-edge continuum architecture that seamlessly meets the communication needs of the entities and the applications in the DIAM system; create algorithms and protocols for necessary autonomy and coordination among human and robotic agents; and design novel mechanisms for building secure, trustworthy, verifiable, and auditable DIAM processes; which cumulatively create a secure, resilient, and trusted DIAM system.

We will pursue this mission through both capacity-building education and developmental goals and an ambitious research agenda consisting of four complementary and integrative research goals found in Figure 1. This strategic plan brings together an interdisciplinary and diverse research team consisting of successful researchers and educators from the four NM academic institutions, including a four-year tribal university (Table 1).

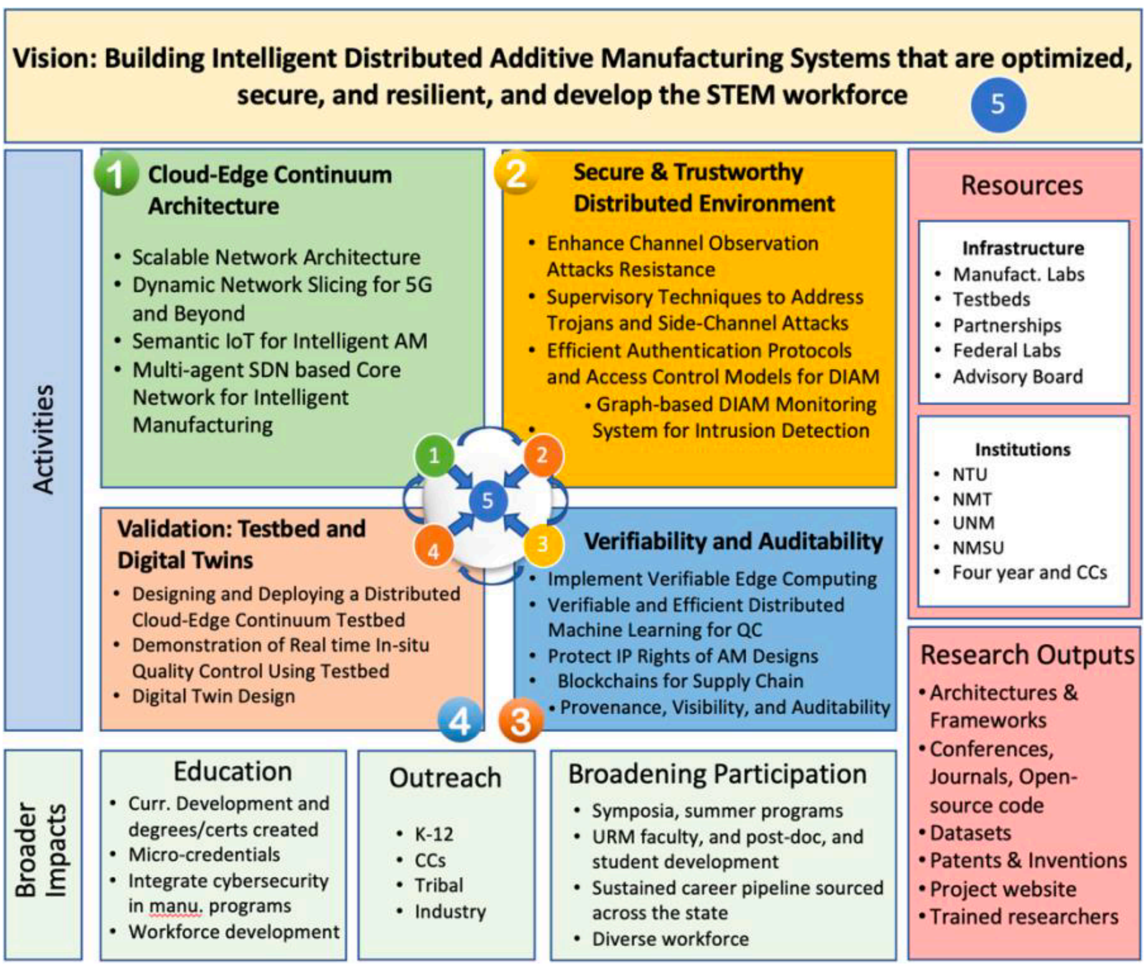

Figure 1: Logic Model of DREAM Center Vision Project Goals

Research Goal Implementation

The first three goals collectively build an architecture incorporating novel design to create a scalable cloud-edge continuum architecture with support for reliable, resilient, and secure production of AM parts, that are trusted, verified, and audited, while enabling detection and mitigation of attacks impinging on the system. Together, they cumulatively inform the fourth goal, which will utilize test facilities and comprehensive simulations of the complete system (enabled by a digital twin) built by Center researchers to study performance. Connections among the goals are iterative for continuous performance improvement.

In this effort, **Research Goal 1 (RG1)** will address fundamental architectural design challenges to build a scalable end-to-end cloud-edge continuum infrastructure. **Research Goal 2 (RG2)** aims to advance basic under-standing of the DIAM environment and build frameworks to enable secure and trustworthy manufacturing. **Research Goal 3 (RG3)** strives to advance the understanding in verifiability and auditability of the computing processes, decision making, and monitoring processes to help build capabilities to enhance trust in the manufacturing outcomes. **Research Goal 4 (RG4)** intends to integrate the outcomes of the other goals to demonstrate the manufacturing and economic/social feasibility of our vision.

The project couples its transformative research agenda with a strong education and outreach program to power local and state economies. **Education and Workforce Development (EWD) Goals** orchestrate these broader capacity-building activities which include investments in two faculty hires, major research equipment purchases to enable research, seed funding that will germinate research and education in regional institutions, and accredited workforce training.

Legend for Parsing the Strategic Plan Tables:

- Annual Milestone tables for each RG or EWD show a qualitative description of the culmination of activity progress by the end of each annual reporting period, with the overall objective goal to be completed by year 4 represented in bold.
- The Activity Gantt Chart tables present the activities planned within each objective with their respective chronological task milestones shown as A, B, C, and so on.
- For each activity, an overall timeline is shown as a compilation of those for the proposed tasks described underneath.
- Each cell in the table represents a quarter of the year, corresponding to the start of the academic year in August.
- Task timelines are described by the colored cells corresponding to the quarters wherein they will be performed. Different shades of red are used to provide contrast between tasks, with white cells signifying inactive periods.

RG1: Building a Cloud-Edge Continuum Architecture

A key DIAM challenge is the need for a secure and resilient cloud-edge continuum network architecture that can support the sensing, data collection, computing, and decision-making operations at the cloud and the edge. Table RG1 presents the annual milestones for this goal.

Research Goal 1: Build a Cloud-Edge Continuum Architecture	Year 1	Year 2	Year 3	Year 4	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.	Chain components atomized after baseline architecture formalized, ready for deployment to edge service solutions.	Fully tested edge service solution deployment, after completed chaining of services.	**Deliver an adaptive, distributed, and scalable on-demand network architecture.**	**Misra, Sun**
Objective 1.2: Implement Dynamic Network Slicing for 5G and Beyond	Built functional prototype of network slicing solution from defined constraints.	Enhancing defined resource management constraints using DRL.	Resource efficiency algorithm being used within simulated environment.	**Deliver a flexible and efficient slicing framework trained by DRL algorithm.**	**Sun**
Objective 1.3: Multi-agent SDN based Core Network for Intelligent Manufacturing	Establish macroservice framework architecture for MaaS and beginning to design agents.	SDN interactions defined, agent functionality implemented for services, and APIs created.	SDN configurations optimized with implemented efficient inter-agent communications.	**Core network tested and validated for resiliency and adaptability.**	**Devetsikiotis**
Objective 1.4: Integrate Semantic IoT for Intelligent AM	Data structure defined and begun building of ontologies based on AM domain knowledge.	Domain knowledge ontologies built and begun to develop efficient semantic query processes.	Mashup system based on sematic query process results ready for finalization.	**Low latency and reliable communication between devices to maintain QoS.**	**Sun**

Table RG1: Annual Milestones for Research Goal 1 – Build a Cloud-Edge Continuum Architecture

Risk Mitigation Strategies for RG1:

- Research leads will address technical capabilities through a progressive reevaluation approach wherein the least resource intensive options will be exhausted before escalating issues through the risk mitigation pipeline.
- Technical challenges will be communicated first to objective leads identified at the rightmost column of Table 2, who will prioritize addressing that challenge themselves before reaching out to the RG leader group listed in the upper rightmost cell of Table 2.
- Project managers will be notified of technical challenges at as they persist enough to impact quarterly projected milestones and interdependent timelines.
- Program manager will interact with the Goal's team regularly to keep the Center leads abreast with the progress.
- Interdependent objectives and activities have been identified and reported to project management and more will likely continue to be identified in response to emergent resource allocations and unforeseen interconnected limitations.

Objective 1.1. Design a Scalable Network Architecture: This objective is the basis for all the other objectives in this research goal with an outcome to investigate the challenges for networking and communications (device heterogeneity, geographic diversity) in intelligent manufacturing along with the need for technology integration (5G, optical wireless, edge computing) to design an adaptive, distributed, and scalable on-demand network architecture.

Activity Outcomes: (1) Use software-defined networking (SDN) and network functions virtualization (NFV) in the design of the architecture for flexible, adaptive, and scalable design. The edge networks use ML models to perform intelligent decision-making for the applications with aid from the Cloud); (2) Expand on the above design and leverage our prior work, to devise service chaining and network function atomization mechanisms for the networked agents/devices; and (3) Expand the architecture with functionalities, such as on-demand edge service discovery, efficient deployment of edge servers, migration of edge servers, scheduling algorithms for edge services, and secure communication and data transfer between edge servers and client devices. Table RG1.1 presents the activity Gantt chart and outcomes for the objective.

Output: 5 publications, 1 patent, and 5 student experts

Research Goal 1: Build a Cloud-Edge Continuum 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	**Sun, Misra, Devetsikiotis**
Objective 1.1: Design a Scalable Network Architecture			Definition of requirements of baseline network for SDN + NFV and identify edge services.				Chain components atomized after baseline architecture formalized, ready for deployment to edge service solutions.				Fully tested edge service solution deployment, after completed chaining of services.				**Deliver an adaptive, distributed, and scalable on-demand network architecture.**				**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 RG1.1: Activity Gantt Chart and Outcomes for Objective 1.1: Design a Scalable Network Architecture

Objective 1.2. Implement Dynamic Network Slicing for 5G and Beyond. With the advent of Industry 4.0, there is a need for low latency (< 1 ms) and reliable (10-9 packet error rates) communications between devices (e.g., IoT gateway and actuators/robots). Also, different AM services may have different quality of service (QoS) requirements in terms of different latency, jitter, and bit error rates. We aim to enhance the architecture proposed in the previous activity to support this advanced manufacturing need. Network slicing can help dynamically partition the radio access network as well as the core network into virtual slices/networks. We hypothesize that this can be used to meet the QoS requirements of different AM services.

Activity Outcomes: (1) Design a flexible and efficient network slicing solution to maximize network resource utilization while scheduling application services such that their QoS requirements are met; (2) Augment the network slicing solution with the design and validation of efficient resource management mechanisms (i.e., power allocation, low-complexity beamforming) for massive multiple-input-multiple-output antennas; and (3) simulate/emulate multi-communication technologies (wired, 5G, wireless) by leveraging prior work. Table RG1.2 presents the activity Gantt chart and outcomes for the objective.

Outputs: 7 publications, 3 student experts.

Research Goal 1: Build a Cloud-Edge Continuum 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	
Objective 1.2: Implement Dynamic Network Slicing for 5G and Beyond			Built functional prototype of network slicing solution from defined constraints.				Enhancing defined resource management constraints using DRL.				Resource efficiency algorithm being used within simulated environment.				**Deliver a flexible and efficient slicing framework trained by DRL algorithm.**				**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	

Table RG1.2: Activity Gantt Chart and Outcomes for Objective 1.2: Implement Dynamic Network Slicing for 5G and Beyond

Objective 1.3. Multi-agent SDN-based Core Network for Intelligent Manufacturing: Objective 1.3 pushes the boundaries of innovation to address the imperative need for a resilient and adaptive network architecture that transcends the limitations of traditional manufacturing. Building upon the microservices-based SDN network architecture proposed in Objective 1.1, we *hypothesize* that to unlock the full potential of AM we need a radical departure from monolithic network architectures to modular microservices meticulously designed to streamline network functionalities to make MaaS a reality, as explored in our preliminary works.

Activity Outcomes: (1) Establishing the microservice SDN framework and defining interactions; (2,3) Investigate microservices and their orchestration using innovative containerization technologies, to establish a foundational layer of our intelligent Core Network. Once optimized, this will serve as the connective tissue in this architectural evolution, with microservices helping create an intricate, flexible, scalable, and dynamic network infrastructure; and (4,5) Seamlessly integrate intelligent agents (routers, microservice servers) into the Core Network, positioning them as tested and validated autonomous decision-makers using ML algorithms (e.g., transformers, reinforcement learning, federated learning) to enable dynamic, real-time decision-making for optimizing the manufacturing ecosystem. Table RG1.3 presents the activity Gantt chart and outcomes for the objective.

Outputs: 5 publications, 5 student experts

Research Goal 1: Build a Cloud-Edge Continuum 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	
Objective 1.3: Multi-agent SDN based Core Network for Intelligent Manufacturing			Establish macroservice framework architecture for MaaS and beginning to design agents.				SDN interactions defined, agent functionality implemented for services, and APIs created.				SDN configurations optimized with implemented efficient inter-agent communications.				**Core network tested and validated for resiliency and adaptability.**				**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

Table RG1.3: Activity Gantt Chart and Outcomes for Objective 1.3: Multi-agent SDN based Core Network for Intelligent Manufacturing

Objective 1.4. Integrate Semantic IoT for Intelligent AM: Modeling a production workflow requires considering aspects from different domains, such as distinct sensors evaluating certain aspects of the basic system, actors used to control the basic system, and costs (e.g., labor, and nominal power consumption of a machine tool). However, due to the heterogeneity of the IoT devices (e.g., different vendor systems, data formats, etc.) across different domains, data/information exchange among different domains is impossible, leading to data silos and hindering effective decision-making. Based on prior work, our *goal* is to integrate semantic technologies to improve the information exchange in the AM system—we *hypothesize* that this integration can break the silos of the generated data to enhance integration and decision-making.

Activity Outcomes: (1) design lightweight ontologies to provide a shared, machine-understandable vocabulary for information exchange among diverse agents (e.g., humans and different machines) interacting and communicating in a heterogeneous DIAM system; and (2) design and develop an efficient semantic query and semantic mashup method to retrieve information explicitly and implicitly over distributed semantic data sets. Table RG1.4 presents the activity Gantt chart and outcomes for the objective.

Outputs: 2 publications, 2 student experts

Research Goal 1: Build a Cloud-Edge Continuum 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	
Objective 1.4: Integrate Semantic IoT for Intelligent AM			Data structure defined and begun building of ontologies based on AM domain knowledge.				Domain knowledge ontologies built and begun to develop efficient semantic query processes.				Mashup system based on sematic query process results ready for finalization.				**Low latency and reliable communication between devices to maintain QoS.**				**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					

Table RG1.4: Activity Gantt Chart and Outcomes for Objective 1.4: Integrate Semantic IoT for Intelligent AM

RG2: Build A Secure and Trustworthy Environment for Distributed Manufacturing

The DIAM system will be subject to a broad range and ever-increasing number of attacks as adoption grows. Here, we will design mechanisms for mitigating security threats and attacks on AM devices and the system to facilitate secure and trusted production. Table RG2 presents the annual milestones for this goal.

Research Goal 2: Build A Secure and Trustworthy Environment for Distributed Manufacturing	**Year 1**	**Year 2**	**Year 3**	**Year 4**	**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.	Performance model algorithm for AM operations built with injection dataset for abnormal behavior, ready for hardware.	Built supervisory ML models with tolerance limits, integrated into FPGAs, ready to deliver working platform.	**Identify AM machine operations and verify AM process integrity in hardware & firmware.**	**Badawy**
Objective 2.2: Develop Efficient Authentication Protocols and Access Control Models for DIAM	Credential system identified and ready for gap analysis.	Authetification system developed using decentralized, anonyous credentials (DAC) using mercurial signatures.	Novel revocable credentialling systems beginning to be built based on defined constraints.	**Secure access control system customized for DIAM needs, including novel revocable credential systems.**	**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.	Collection of new and publically available datasets of cyber and human data with ongoing visualization of HIN.	HIN constructed, HetG-CH graph model abstraction ready for delivery, ongoing intrusion detection model development.	**Graph-based DIAM Intrusion Detection System.**	**Roy**

Table RG2: Annual Milestones for Research Goal 2 – Build A Secure and Trustworthy Environment for Distributed Manufacturing

Risk Mitigation Strategies for RG2:

- Research leads will address technical capabilities through a progressive reevaluation approach wherein the least resource intensive options will be exhausted before escalating issues through the risk mitigation pipeline.
- Technical challenges will be communicated first to objective leads identified at the rightmost column of Table 2, who will prioritize addressing that challenge themselves before reaching out to the RG leader group listed in the upper rightmost cell of Table 2.
- Project managers will be notified of technical challenges at as they persist enough to impact quarterly projected milestones and interdependent timelines.
- Program manager will interact with the Goal's team regularly to keep the Center leads abreast with the progress.
- Interdependent objectives and activities have been identified and reported to project management and more will likely continue to be identified in response to emergent resource allocations and unforeseen interconnected limitations.

Objective 2.1. Design Supervisory Techniques to Address Trojans and Side-Channel Attacks: Prior work has shown that the power signatures of many systems can identify their behavior. We *hypothesize* that the operations of AM machines can be identified using power profiling and, with a trusted SVD file, we can use power signatures to verify if the AM process is truly recreating the design in the SVD file.

Activity Outcomes: (1) collect behavioral characteristics from the power line monitoring of valid operations to build a normal profile of performance for various AM operations, especially tasks from other activities or objectives; (2) build ML models that can differentiate between normal vs. abnormal behavior using the collected characteristics above; (3) combine hardware acceleration of ML trained models on field programmable gate arrays (FPGAs) and possibly application-specific integrated circuits (ASICs) for real-time performance; (4) combine attack-resilient, hardware-accelerated ML inference models to result in trusted ML models that can validate and supervise various AM operations; and (5) augment the supervisory model with feedback from model-based tests in RG4. Table RG2.1 presents the activity Gantt chart and outcomes for the objective.

Outputs: 5 publications, 5 student experts.

Research Goal 2: Build A Secure and Trustworthy Environment for Distributed 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	
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.				Performance model algorithm for AM operations built with injection dataset for abnormal behavior, ready for hardware.				Built supervisory ML models with tolerance limits, integrated into FPGAs, ready to deliver working platform.				**Identify AM machine operations and verify AM process integrity in hardware & firmware.**				**Badawy**
1		Build a performance profile of AM operations					A	B											Badawy, Misra, Mahajan
Tasks	A	Decide on Segment Anything Model (SAM)					A												
	B	Deliver workable model algorithm						B											
2		Build ML models to differentiate normal vs. abnormal behavior							A				B						Badawy, Mahajan
Tasks	A	Build injection dataset to generate abnormal behavior							A										
	B	Finalize tolerance limits used to distinguish abnormal/normal behaviors											B						
3		Combine hardware acceleration of ML trained models on FPGAs									A					B			Badawy
Tasks	A	Integrate model into FPGAs to be tested									A								
	B	Finalized version of software model on hardware with profile of tolerance														B			
4		Create Trusted ML models with resilient, accelerated inference													A	B			Badawy
Tasks	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

Table RG2.1: Activity Gantt Chart and Outcomes for Objective 2.1: Design Supervisory Techniques to Address Trojans and Side-Channel Attacks

Objective 2.2. Develop Efficient Authentication Protocols and Access Control Models for DIAM: Authentication is critical for the security of the DIAM system by verifying the identity of an entity (user or device) to prevent unauthorized access to the system. We will explore a variety of access control methods for authentication. Broadly, in the research literature, there are two ways to define access control and enforce authentication. One is defining access control policies and relying on an authentication server (or a distributed group of servers with a threshold honesty assumption). This technique forms the basis of attribute-based access control (ABAC) and role-based access control (RBAC). The other is cryptographic access control. Neither of these techniques has been explored in the DIAM literature.

Activity Outcomes: (1) Explore attribute-based access control and role-based access control techniques where users are given attributes, and resources are assigned policies that govern what attributes are needed to access a given resource. This type of access control relies on an authentication server(s) to enforce the policies, but is relatively inexpensive and straightforward to implement, which makes it attractive for resource constrained IoT devices in the DIAM system; and (2) Investigate the use of attribute-based cryptosystems for authentication. This line of research uses attributes and policies. However, the main difference between this and the previous activity is that the checks required for authentication are *cryptographically and mathematically enforced* as opposed to relying on an authentication server to enforce them. Table RG2.2 presents the activity Gantt chart and outcomes for the objective.

Outputs: 4 publications, 4 student experts.

		Research Goal 2: Build A Secure and Trustworthy Environment for Distributed 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	
		Objective 2.2: Develop Efficient Authentication Protocols and Access Control Models for DIAM	Credential system identified and ready for gap analysis.				Authetification system developed using decentralized, anonyous credentials (DAC) using mercurial signatures.				Novel revocable credentialling systems beginning to be built based on defined constraints.				**Secure access control system customized for DIAM needs, including novel revocable credential systems.**				**Vishwanathan**
1		Develop authentication systems using decentralized, anonymous credentials (DAC)			A		B			C									Vishwanathan
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	

Table RG2.2: Activity Gantt Chart and Outcomes for Objective 2.2: Develop Efficient Authentication Protocols and Access Control Models for DIAM

Objective 2.3 Design Graph-based DIAM Monitoring System for Intrusion Detection: Continuous monitoring of the DIAM communication channels is imperative to uphold network security and ensure seamless system operability. Employing next-generation anomaly detection and monitoring systems is essential for identifying potential cyber threats, anomalies, or unauthorized activities throughout the manufacturing process. Real-time monitoring of machine and operator behavior, process parameters, and data integrity can enable early detection and response to potential security breaches, safeguarding the integrity and reliability of the DIAM environment. Heterogeneous information from the network activity and human behavioral factors can be represented using a heterogeneous graph to enable multi-domain analysis and anomaly detection. Expanding our prior work GraphCH, we will design a next-generation cyber-human behavioral graph-based intrusion detection framework.

Activity Outcomes: (1) collect cyber and human behavioral data during AM operations; (2) construct a heterogeneous information network (HIN) from the behavioral data for complex cyber-human behavioral analysis; (3) develop a graph representation learning model using GNN for understanding the multidomain relationships in the HIN; and (4) build AI model for intrusion detection leveraging the cyber-human graph semantics. Table RG2.3 presents the activity Gantt chart and outcomes for the objective.

Outputs: 3 publications, 6 student experts.

		Research Goal 2: Build A Secure and Trustworthy Environment for Distributed 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	
		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.				Collection of new and publically available datasets of cyber and human data with ongoing visualization of HIN.				HIN constructed, HetG-CH graph model abstraction ready for delivery, ongoing intrustion detection model development.				**Graph-based DIAM Intrusion Detection System.**				**Roy**
1		Collect cyber and human behavioral data			A		B				C								Roy
Tasks	A	IRB Approval			A														
	B	Identify human factors to analyze					B												
	C	Collect new and publicly available datasets									C								
2		Construct a heterogeneous information network (HIN)					A						B						Roy
Tasks	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

Table RG2.3: Activity Gantt Chart and Outcomes for Objective 2.3: Design Graph-based DIAM Monitoring System for Intrusion Detection

RG3: Ensure Verifiability and Audibility of DIAM

Given the broad attack surface for DIAM systems and the significant scope for device, data, and systems compromise (and incentives for it), we will address system security challenges related to verifying design files, correct operations of applications, and guaranteeing overall supply chain auditability. Table RG3 presents the annual milestones for this goal.

Research Goal 3: Ensure Verifiability and Auditability of DIAM	Year 1	Year 2	Year 3	Year 4	Responsibility Panwar, Sun
Objective 3.1: Implement Verifiable Edge Computing	Zero-knowledge proof systems reviewed, begun evaluation for applicability to DIAM.	ZKproof framework buil and integrated Trusted Execution Environments and ready to deliver secure enclaves.	Platform built for integrating trusted execution environments for verfiable computation at network edge.	**Zero-knowledge succinct non-interactive arguments of knowledge (zkSnark) Framework 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.	Trained and tested novel pseudo-labeling model designed for DIAM, ready for application to training over images.	Delivered semi-supervised ML for diverse image set applied to distributed training and adjusted for freshness.	**Semi-supervised, asynchronous FL framework for semantic segmentation and prediction for QC.**	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.	Blockchain ready for deployment, developed reputation system with policies for role-based access control.	Built privacy-aware reputation system with decision-making, defined blockchain-based firmware updates.	**Delivered supply chain visibility and auditability of DIAM via blockchain and privacy-aware reputation system.**	Panwar

Table RG3: Annual Milestones for Research Goal 3 – Ensure Verifiability and Audibility of DIAM

Risk Mitigation Strategies for RG3:

- Research leads will address technical capabilities through a progressive reevaluation approach wherein the least resource intensive options will be exhausted before escalating issues through the risk mitigation pipeline.
- Technical challenges will be communicated first to objective leads identified at the rightmost column of Table 4, who will prioritize addressing that challenge themselves before reaching out to the RG leader group listed in the upper rightmost cell of Table 4.
- Project managers will be notified of technical challenges at as they persist enough to impact quarterly projected milestones and interdependent timelines.
- Program manager will interact with the Goal’s team regularly to keep the Center leads abreast with the progress.
- Interdependent objectives and activities have been identified and reported to project management and more will likely continue to be identified in response to emergent resource allocations and unforeseen interconnected limitations.

Objective 3.1. Implement Verifiable Edge Computing: Given the propensity of device compromise and the potential for malicious operations post-compromise, there is a need to verify computation correctness. Existing solutions for verifiable computation (VC) depend on replicated computation, probabilistic solutions, or leverage computation inside trusted execution environments (TEEs) and are non-scalable for real-world implementations. Recently, zero-knowledge succinct non-interactive arguments of knowledge (*zkSnarks*) have been proposed as a promising approach (*hypothesis*), where an entity can provide proof of correct computation to a questioning entity. However, there are some challenges regarding the computational complexity of proof generation and verification. Lightweight verification of proofs is a key objective for such frameworks in edge networks because of the resource-constrained nature of the parties involved. In DIAMs, the verifiable computation systems will help in verifying the execution of the manufacturing operation by the 3D printers at the edge. The verifying party could be a customer or the manufacturing company in the cloud checking that the edge device that executed the code for the 3D printing performed the operations correctly.

Apart from VC, there is still need a need for quality control (QC) systems for physical inspection and verification in the physical realm. The cryptographic proof systems proposed in the literature rely on the conversion of code into arithmetic circuits used in the proving frameworks which is a non-trivial task since the circuit converters need to support all the possible functionality that is supported by the same code language. There are various efforts to build a circuit builder but there are limitations to the approaches such as support for the functionality of the code being converted and in other cases writing the code in a specialized high-level language instead of common use ones such as Python, Java, or C++. TEEs have been to execute sensitive code, but this is problematic due to the resource constraints on the systems and requires a framework that offloads critical sections of the execution to the TEE to be able to scale. Integrating TEEs in the DIAM domain will require the identification of key characteristics of the edge 3D printing workflow and identification of weak points and attack vectors possible in the system.

Activity Outcomes: (1) investigate the available proof systems and build a framework that applies to the DIAM domain, building on our prior work; and (2) we will investigate and build a platform utilizing TEEs at the network edge as an alternative to purely cryptographic systems to verify the high-fidelity results. We will also investigate frameworks that leverage TEEs and cryptography to build hybrid frameworks to overcome the shortcomings of the individual approaches. Table RG3.1 presents the activity Gantt chart and outcomes for the objective.

Outputs: 3 publications, 1 patent, and 3 student experts

Research Goal 3: Ensure Verifiability and Auditability of DIAM			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	
Objective 3.1: Implement Verifiable Edge Computing			Zero-knowledge proof systems reviewed, begun evaluation for applicability to DIAM.				ZKproof framework buil and integrated Trusted Execution Environments and ready to deliver secure enclaves.				Platform built for integrating trusted execution environments for verfiable computation at network edge.				**Zero-knowledge succinct non-interactive arguments of knowledge (zkSnark) Framework for DIAM.**				**Panwar**
1		Build a non-interactive zero-knowledge (zkSnark) based framework			A			B											Vishwanathan, Misra
Tasks	A	Identify and review ZKproof (zero-knowledge) systems			A														
	B	Evaluated ZKproof systems for applicability to DIAM						B											
2		Build a platform integrating Trusted Execution Environments for verifiable computation at the network edge						A			B			C					Panwar, Misra
Tasks	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					

Table RG3.1: Activity Gantt Chart and Outcomes for Objective 3.1: Implement Verifiable Edge Computing

Objective 3.2. Verifiable and Efficient Distributed ML for Quality Control and Defect Detection: Quality control in AM is critical to ensure the production of high-quality parts by identifying and mitigating defects that could compromise the performance, reliability, or safety of manufactured components. One of the widely used defect detection methods in AM quality control is semantic segmentation, which applies computer vision and machine learning (ML) to identify and classify different types of defects or anomalies within an image
of productions at a pixel-level precision. The effectiveness of identifying defects relies on the ML model's performance. The current solution to obtain a high-quality ML model is to train it with numerous labeled images on a centralized server, which is difficult to implement if not impossible. This is because: 1) raw production images are unlabeled, and manually labeling all the pixels in these images is time-consuming and leads to high labor costs. and 2) uploading images to a centralized server to train the ML model is inefficient, consuming humongous network resources and leading to long network delay, and may be impossible due to data privacy, i.e., different AM machines are reluctant to share their production images with a centralized server, which is owned by a third-party entity.
To tackle this challenge, we propose a semi-supervised asynchronous federated learning for semantic segmentation framework to enable different AM machines to train the ML model in a distributed and collaborative setting, without sharing raw production images and manually labeling all the training images.

Activity Outcomes: (1) self-adaptive pseudo labeling to obtain artificial labels for unlabeled images based on the soft-max probabilities; (2) semi-supervised federated training over images with accurate and artificial labels; (3) staleness-aware model aggregation to improve the training efficiency in asynchronous federated learning, where the weight of a local model during the model aggregation depends on the freshness of the local model. The team has developed resource management, client selection, and model aggregation in both wireless synchronous and semi-synchronous federated learning and applied federated learning to train generative adversarial networks (GANs) that are used for molecule discovery. All these prior works serve as the foundation for the success of this research objective. Table RG3.2 presents the activity Gantt chart and outcomes for the objective.

Outputs: 4 publications, and 3 student experts.

Research Goal 3: Ensure Verifiability and Auditability of 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	
Objective 3.2: Verifiable and Efficient Distributed Machine Learning for Quality Control and Process Improvements			Collected datasets applicable for self-adaptive pseudo-labeling.				Trained and tested novel pseudo-labeling model designed for DIAM, ready for application to training over images.				Delivered semi-supervised ML for diverse image set applied to distributed training and adjusted for freshness.				**Semi-supervised, asynchronous FL framework for semantic segmentation and prediction for QC.**				**Sun**
1		Self-adaptive pseudo labeling based on softmax probabilities				A		B		C									Mahajan, Sun
Tasks	A	Collect datasets that are publically 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		Semi-supervised federated training over images									A			B					Sun
Tasks	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		Adjusting local weights based on freshness in async FL aggregation												A				B	Sun, Misra
Tasks	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	

Table RG3.2: Activity Gantt Chart and Outcomes for Objective 3.2: Verifiable and Efficient Distributed Machine Learning for Quality Control and Process Improvements

Objective 3.3. Design Blockchains for Supply Chain Provenance, Visibility, and Auditability: Future distributed supply chains will require significant coordination among the participants. The COVID-19 supply chain perils have shown that visibility and auditability of the supply chain (by producers and governments) are necessary for robust manufacturing. We *hypothesize* that poor visibility is primarily due to the difficulty in gathering and disseminating supply chain information, which is compounded by the need for a) pervasive visibility across the pipeline; b) identifiability of missing, corrupt, and malicious data; and c) privacy and provenance of the on-chain data.

Activity Outcomes: (1) designing and building a global, permissioned distributed ledger to synchronize information on items' visibility and authorizations; and the provenance of data/transactions across agents; (2) building a privacy-aware reputation system to assess the reputation of the entities (vendors, distributors, etc.) based on our prior work; and (3) using blockchain for secure and efficient cloud-based software-firmware updates for machines and IoT devices in the system secure, with trust and auditability. Table RG3.3 presents the activity Gantt chart and outcomes for the objective.

Outputs: 4 publications, and 3 student experts.

Research Goal 3: Ensure Verifiability and Auditability of 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	
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.				Blockchain ready for deployment, developed reputation system with policies for role-based access control.				Built privacy-aware reputation system with decision-making, defined blockchain-based firmware updates.				**Delivered supply chain visibility and auditability of DIAM via blockchain and privacy-aware reputation system.**				**Panwar**
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	

Table RG3.3: Activity Gantt Chart and Outcomes for Objective 3.3: Design Blockchains for Supply Chain Provenance, Visibility, and Auditability

RG4: Perform Validation using Testbeds and Digital Twins

For large-scale DIAM operation, it is important to test the new processing and cyber parameters from RGs 1-3 across manufacturing systems and geographical locations. The testbed will assure flawless network communication and robust cyber security needs for real-time distributed manufacturing. Further, a digital twin framework will help in the assessment of scalability of the proposed research outcomes. Table RG4 presents the annual milestones for this goal.

Research Goal 4: Perform Validation using Testbeds and Digital Twins	**Year 1**	**Year 2**	**Year 3**	**Year 4**	**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.	Test coupons printed and evaluated for consistency at aligned sites.	Remote connection process used to define baseline print consistency, ready for security framework and edge devices.	**Cloud-edge continuum implemented to test frameworks and architecture for resilience in realistic settings.**	**Mahajan, Sun**
Objective 4.2: Test Security Posture in Deployment	Awaiting collection of datasets for edge ML model.	Deployed edge ML model in situ for testing of verifiable computing.	Verified ML model and model security, tested for privacy with power metrics and audio morphing.	**Test suite to test network communications, data transfer, and decision-making effectiveness and scalability.**	**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.	FL algorithm defined and ML for layer analysis deployed for extrusion process.	Delivered finalized FL algorithm after testing and ML for predictive manufacturing quality.	**Testing FL setup to compare added layers to predict product outcomes and reduce carbon footprint.**	**Mahajan, Sun**
Objective 4.4: Digital Twin Design	Determined enabling technology for digital twin system for DIAM and supply chain.	Digital twin system prototype delivered and tested against actual with DIAM supply chain conceptualized.	Digital twin verfied and used to represent DIAM supply chain.	**Digital twin with visualizations scoped from reliable low-latency networks to federated machine learning.**	**Misra, Panwar**

Table RG4: Annual Milestones for Research Goal 4 – Perform Validation using Testbeds and Digital Twins

Risk Mitigation Strategies for RG4:

- Research leads will address technical capabilities through a progressive reevaluation approach wherein the least resource intensive options will be exhausted before escalating issues through the risk mitigation pipeline.
- Technical challenges will be communicated first to objective leads identified at the rightmost column of Table 4, who will prioritize addressing that challenge themselves before reaching out to the RG leader group listed in the upper rightmost cell of Table 4.
- Project managers will be notified of technical challenges at as they persist enough to impact quarterly projected milestones and interdependent timelines.
- Program manager will interact with the Goal's team regularly to keep the Center leads abreast with the progress.
- Interdependent objectives and activities have been identified and reported to project management and more will likely continue to be identified in response to emergent resource allocations and unforeseen interconnected limitations.

Objective 4.1. Designing and Deploying a Distributed Cloud-Edge Continuum Testbed: The *hypothesis* is that NM's mostly rural and disconnected nature lends itself perfectly to the efficacy of distributed manufacturing testing and implementation. NTU has developed a robust advanced manufacturing laboratory that supports mainly metal additive manufacturing and the supporting technologies, the Center for Advanced Manufacturing (CAM). This lab will serve as the foundational testbed for building a distributed, connected testbed across all institutions and implementing cybersecurity measures and a showcase for implementing cybersecurity as this collaborative to aid the Navajo Nation in its move to establish a distributive manufacturing industry.
The *goal* includes developing resilience for distributed AM manufacturing to produce compatible parts or stand-alone components with reproducible quality in a distributed setting.

Activity Outcomes: (1) carefully choose individual parts and an assembly of parts, as test cases, for metallic 3-D printing at the dispersed sites participating in this project; (2) collect the different prints from the sites and compare at a high level for produced dimensions, tolerances, and ability to reproduce a part by the partners or successfully assemble parts produced by different partners (this helps identify if the networking and security processes have an impact in the manufacturing process); (3) create the computer network topology (local and inter-entity) to connect the different manufacturing sites via the communication network architecture built in RG1; (4) incorporate the security and coordination frameworks to form this network; and (5) deploy various edge devices (e.g., NVIDIA Jetson TX2 computing boards and Qualcomm Mobile Hardware Development Kits) at manufacturing sites to offer low latency computing services and integrate the cloud in the architecture using Amazon Web Services (AWS) through the National Science Foundation (NSF) Cloud Bank to test the interchangeability of software/hardware systems of the disparate AM machines (with different printing technology) and their integration. Thus, we will successfully demonstrate a proof-of-concept statewide operational distributed manufacturing infrastructure, thereby building capacity for distributed AM manufacturing in NM. This proof-of-concept also applies to space explorations and defense applications of interest to the NM-based Army Research Lab at White Sands Missile Range, AFRL at Kirtland Air Force Base, NASA-White Sands, and the State's burgeoning private aerospace industry. Table RG4.1 presents the activity Gantt chart and outcomes for the objective.

Outputs: 5 publications, and 9 student experts.

Research Goal 4: Perform Validation using Testbeds and Digital Twins			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	
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.				Test coupons printed and evaluated for consistency at aligned sites.				Remote connection process used to define baseline print consistency, ready for security framework and edge devices.				**Cloud-edge continuum implemented to test frameworks and architecture for resilience in realistic settings.**				**Mahajan, Sun**
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
	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				

Table RG4.1: Activity Gantt Chart and Outcomes for Objective 4.1: Designing and Deploying a Distributed Cloud-Edge Continuum Testbed

Objective 4.2. Test Security Posture in Deployment: Once the statewide network is established using the proposed architecture, the distributed production assembly and the corresponding manufacturing will involve sharing of files, data for building inference models, and remote inference for quality control and process optimization. All this will necessitate significant network communications, decision-making at the edges, and data transfer between the different locations. This will be a comprehensive application scenario for studying the impacts of security, privacy, and access control attacks identified in RG3 on the collaborative manufacturing network infrastructure.

Activity Outcomes: (1) Test the applicability of power measurements and morphing audio signatures in AM for guaranteeing manufacturing privacy while maintaining process integrity of the manufacturing processes; (2) test the utility of different verifiable computation approaches by using the ML models at the edge as test cases; and (3) test the proposed cloud-based security approaches (encryption, access control, etc.) for scalability and iterative refinement in real-world setting. Table RG4.2 presents the activity Gantt chart and outcomes for the objective.

Outputs: 3 publications, and 3 student experts

	Research Goal 4: Perform Validation using Testbeds and Digital Twins	**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	
	Objective 4.2: Test Security Posture in Deployment	Awaiting collection of datasets for edge ML model.				Deployed edge ML model in situ for testing of verifiable computing.				Verified ML model and model security, tested for privacy with power metrics and audio morphing.				**Test suite to test network communications, data transfer, and decision-making effectiveness and scalability.**				**Panwar, Misra**
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

Table RG4.2: Activity Gantt Chart and Outcomes for Objective 4.2: Test Security Posture in Deployment

Objective 4.3. Demonstration of Real time In-situ Quality Control Using Federated ML as a Use-Case: The flexibility of the AM manufacturing process and the often-iterative process of manufacturing a product opens it to many variations in processing quality. Successful real-time quality control of the manufacturing *in situ* holds significant promise of reducing global logistics volumes while enabling the digitization of the production process and overall having a low carbon footprint overall. We hypothesize that this is the perfect use case for demonstrating the impacts of a distributed manufacturing setup.

Activity Outcomes: (1) Using the proposed federated learning (FL) algorithm in Objective 3.2 to assess, in real time, the quality of the printed product, compared with its digital twin reference schematic via a segmentation of digital images of the printed part. While the overall infrastructure building is agnostic of the type of material and AM printing technique, we will use the material extrusion AM printing technique as an illustrative example for real-time, remote quality control. (2) Develop an ML algorithm trained to assess the top layer (TL) in comparison with the previous layers (PLs) can predict the final product outcome. Such an algorithm can be finetuned with several federated learning QC instances working together, which is an aim of this activity. Table RG4.3 presents the activity Gantt chart and outcomes for the objective.

Outputs: 2 publications, and 2 student experts.

Research Goal 4: Perform Validation using Testbeds and Digital Twins		**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	
Objective 4.3: Demonstration of Real time In-situ Quality Control Using Testbed		Ongoing FL algorithm development while awaiting creation of edge ML model.				FL algorithm defined and ML for layer analysis deployed for extrusion process.				Delivered finalized FL algorithm after testing and ML for predictive manufacturing quality.				**Testing FL setup to compare added layers to predict product outcomes and reduce carbon footprint.**				**Mahajan, Sun**
1	Investigate the proposed federated learning (FL) algorithm for scalability, resilience, etc.						A				B	C						Sun
Tasks	A Define FL algorithm						A											
	B Produce testable FL algorithm										B							
	C Deliver finalized model											C						
2	Use ML for layer analysis to predict manufacturing quality								A				B				C	Misra, Mahajan, Sun
Tasks	A Deploy for extrusion process								A									
	B Deliver refined version												B					
	C Completed practical ML analysis																C	

Table RG4.3: Activity Gantt Chart and Outcomes for Objective 4.3: Demonstration of Real time In-situ Quality Control Using Testbed

Objective 4.4. Digital Twin Design: Various technologies are needed to enable a DIAM digital twin. We hypothesize that to study the impact, interaction, and efficacy of our research outcomes mentioned in RG1-3, we will need a digital twin to not only study the DIAM system, but also the supply chain ecosystem.

Activity Outcomes: (1) identify the enabling technologies developed in RGs1-3 for the digital twin (potential technologies include the cloud-edge continuum network architecture supporting reliable and low latency communications, semantic IoT for high interoperability of heterogeneous IoT devices, secure communication protocols and verifiable computing techniques, and distributed real-time machine learning for quality control; (2) design and implement a base digital twin for the DIAM system by integrating the enabling technologies identified in activity 1, and additional ones such as virtual reality/augmented reality (VR/AR) . The digital twin will include a virtual model of the physical testbed (Objective RG 4.1), which interacts with the physical testbed to realize a variety of services. (3) Design a DIAM supply chain digital twin framework that can help understand the supply chain dynamics as well as drive supply chain transparency by developing a virtual model—i.e., a detailed computer simulation model that is run offline and integrate our activities in RG3 to design an end-to-end model of the DIAM production and supply chain process. We will also build a simulator for blockchain technology to secure the data and transactions. Table RG4.4 presents the activity Gantt chart and outcomes for the objective.

Outputs: 4 publications, and 3 student experts.

Research Goal 4: Perform Validation using Testbeds and Digital Twins	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	
Objective 4.4: Digital Twin Design	Determined enabling technology for digital twin system for DIAM and supply chain.				Digital twin system prototype delivered and tested against actual with DIAM supply chain conceptualized.				Digital twin verfied and used to represent DIAM supply chain.				**Digital twin with visualizations scoped from reliable low-latency networks to federated machine learning.**				**Misra, Panwar**
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													
Tasks 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									
Tasks 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									
Tasks B Use simulation software to create a virtual representation of the AM supply chain using the DT framework												B					
Tasks C Extract data feeds for integration, apply ML for prediction capabilities, deliver visualizations for live insights																C	

Table RG4.4: Activity Gantt Chart and Outcomes for Objective 4.4: Digital Twin Design

Education and Workforce Development (EWD) Goal Implementation

To prepare a new cadre of competitive workers, researchers, innovators, and educators, Education and Workforce Development (EWD) activities will: 1) Increase the capacity and research competitiveness of DREAM faculty, postdoctoral researchers, and students; 2) Engage and retain diverse students by forming a pipeline from middle school to higher education in STEM principles and AM as a profession in NM.

EWD1: Increase Research Capacity

Through strategic faculty hires and providing opportunities for professional development we aim to implement the following objectives:

1) *Faculty expertise*: The SWOT analysis by the team identified two gaps: device security and cloud/edge computing (both specific to DIAM), to support project goals and develop NM's AM capacity. 2) *Postdoctoral and early career training*: The postdoctoral period is a formative time for skill development as researchers. Both postdoctoral scholars and early career faculty require core professional competencies which are not typically provided during graduate programs. 3) *Science communication to the public*: Effectively sharing research results and engaging with the public are important skills for researchers and an essential element in the success of communication and outreach activities of DREAM.

Table EWD1 presents the annual milestones of this goal.

Risk Mitigation:

- Education and Workforce Development leads will address capabilities through a progressive reevaluation approach wherein the least resource intensive options will be exhausted before escalating issues through the risk mitigation pipeline.
- Challenges will be communicated first to objective leads identified at the rightmost column of Table 6, who will prioritize addressing that challenge themselves before reaching out to the RG leader group listed in the upper rightmost cell of Table 6.
- Project managers will be notified of challenges at as they persist enough to impact quarterly projected milestones and interdependent timelines.
- Interdependent objectives and activities have been identified and reported to project management and more will likely continue to be identified in response to emergent resource allocations and unforeseen interconnected limitations.

EWD Goal 1: Increase Research Capacity	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	**Netongo, Chatterjee, Misra, RIO-NM**
Objective EWD.1.1: Fill key gaps in faculty research expertise	Awaiting administrative bandwidth for hiring processes.	Device security expert hired.	Evaluated need and posted job for cloud/edge computing expert at UNM with hiring ongoing.	**Hire device security and cloud/edge computing expert for research and education.**	**Netongo**
Objective EWD.1.2: Early Research Career Workshops	Designed Early Research Career workshops, ready to be held.	1st Early Research Career workshop held, ready to hold 2nd.	2nd Early Research Career workshop, ready for continuation.	**Yearly workshops held to enhance research profession skills for early career faculty and post-docs.**	**Misra, RIO-NM**
Objective EWD.1.3: Developing Science Communication to the Public	Designed Science Communication content and proposed to RIO-NM, ready for development.	Proposal response received, ready to hold 1st workshop in Y3	1st Science Communication content/workshop held, ready for continuation.	**Science communications feedback from at least 10 graduate students, 2 postdocs, and junior faculty.**	**Chatterjee, RIO-NM**

Table EWD1: Annual Milestones for Research Goal EWD1 – Increase Research Capacity

Objective EWD.1.1. Fill key gaps in faculty research expertise: Faculty hires will provide the complementary expertise to build DREAM and bolster the expertise of the team.

Activity Outcomes: (1) A device security expert with manufacturing background (NTU; Y2/Y3) will increase the capacity of cybersecurity course offerings and the understanding of the group in AM printers' security. (2) A cloud and edge computing expert, in using machine learning across the cloud-edge continuum will provide the requisite expertise. Table EWD1.1 presents the activity Gantt chart and outcomes for the objective.

Outputs: 2 hired technical experts, 2 onboarding process experts.

EWD Goal 1: Increase Research Capacity		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	
Objective EWD.1.1. Fill key gaps in faculty research expertise		Awaiting administrative bandwidth for hiring processes.				Device security expert hired.				Evaluated need and posted job for cloud/edge computing expert at UNM with hiring ongoing.				**Hire device security and cloud/edge computing expert for research and education.**				**Netongo**
1	Hiring device security expert at NMSU								A									Netongo
2	Hiring cloud and edge computing expert at UNM										A				B			Devetsikiotis
Tasks A	Evaluate need and post job										A							
B	Hired Personnel														B			

Table EWD1.1: Activity Gantt Chart and Outcomes for Objective EWD1.1: Fill key gaps in faculty research expertise

Objective EWD.1.2 Early Research Career Workshops: To enhance the professional skills of postdocs and early career faculty in research. The workshops held by RIO-NM will build on prior, successful NM EPSCoR workshops and will support near-peer interactions for participants from NM institutions, including SNL and LANL. Workshop topics include technical project management and securing funding via proposal writing and solicitation searches. Project-supported postdocs and new faculty hires will be expected to attend.

Activity Outcomes: Workshops developed for early career research professionals in STEM held once each year: 2025–2028. Table EWD1.2 presents the activity Gantt chart and outcomes for the objective.

Outputs: 12 participants (estimated)

		EWD Goal 1: Increase Research Capacity	**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	
		Objective EWD.1.2: Early Research Career Workshops	Designed Early Research Career workshops, ready to be held.				1st Early Research Career workshop held, ready to hold 2nd.				2nd Early Research Career workshop, ready for continuation.				**Yearly workshops held to enhance research profession skills for early career faculty and post-docs.**				**Misra, RIO-NM**
Tasks	1	Workshops enhancing leadership, grant/proposal writing for early career faculty and post-docs				A	B				B				B				RIO-NM
	A	Leverage existing material to design workshop through RIO-NM				A													
	B	Hold workshop for DREAM participants and affiliated					B				B				B				

Table EWD1.2: Activity Gantt Chart and Outcomes for Objective EWD1.2: Early Research Career Workshops

Objective EWD.1.3 Developing Science Communication to the Public: To introduce participants to fundamental science communication techniques that are effective, practical, and applicable to broad audiences. Content from K-12 Pathways will be identified and leveraged to develop content similar to the Portal to the Public program. A proposal for workshops using this content will also be submitted to RIO-NM for support, aiming to develop communicators in STEM fields, enabling democratization and sharing of academic research with broader audiences.

Activity Outcomes: Propose workshops containing Portal to the Public material content held annually until 2028. Table EWD1.3 presents the activity Gantt chart and outcomes for the objective.

Outputs: 1 proposal, feedback from 10 graduate students + 2 post-doc/faculty participants.

EWD Goal 1: Increase Research Capacity			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	
Objective EWD.1.3: Developing Science Communication to the Public			Designed Science Communication content and proposed to RIO-NM, ready for development.				Proposal response received, ready to hold 1st workshop in Y3				1st Science Communication content/workshop held, ready for continuation.				**Science communications feedback from at least 10 graduate students, 2 postdocs, and junior faculty.**				**Chatterjee, RIO-NM**
	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	

Table EWD1.3: Activity Gantt Chart and Outcomes for Objective EWD1.3: Developing Science Communication to the Public

EWD2: Engage, train, and retain diverse students in STEM to create a STEM Workforce

Hispanics and Native Americans are underrepresented in the completion of STEM degrees and entry into STEM careers, yet they represent more than one-half of NM's population. Although gender parity has improved in disciplines like biology and chemistry, women remain underrepresented in engineering and computer science. This is particularly significant as engineering and computing occupations represent over 80% of the STEM workforce. Given NM's status as a minority majority state (NM's population of URM and female children stands at 88%), the engagement and retention of diverse students is imperative for NM's future research enterprise. However, this is hampered by a lack of resources for teachers and inadequate opportunities for new uptraining. Table EWD2 presents the annual milestones for this goal.

Risk Mitigation:

- Education and Workforce Development leads will address capabilities through a progressive reevaluation approach wherein the least resource intensive options will be exhausted before escalating issues through the risk mitigation pipeline.
- Challenges will be communicated first to objective leads identified at the rightmost column of Table 7, who will prioritize addressing that challenge themselves before reaching out to the RG leader group listed in the upper rightmost cell of Table 7.
- Project managers will be notified of challenges at as they persist enough to impact quarterly projected milestones and interdependent timelines.
- Interdependent objectives and activities have been identified and reported to project management and more will likely continue to be identified in response to emergent resource allocations and unforeseen interconnected limitations.

EWD Goal 2: Engage, train, and retain diverse students in STEM to create a STEM Workforce	Year 1	Year 2	Year 3	Year 4	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.	Submitted curriculum awaiting approval with course in DIAM created via NMSU Global.	Curriculum resources for bachelor's program and NMSU Global DIAM course delivered and refined.	**Created degree map, lab modules, and courses for cybersecurity and manufacturing cybersecurity.**	**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.	Upward progression mechanism ready for delivery, 2nd tele-workshop held.	Curriculum for upward progression ready for submission, 3rd tele-workshop held.	**Pipeline and tele-workshop established to recruit five MS and 3 Ph.D. students from 2- and 4-year colleges.**	**Chatterjee, Roy**
Objective EWD.2.3. Micro-credential in Cybersecurity for Manufacturing	Curriculum requirements ready to be finalized for micro-credential course.	Curriculum defined and ready for course to launch.	Launched course for micro-credential in cybersecurity in manufacturing.	**2 micro-credentialed courses by end of Year 2, 5 digital badges awarded by Year 3, 10 digital badges by Year 4.**	**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.	Relationships built with middle and high schools, onboarded teacher participants codesigned and implemented units.	2nd year of teacher onboarding and co-designing through PAR.	**Implement 6 study units over first three years; trained 20 teachers (Y2-Y4), assessed and revised unit plans.**	**Chatterjee**

Table EWD2: Annual Milestones for Research Goal EWD2 – Engage, train, and retain diverse students in STEM to create a STEM Workforce

Objective EWD.2.1. Support for cybersecurity at NTU: Working with NTU, DREAM will lay the foundation for the country's first engineering graduate program at a Tribal University. In preparation for developing a distributed Advanced Manufacturing industry, NTU has developed a cybersecurity associates program approved by the NM Higher Learning Council. This proposal will provide the collaboration to strengthen this new program and to develop strong educational student projects within the CAM, to create student internship opportunities (other institutions), and develop an effective workforce development program. This proposal will be supplemented through other Tribal College and Universities Program (TCUP) cybersecurity infrastructure proposals to Cyberinfrastructure Health, Assistance, and Improvements (CHAI) program, which was developed to provide Tribal Colleges/Universities funding to upgrade cybersecurity infrastructure. The Center team will coordinate with NTU's IT department to create an implementation plan to not only secure the CAM Center through upgraded switches, storage, and secure data transfer services, but to also address monitoring and training staff and students in workplace cybersecurity protocols. Support will also include cybersecurity courses and lab assignments creation.

Activity Outcomes: (1) Creation of a bachelor's program at NTU with hands-on work supplemented by resources and coursework resources from other partnering institutions like NMSU. (2) Collaborative creation of online courses for secure manufacturing to be distributed via NMSU Global (Y2 & 3). Table EWD2.1 presents the activity Gantt chart and outcomes for the objective.

Outputs: 1 publication, 1 student expert.

EWD Goal 2: Engage, train, and retain diverse students in STEM to create a STEM Workforce			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	
Objective EWD.2.1. Support for cybersecurity at NTU			Defined curriculum requirements for bachelor's program at NTU, ready to submit for approval.				Submitted curriculum awaiting approval with course in DIAM created via NMSU Global.				Curriculum resources for bachelor's program and NMSU Global DIAM course delivered and refined.				**Created degree map, lab modules, and courses for cybersecurity and manufacturing cybersecurity.**				**Netongo**
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	

Table EWD2.1: Activity Gantt Chart and Outcomes for Objective EWD2.1: Support for cybersecurity at NTU

Objective EWD.2.2 Creating a pipeline for students in NTU and other 2- and 4-year colleges in NM: Establishing a pipeline from colleges like NTU to research universities is a focus. Regular tele-workshop sessions and early student engagement in collaborative research will facilitate this connection.

Activity Outcomes: (1) Create a pipeline for students in higher education, with mechanisms for progression and curriculums and programs identified throughout NM. (2) Connecting researchers with students through virtual co-working and tele-workshop events recruiting five MS and three Ph.D. students from 2- and 4-year colleges between Y1-Y3. Table EWD2.2 presents the activity Gantt chart and outcomes for the objective.

Outputs: 1 publication.

EWD Goal 2: Engage, train, and retain diverse students in STEM to create a STEM Workforce			**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	
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.				Upward progression mechanism ready for delivery, 2nd tele-workshop held.				Curriculum for upward progression ready for submission, 3rd tele-workshop held.				**Pipeline and tele-workshop established to recruit five MS and 3 Ph.D. students from 2- and 4-year colleges.**				**Chatterjee, Roy**
1	Creating a pipeline for students to start their higher education						A				B				C				Chatterjee, Netongo, Devetsikiotis, Misra
Tasks	A	Progression map from associates to bachelors to graduate studies					A												
	B	Create mechanism for upward progression									B								
	C	Approve curriculum													C				
2	Connect researchers with students through tele-workshops research				A	B			B				B				B		E-CORE, Chatterjee, Roy
Tasks	A	Design workshop for identified associates degree students (involve E-CORE)			A														
	B	Hold Tele-workshop				B			B				B				B		

Table EWD2.2: Activity Gantt Chart and Outcomes for Objective EWD2.2: Creating a pipeline for students in NTU and other 2- and 4-year colleges in NM

Objective EWD.2.3. Micro-credential in Cybersecurity for Manufacturing: We will develop and launch a micro-credential through NMSU's Global Campus to provide courses relevant to Cybersecurity in Manufacturing. NMSU Global offers skill development for traditional and non-traditional learners. Courses, structured in micro-credential format, consist of monthly modules. Accessible to all DREAM institutions, they involve the research team and industry partners.

Activity Outcomes: Developing two micro-credentialed courses (Y2-3), implementing them at NMSU (Y3), and awarding 5 digital badges in Y3, followed by 10 in later program years. Table EWD2.3 presents the activity Gantt chart and outcomes for the objective.

Outputs: 1 publication, 1 student expert

	EWD Goal 2: Engage, train, and retain diverse students in STEM to create a STEM Workforce	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	
	Objective EWD.2.3. Micro-credential in Cybersecurity for Manufacturing	Curriculum requirements ready to be finalized for micro-credential course.				Curriculum defined and ready for course to launch.				Launched course for micro-credential in cybersecurity in manufacturing.				**2 micro-credentialed courses by end of Year 2, 5 digital badges awarded by Year 3, 10 digital badges by Year 4.**				**Chatterjee**
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								

Table EWD2.3: Activity Gantt Chart and Outcomes for Objective EWD2.3: Micro-credential in Cybersecurity for Manufacturing

Objective EWD.2.4. Creating K-12 Pathways for Advanced Manufacturing: Teachers and schools face many barriers to engineering and computing integration: (1) There are few instructional approaches and materials available to educators. The field has witnessed a proliferation of approaches/materials to support Next Generation Science Standards (NGSS) science practices such as carrying out investigations, modeling, and argumentation. However, the development of parallel resources for engineering and computing as STEM practice has lagged. (2) Most science teachers have limited experience in teaching engineering and computing and lack the self-efficacy necessary to do so. (3) Gaps in access to computing resources, unreliable internet access outside of school are still widespread in school systems across the US, thus limiting computational activities. Engaging teachers as collaborators in research projects can help build bridges between teachers and researchers, connecting professional and scientific knowledge. Thus, in this activity we aim to use participatory action research (PAR) to engage participants in effective reflective processes to improve their instructional practices through professional development.

Activity Outcomes: (1) Build relationships with middle and high schools identified as receptive and interested in STEM-related outreach; (2) Design a professional development program for teachers to support them in integrating cybersecurity and advanced manufacturing in CS courses for high school; (3) Recruit a cohort of teachers and work with them to provide resources and support to create culturally relevant, customizable programs for their minority students; (4) Co-design, implement, and revise 6 study units through participatory action research (PAR). Table EWD2.4 presents the activity Gantt chart and outcomes for the objective.

Outputs: 5 publications, 4 student experts, 20 trained teachers from 2025-2028.

EWD Goal 2: Engage, train, and retain diverse students in STEM to create a STEM Workforce			**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	
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.				Relationships built with middle and high schools, onboarded teacher participants codesigned and implemented units.				2nd year of teacher onboarding and co-designing through PAR.				**Implement 6 study units over first three years; trained 20 teachers (Y2-Y4), assessed and revised unit plans.**				**Chatterjee**
1		Middle and high school relationship building		A		B		C											Chatterjee, Vishwanathan
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											
2		Cybersecurity and AM curriculum for middle and high schools		A				B	C					D					Chatterjee, Vishwanathan
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, Vishwanathan
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, Vishwanathan
Tasks	A	Iterations of co-design with teachers									A				A				
	B	Collaborative assessment														B			
	C	Revised units																C	

Table EWD2.4: Activity Gantt Chart and Outcomes for Objective EWD2.4: Creating K-12 Pathways for advanced manufacturing

Project Management, Evaluation and Assessment (PMEA)

The project's foundation comprises PIs and senior personnel (see Table 1). Institutional leads and the DREAM Research Center Project Manager form the Core Management Team to oversee research and EWD portfolios in each university to ensure activities meet goals and deadlines. The Project Manager autonomously sets agendas and checks for adherence to the strategic plan deadlines, hearing from reports at regular meetings for progress and setbacks. Together, the Core Management Team will also oversee the creation of an Advisory Board.

Risk Mitigation:

- Research leads will address technical capabilities through a progressive reevaluation approach wherein the least resource intensive options will be exhausted before escalating issues through the risk mitigation pipeline.
- Technical challenges will be communicated first to objective leads identified at the rightmost column of Table 4, who will prioritize addressing that challenge themselves before reaching out to the RG leader group listed in the upper rightmost cell of Table 4.
- Project managers will be notified of technical challenges at as they persist enough to impact quarterly projected milestones and interdependent timelines.
- Interdependent objectives and activities have been identified and reported to project management and more will likely continue to be identified in response to emergent resource allocations and unforeseen interconnected limitations.

Evaluation Plan:

In collaboration with the DREAM leadership, the evaluation team will ensure ongoing data collection aligned with the strategic plan. Regularly reviewing this data will track progress, with the evaluator coordinating clear data collection plans with the project team. Formative and summative assessments will evaluate effectiveness and impact, guided by strategic plan metrics and milestones. Key metrics include secure distributed manufacturing tasks, education/ workforce milestones, and demographic data. Formative assessments involve regular stakeholder feedback, including postdocs and faculty training experiences. Summative assessments focus on impact data, diversity, leveraged grants, innovations, degrees awarded, and economic impact. The evaluator will annually compile this data for review, generating documented recommendations. Sustainability efforts and DEI evaluation, including demographics and retention rates, will have yearly examination. Collaboration strength metrics will track impactful relationships, funding received, research findings, and innovations. Co-sponsored events, internships/experiences, new programs, and sustained collaborations will be monitored. Faculty progression and productivity will be tracked through yearly meetings.

Administration Activities: Project Management and Evaluation activities will be conducted throughout the course of this program, including deliverance of an approved strategic plan, conducting regular in-person and virtual meetings in a biweekly, monthly, and quarterly cadence, submitting annual updates, and organizing all-hands meet-ups. Table PMEA1 presents the activity Gantt chart and outcomes for this objective.

Outputs: Strategic Plan, at least 24 meetings per year, annual submissions, and all-hands meet-ups at the start of year 2 and end of year 3.

Project Management, Evaluation, and Administration (PMEA) Goal 1			**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	
PMEA Objective 1.1: Administrative Activities			Defined curriculum requirements for bachelor's program at NTU, ready to submit for approval.				Submitted curriculum awaiting approval with course in DIAM created via NMSU Global.				Curriculum resources for bachelor's program and NMSU Global DIAM course delivered and refined.				**Created degree map, lab modules, and courses for cybersecurity and manufacturing cybersecurity.**				**Misra, Martins**
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				

Table PMEA1.1: Activity Gantt Chart and Outcomes for Objective PMEA1.1: Administrative Activities

Advisory Board: An Advisory Board is to be created including experts from industry (Desktop Metal, Optomec, Corning, IDS, Plug Power) and national labs (Sandia, Los Alamos, DEVCOM Analysis Center) will meet annually to analyze and guide project outcomes. Within the first year, we plan to create bylaws and documentation, nominate members, and induct members after which we plan to hold annual advisory board meetings beginning in quarter 1 of year 2. Table PMEA1 presents the activity Gantt chart and outcomes for this objective.

Outputs: Advisory Board comprised of experts from industry and national labs.

Project Management, Evaluation, and Administration (PMEA) Goal 1			**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	
PMEA Objective 1.2: Advisory Board			Defined curriculum requirements for bachelor's program at NTU, ready to submit for approval.				Submitted curriculum awaiting approval with course in DIAM created via NMSU Global.				Curriculum resources for bachelor's program and NMSU Global DIAM course delivered and refined.				**Created degree map, lab modules, and courses for cybersecurity and manufacturing cybersecurity.**				**Misra, Martins**
Tasks	1	DREAM Center Industry Advisory Board from Private Companies and National Labs		A	B	C	D				D				D				Martins
	A	Create bylaws and documentation		A															
	B	Nominate members			B														
	C	Induct members				C													
	D	Annual Advisory Board Meetings					D				D				D				

Table PMEA1.2: Activity Gantt Chart and Outcomes for Objective 1.2: Advisory Board

Risk Mitigation

Barriers and Opportunities

This collaboration will face challenges such as the distributed nature of the project and the geographical separation among partner schools; the rapidly changing landscape of the AM industry; the need for more expert faculty and research capacity; the resource intensity of the establishment of a successful center; and the attraction and retention of successful under-represented minority students through a novel pipeline.

On the other hand, these same challenges provide opportunities to develop and strengthen relationships via virtual and informal meetups, leverage a dedicated advisory board of industry and national lab contacts, attracting new talent via outreach and promotional materials, establishing multiple sources of funding to supplement federal investments, and broadening accessibility with innovative workshops, educational resources, and incentives for a diverse workforce population.

Mitigation Strategies

We aim to address the highest impact risks determined by the SWOT Analysis, included in the Appendix, by conducting the following:

Managing project focus and investing in team relationships

- Conduct bi-weekly meetings for project check-ins and milestone updates wherein project management will utilize an ongoing dynamic strategic plan to capture progress and adherence to strategic plan.

- Quarterly virtual meetups in centralized conference rooms at each institution to provide team building and showcase key milestones from less visible members of the team.

- Organize short-term exchange groups of researchers to work from a partnering lab location wherein 2-3 students visit for 1-2 weeks to conduct alignment activities, report on lab operational differences, and strengthen comradery between collaborators at the bench level.

Promoting and connecting externally

- Co-author publications and presentations for relevant domestic and international conferences wherein representatives from multiple institutions can come together to showcase DREAM project outputs.

- Establishing an Advisory Board cohort of at least 6 experts from private industry, national labs, and governing bodies, with whom we will share snapshots of progress and outputs on a semi-annual cadence along with capturing industry perspectives via questionnaires and review notes.

- Promoting participation via workshops, community competitions, and infotainment for a range of student outreach populations, including community practices for skill-sharing and continuation of industry topic discussions.

Growing resource pools and funding for research activities

- Tackling fundamental DIAM research challenges as a group by following through with strategic plans, including risk mitigation activities for each key element, as aided by the Advisory Board.

- Investment in targeted faculty hires that fill critical expertise gaps

- Enhancing research infrastructure (equipment, testbeds, cyberinfrastructure) to support the DIAM investigations

- Expanding budgets through crossroad funding opportunities and cost-sharing from lateral institutions with intersectional visions.

- Leverage resources from programs conducted by the NM NSF EPSCOR Office such as early career leadership workshops, science communication workshops, people and project management resources, grant-writing, and teaching and mentoring.

Providing inclusive training for participants, students, and researchers

- Establish cooperative internships and externships for mentoring undergraduate and graduate students within participating DREAM Center labs and a growing number of partners such as collaborating national labs and private sector companies.

- Develop and host community workshops to bring together industry partners, academic researchers, and the larger maker-space community for showcasing industry strengths and addressing industry challenges through hands-on AM training/recruitment content, networking, and crowd-sourced discussions on a range of AM topics, from filament supply chain to cybersecurity of 3D model assets.

- Inspire partnership opportunities by including dedicated grant writers and agency connections for helping generate opportunities for follow-up research activities, and investment pitches to industry representatives and/or the DREAM Research Team.

Succession Strategy

Should the Principal Investigator (PI) position become vacant, the Co-PI with the broadest involvement across research and education Co-PI Roopa Vishwanathan will become the PI. In the event of PI Vishwanathan not being available, Senior Personnel Panwar will be the PI. The attempt will be to keep the lead functions at NMSU, given that research leadership is shared across institutions by design.

Should any of the institutional lead positions, such the Co-PIs or senior personnel, become vacant, roles will be filled by team participants working in conjunction with the Core Management Team and the Advisory Board to ensure that diversity objectives are maintained. The Core Management Team and project goal teams provide a pool of potential candidates for senior personnel and Co-PI vacancies. Project Goals have at least two leaders (listed throughout the document) to ensure continuous leadership throughout the project; An additional (ideally, more junior) co-leader(s) will be selected from within the project teams to be mentored and prepared for leadership responsibilities should changes in lead participation occur or it be deemed desirable to have additional leaders responsible for an activity, objective, or goal. The team is already involving other researchers into the team, e.g., Dr. Sirimuvva Chirala and Dr. Rajaraman Jayaraman at NMSU have joined the DREAM team as collaborating researchers. The plan is to encourage the growth of the team in the other institutions as well so that the bench strength increases with time setting the center up for an NSF ERC submission in the future.

APPENDICES

SWOT/Risk Mitigation Analysis

Strengths (internal)

Teamwork Attributes

- Motivated young faculty wanting to achieve prominence academically
- Many have worked together before, this is a great chance to collaborate more deeply and meaningfully, co-advising students, and working with folks from areas we won't work within our own comfort zone
- Strengthening the relationship across the NM research institutions
- The core leadership of the project has been collaborating for some time
- A diverse set of faculty from many disciplines and universities
- Close proximity and potential for in-person meetings will foster potential for future collaborative research across the institutions.
- Different levels of readiness for implementation

Research Attributes

- Research is cutting edge and very promising with lots of open questions
- Cross-pollination of ideas will lead to more publications, proposals, and graduates out of this center.
- The project comprises professionals with diverse skills, experience, and knowledge, giving the research a platform where solutions will be tailored and resolved rapidly.
- The team has gathered preliminary results and insights in areas like distributed machine learning and wireless communications for additive manufacturing. These foundational experiences strengthen the project by providing a solid base for further development and validating key concepts.
- The problems identified in the project are timely and of importance to the state as documented in its Science and Technology plans.
- The research outcomes outlined have been identified as essential for making distributed manufacturing feasible and scalable.
- All participating collaborators share common goals for this research.
- The expertise required to accomplish the identified tasks in the project is covered well within the teams across institutions.

External Connections

- The faculty members in the project have established collaborations with LANL, SNL, AFRL, and WSMR.
- The project aims to develop the workforce from K-12 and higher education.
- Many participants have patents and experience in technology acceleration.

Resources
- Resources in place to achieve the goals

Opportunities (external)

Industry
- Secure industry partnerships
- Identify needs and challenges for workforce

Facilities and Equipment
- Large diverse equipment uses opportunities
- Siloed, open-ended for connectivity

Tie to Economy
- Economic growth potential
- Chance to establish innovative AM leadership
- Potential rural development (bridging rural-urban divide)
- Distributed manufacturing is a strong vehicle for democratizing economic development in our tribal and rural areas

Funding Potential
- Future funding through Engineering Research Center development
- Distributed manufacturing is becoming a large focus area nationally, the number of federally funded opportunities will rise.
- Potential to attract state level funding to this project.
- Will help create (cybersecurity) opportunities that will help institutions apply for and get NSA CAE-CD, or NSA-CO, CAE-R certification.

Capacity Building
- The team is young, barring the two professors, everybody else is an associate or assistant professor (10 total), this is a great opportunity to create a leadership core for the future
- Attract more expertise, students, and industry by showcasing innovations in a rural setting.
- Opportunities for knowledge transfer across the institutions
- Is there any possibility of encouraging student exchange programs?
- Build an additive manufacturing (AM) certificate program to help professionals and students gain specialized knowledge and skills in AM.

Weaknesses 1 (internal)
Likelihood (H, M, L) / Impact (H, M, L)

Cyberinfrastructure

- The labs in the institutions are currently not connected, which will be necessary to succeed on the testbed side. (H/L)
- Lack of Cyberinfrastructure knowledge for some (also an opportunity) (H/L)
- Complexity due to broad scope (L/L)

Funding

- Resource intensity for infrastructure and center establishment (H/H)
- Future dependence on multiple funding sources (M/H)

Collaboration

- The size of the state (fifth biggest in US) and the geographical spread of the collaborators will hinder quick dissemination. (M/L)
- As mentioned above, there is physical separation, especially between NTU and their labs. Need/could try to turn into an opportunity. (M/L)
- Folks not working individually and do not collaborate as much since they need to show that they have their own independent research as younger more junior faculty. (M/M)
- Not enough travel budget to visit other Universities and only doing remote Teams/Zoom meeting without meeting as a whole group (M/M)

Project Management

- NMSU is building its grant oversight and management infrastructure to manage such a large and diverse grant. (L/M)
- Losing focus of the goals set forth for the Center (L/H)

Research Impact

- Distributed advanced manufacturing is a broad field, and making a significant impact will require more resources and manpower, which may restrict its impact. (M/L)

Education and WFD Impact

- Explore more of the school curriculum to integrate the content. (L/L)
- Being a majority-minority state, we will have to make sure outreach efforts can help attract students who would then be able to contribute to research outcomes and the workforce development objectives. (H/M)
- The connections with school districts the institutions collaborate with needs to be explored more to execute the education plans. (M/M)
- Recruiting students is a concern for all (H/M)

- No platform to strengthen young professionals. (M/H)

Recruiting and Retaining Project Personnel

- Also, recruiting and retaining top scientists (M/M)

- Continuity of project personnel, e.g., what to do if/when someone leaves? (L/H)

Threats (external)
Likelihood (H, M, L) / Impact (H, M, L)

Technological
- Technological challenges in integration (M/L)
- Uncertainty in future technology adoption (M/L)
- Cybersecurity risks (L/H)

Relevance
- This topic is changing rapidly; how to ensure that research keeps pace with state-of-the-art (L/M)

Funding
- Funding continuity risks (M/H)
- Shifting federal funding priorities; change in administration (H/H)

Attrition/Retention/Recruitment
- Talent retention within NM (L/M)
- Attrition of faculty/talent will be a challenge during the course of the project (L/H)
- Collaborating faculty switching institute (L/H)
- Apart from the salary in cybersecurity professionals, what other motivation can be used to attract students to continue in this field to enable future leadership. (M/M)
- The focus of the collaborating institutions and the faculty may change over the course of the project. (L/M)

Shifting Priorities
- There is a possibility that the focus of the state will change (L/L)
- The workforce created may not be gainfully employed if this area falls out of favor at the state level or in the private sector. (L/M)

Industry Engagement
- Getting the private sector interested in the DREAM Center will be challenging given the low critical mass of companies in NM (M/M)

Glossary

ABAC - Attribute-Based Access Control
AFRL - Air Force Research Lab
AIS - Aggie Innovation Space
AR - Augmented Reality
ASIC - Application-Specific Integrated Circuit
AWS - Amazon Web Services
CAM - Center for Advanced Manufacturing
CC - Community College
CHAI - Cyberinfrastructure Health, Assistance, and Improvements
Co-PI – Co-Principal Investigator
DOE - Department of Energy
DREAM – Distributed Resilient Emerging-intelligence-based Additive Manufacturing
EDD - Development Department
EPSCoR – Established Program to Stimulate Competitive Research
EWD - Education and Workforce Development
FL - Federated Learning
GAN - Generative Adversarial Network
GNN – Graph Neural Network
HIN - Heterogeneous Information Network
IoT - Internet of Things
LANL – Los Alamos National Lab
MaaS – Mobility as a Service
MSIs - Minority Serving Institutions
NFV - Network Functions Virtualization
NGSS - Next Generation Science Standards
NM - New Mexico
NMSU – New Mexico State University
NMT – New Mexico Institute of Mining and Technology
NSF - National Science Foundation
NTU - Navajo Technical University
PAR - Participatory Action Research
PI – Principal Investigator
PL - Previous Layer
QC – Quality Control
QCAM - Quality Control of Additive Manufacturing
QoS - Quality of Service
RBAC - Role-Based Access Control
RG - Research Goal
S&T - Science & Technology
SDN - Software-Defined Networking
SNL – Sandia National Lab
SVD – Solid View Design

TCUP - Tribal College and Universities Program
TEE - Trusted Execution Environment
TL - Top Layer
UNM – University of New Mexico
URM - Under-represented Minority
VC - Verifiable Computation
VR – Virtual Reality
zkSnarks - Zero-Knowledge Succinct Non-interactive Arguments of Knowledge

DREAM Research Center - Brand Style Guide

The intention behind creating a brand style and guide for this research effort is to unify and focus the efforts of contributors coming from the 4 collaborating institutions in New Mexico under a similar visual identity.

With the creation of a logo and accompanying graphics for use in presentations, posters, and outreach material, the DREAM Research Center brand represents an interconnectivity between all parts of New Mexico with homage to the colors and locations of each institution within the state. By reflecting aspects of layering, extruding, and segmentation, the DREAM Center brand communicates core aspects of additive manufacturing and the distributed nature of both the research collaborators' locations and the decentralized data science that underpins our proposed cyberinfrastructure.

Created by graphic designer Stella Aude of NMSU, the logo and identity was voted on by members of the grant during the Strategic Planning Kick-off meeting in October of 2024.

See next page for a copy of the Brand Style Guide document created in fall of 2024.

MAIN LOGO

DREAM

OBJECTIVE

The broad vision of this project is to make foundational innovations in distributed networking, cybersecurity, and digital-twin design in additive manufacturing (AM) leading to the creation of robust research programs in AM in New Mexico.

PRIMARY COLORS BREAKDOWN

The DREAM logo colors were picked following the collaboration among four New Mexico institutions, each color representing each university.

PRIMARY COLORS

#D51C24 #BA0C2F #8C0B42 #0C2753

SUPPORTING COLORS

#007A86 #78291C #000000 #FFFFFF

SECONDARY COLORS (COLOR BLIND FRIENDLY)

#E1BE6A #E66100 #40B0A6 #D41159 #994F00 #1A85FF

DREAM

TITLE/HEADLINE FONT

DREAM

BUNGEE - REGULAR

THE FONT WAS MODIFIED FOR THE PURPOSE OF THE LOGO.

SECONDARY FONTS

Tahoma - headlines

Garamond - Body

LOGO VARIATIONS ON WHITE BACKGROUND

DREAM

LOGO VARIATIONS ON BLACK BACKGROUND

DREAM

DREAM