

Roadmap to United States Naval Academy

Additive Manufacturing Excellence

CAPT Brad Baker, Associate Professor USNA, August 2020



Mission. To develop the infrastructure and technical expertise for the United States Naval Academy (USNA) to become a recognized leader in additive manufacturing (AM) by achieving the following core AM mission tasks by 2024:

AM Process Expertise: Develop and sustain expertise in all AM process categories as defined in ASTM52900. USNA will actively collaborate with Department of the Navy (DON) and industry entities to focus primarily on material extrusion, vat photopolymerization, and powder bed fusion methods while also developing proficiency in other processes.

USNA AM Education: Educate and train future Naval and Marine Corps officers in AM preparing them specifically for AM uses and challenges they will encounter in the Fleet. USNA will incorporate AM education and training into the core USNA curriculum for all students, which is achievable within the current academic structure.

Fleet AM Education: Use state of the art pedagogical methods to develop and deliver innovative training materials in support of both traditional classroom instruction as well as virtual instruction that directly supports Fleet training efforts. USNA will work directly with DON groups to both identify instructional needs and provide training materials to meet those needs.

Design for AM: Develop practices for and train users on the art, science, and skill required to improve design for AM. USNA will utilize modern computer aided design and manufacturing processes to incorporate design considerations specific to AM leading to increased efficiencies and design flexibility of AM components.

AM Cybersecurity: Identify and develop methods to address cybersecurity issues specifically regarding AM use afloat or in expeditionary roles. USNA will leverage the growing Center for Cyber Security Studies at USNA to develop methods to protect and enhance cybersecurity of shipboard AM in a manner that can be directly applied to Fleet use.

AM Part Qualification: Utilize modern materials characterization capability to evaluate the performance of parts made by AM to help DON determine when, where, and how AM may be utilized to improve Fleet readiness. USNA will utilize current and future characterization capability to identify processing, microstructure, and material property relationships to improve overall AM part performance.

Next Generation AM: Pioneer and evaluate new and novel AM methods including multifunctional printing techniques and components, hybrid manufacturing methods, and AM methods not currently identified. USNA will work with other DON and industry partners as well as work independently to identify new and novel applications of AM methods and AM components.

Background. USNA has a growing capability in AM and actively collaborates with DON, industry, and other academia on several AM topics including evaluation of AM methods, characterization of AM components, and AM education. Interest in AM at USNA has grown to include every engineering department and dozens of faculty and staff. This roadmap reviews current successes in AM, outlines future mission areas, identifies challenges to AM excellence, and reviews active partners for USNA.

Success Stories. AM capability at USNA principally resides in the Center for Material Characterization in a laboratory area referred to as MakerSpaceUSNA (www.makerspaceusna.com). MakerSpaceUSNA is a modern, open, and student-oriented laboratory space that has grown from two printers in 2015 to over thirty printers supporting

over 100 registered student users in 2020. Research projects from MakerSpaceUSNA have included: powertrain components in the FSAE car team, a patent pending design for an AM radiation detector, novel uses of AM for sensors, components for unmanned vehicles, several scientific presentations and publications, and several projects in direct support of DON efforts. For 2021, it is anticipated that approximately 1/5 of all Capstone projects are directly on AM, 1/3 will directly include AM, and close to 1/2 will utilize AM to some degree. Working directly with NAVSEA, MakerSpaceUSNA hosted enlisted Sailors from the first Additive Manufacturing Lab (AML) afloat for six months producing training materials and projects in direct support of the Fleet. MakerSpaceUSNA has several direct collaborations with governmental and industry partners, many of whom have visited USNA as guest lecturers in support of AM education at USNA. This list has included leaders of industry as well as AM leaders in the DON. USNA is poised to achieve AM excellence.

Challenges. Like many disruptive technologies, there is technological risk associated with implementation of AM. This is highlighted by recent DON efforts to incorporate specific commercial off the shelf 3D printers aboard ships. Working directly with NAVSEA, USNA was involved with evaluation of specific afloat uses of 3D printers and provided feedback on their capability and implementation. However, the company behind this technology has experienced significant developmental challenges and likely will not be a viable long-term solution. This risk is not limited to vendors alone and applies to entire process categories (e.g. VHS versus Betamax, Blu-ray versus HD-DVD, etc.). USNA is uniquely qualified to help manage this risk to DON by utilizing expert faculty and staff, an engaged and creative student base, and access to modern engineering tools to develop and evaluate AM advances all without risk to operational readiness. There are, however, challenges that remain at USNA that need to be addressed. Specifically, the mission areas established require an infrastructure that, while fully compatible with current USNA infrastructure, requires a more robust capability that can respond to the changing nature of AM. Additionally, the dynamic nature of AM requires an equally dynamic acquisition capability that is willing to accept technological risk. The proposed method to handle this risk is to conduct basic research to assess and improve the technology readiness level of AM particularly as it applies to afloat and expeditionary situations. USNA's primary effort will be to develop AM methods and train users how to use those methods while also assisting DON on how, when, and where those methods are used.

Partners. MakerSpaceUSNA has a long record of successful collaborations both internally and externally. AM at USNA started as a few faculty users working independently on AM projects, progressed to a strong core of faculty within the Mechanical Engineering Department, and is now a robust interdisciplinary team that includes every engineering department at USNA as well as some non-engineering departments. MakerSpaceUSNA also has strong DON collaborations at every level of AM management. Through the Naval Academy Foundation and other collaborations, MakerSpaceUSNA also has strong connections to major DON contractors as well as individual 3D printing companies.

Summary. Additive Manufacturing is not a new concept to the DON. In a NAVADMIN in 2017, the CNO ended his AM guidance, "Additive Manufacturing – A Challenge for Every Sailor", as follows:

"A concerted enterprise push to integrate AM into all aspects of naval operations will lead to a stronger, smarter, more agile, and more innovative fighting force. AM will not be a panacea to every material problem, but it will be an important operational and acquisition tool as we transform into a digital Navy that is agile and ready to adapt in an uncertain global environment."

MakerSpaceUSNA is poised to become a center of AM Excellence for the DON.



*Center for Material Characterization coin
designed and printed in stainless steel at USNA*



MakerSpaceUSNA Key Participants and Partners:

USNA Faculty

Name	Position
Brad Baker, CAPT USN, PhD	Permanent Military Professor Associate Professor Mechanical Engineering Director Center for Materials Characterization
Peter Joyce, PhD	Professor Mechanical Engineering
Rick Link, PhD	Professor Mechanical Engineering
Steve Graham, PhD	Professor Mechanical Engineering Chairman Mechanical Engineering Department
Michelle Koul, PhD	Professor Mechanical Engineering
Joel Schubbe, PhD	Professor Mechanical Engineering
Emily Retzlaff, PhD	Associate Professor Mechanical Engineering
Liz Getto, PhD	Associate Professor Mechanical Engineering
Samar Malek, PhD	Associate Professor Mechanical Engineering
Marshall Millett, PhD	Associate Professor Mechanical Engineering
Deborah Mechtel, PhD	Professor Electrical Engineering
Brian Jenkins, PhD	Associate Professor Electrical Engineering
Hatem Elbidweihy, PhD	Associate Professor Electrical Engineering
Steven Yee, LT USN	Master Instructor Electrical Engineering
Jin Kang, PhD	Associate Professor Aerospace Engineering
Tae Lim, PhD	Associate Professor Aerospace Engineering
John Gregory, LT USN	Master Instructor Aerospace Engineering
Andy Gish, CAPT USN, PhD	Permanent Military Professor Assistant Professor Naval Architecture & Ocean Engineering
Jan Rice, CAPT USN	Master Instructor Naval Architecture & Ocean Engineering Deputy Division Director Engineering & Weapons
Doug Chapman, PhD	Corbin A. McNeill Chair in Naval Engineering
Jon Gibbs, CDR USN, PhD	Permanent Military Professor Assistant Professor Naval Architecture & Ocean Engineering
Alex Laun	Hydro Laboratory Supervisor, Engineering & Weapons Division
John Donnal, PhD	Associate Professor Weapons, Robotics, & Control Engineering
Mike Kutzer, PhD	Associate Professor Weapons, Robotics, & Control Engineering
Dave Durkin, CDR USN, PhD	Permanent Military Professor Assistant Professor Chemistry

DON AM Leadership

Name	Position
Jenn Wolk, PhD	Office of Naval Research
Justin Retalliatta, PhD	NAVSEA 05T, Technical Warrant Holder for Additive Manufacturing
Ryan Hayleck	NAVSEA 05T
Jim Pluta	NAVSEA 05T

Industry AM Leadership

Name	Position
Josh McClellan	Northrop Grumman, Section Manager for Strategy Development and Consulting Engineering
Gregg Wilson	General Electric Additive, Principal Engineer - AddWorks
Greg Elfering	Ultimaker, President of Americas Ultimaker
Matt Griffin	Ultimaker, Director of Community Development, Ultimaker
Chris Crowley	Formlabs, Enterprise Account Manager
Mara Hitner	Vice President of Strategic Partnerships at MatterHackers
Josh Cramer	Director of Education and Workforce Development at America Makes

Academia Leadership

Name	Position
Todd Palmer, PhD	Penn State University, Professor of Materials Science and Engineering
Rick Blanton	University of Maryland College Park, Director, Technical Operations A. James Clark School of Engineering