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Leveraging Machine Learning and AI to Identify Novel Additive Manufacturing Technological Capabilities to Improve Fleet Readiness

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Mihiri Rajapaksa—is an Engagement Manager at Govini. Prior to joining Govini, she spent over 5 years working as a civilian for the U.S. Navy. She started at NSWC Philadelphia as a HM&E ancillary equipment SME and then transitioned to PEO IWS 3.0. Within IWS 3, she worked in IWS 3L, the Vertical Launching Systems Program Office, for over 4 years overseeing new construction and fleet support as well as various tech refreshes and engineering development efforts. She holds a Master of Science in Robotics from the University of Pennsylvania.

Abstract

As competition between the United States and adversarial nations intensifies, the U.S. Navy faces a challenge to maintain advantages in the maritime domain. While the outcome of this competition will depend on many factors, one critical factor will be the speed and agility of the U.S. Navy to sustain the Navy's operational availability (Ao). However, current logistics, supply chain, and manufacturing capabilities seem unable to meet the current demands of the fleet. One technology that could support this is additive manufacturing (AM). Leveraging AM technologies to manufacture long lead time and high demand parts will enhance readiness and reduce logistic burdens.

What seems certain is that the country that leverages AM technology the fastest can gain and maintain a technological lead.

AM technology can augment traditional manufacturing techniques. Since some commercial practices must be modified to meet military requirements, this study looks at the current investment landscape across the U.S. government (USG) in the AM technology space to see what AM USG contracts are available now across to explore potential contracting actions. This study identifies the organizations developing cutting-edge AM technology that can be used by the U.S. Navy today to improve overall fleet readiness.

Introduction

Traditionally, bureaucratic and contracting hurdles have limited the U.S. government's (USG) ability to acquire new, key technology quickly. Without the ability to adopt cutting-edge technology from the manufacturing sector into the fleet sustainment and readiness missions, the U.S. Navy risks diminished or loss of advantage in the maritime domain.

Govini developed a repeatable and scalable methodology to analyze the additive manufacturing (AM) market. The methodology examines investments across the USG and Navy to identify active contracts that could enable Navy organizations to access and test with AM technology. To accomplish this task, the study leveraged machine learning (ML) and artificial intelligence (AI) to identify AM related contracts, subcontracts, grants, OTAs, academic research articles, and patents. The resulting data sets were then tagged and aligned to specific technology areas creating a scoped list of key AM vendors. The AM vendors were further refined by isolating USG contracts with available periods of performance and contract ceiling. Our assumption is that existing, active contracting

vehicles could speed access to innovative technologies and implementation within the fleet. This study highlights the contracts that might be leveraged to quickly access AM technologies.

The U.S. Navy has started down the right path by approving Huntington Ingalls Industries to utilize certain additively manufactured parts, but there is a further expanded use for this technology (Katz, 2023). The insights from the study can aid decision-makers in the Department of the Navy (DoN), Department of Defense, and broader USG as they grapple with the challenges of accelerating production and maintaining U.S. maritime superiority.

Key Findings

- **USG demand for AM technology is currently at its peak.** There are 210 active contracts for AM technology or services across the USG. The Air Force contracted roughly 5 times as much as the Navy on AM from Fiscal Year (FY) 2018 to FY2022.
- **The industrial base for AM is large but underutilized by the USG.** There are 7,800 vendors in this space, and 135 are currently being used by the USG—representing less than 2% of the entire vendor ecosystem. AM vendors span a spectrum from small, start-up private companies to large, publicly traded, and well-known defense companies.
- **$1.3 billion of contract ceiling is currently available on active AM contracts across the USG.** Available contract ceiling means that the USG has available contract vehicles to potentially leverage to quickly access this innovative technology.

Methodology

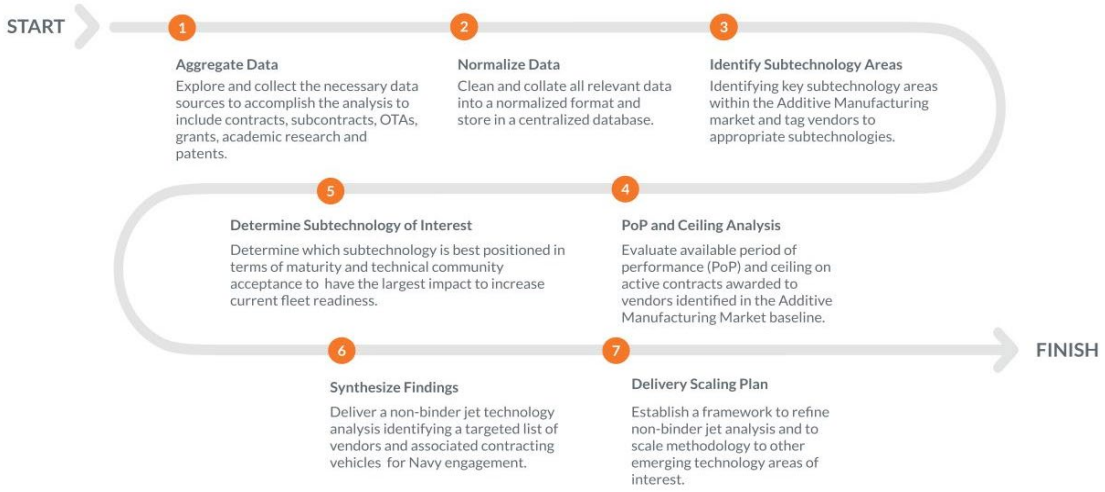


Figure 1: Analytical Methodology Utilized for This Report

Through an iterative process, a robust set of keywords were generated to query Govini's National Security Knowledge Graph (NSKG) for relevant contract awards in the AM market. The NSKG is driven by Govini's patent-pending Object Fusion data engine that continuously ingests, normalizes, and integrates new data sources with existing data catalogs. Govini analysts leveraged the information in the NSKG to construct the associated vendor landscape views across the AM market through the use of ML algorithms. This comprised the baseline data set for analysis.

The first phase of this study analyzed historical and current USG award data, academic research, and patents to create a baseline of vendors operating in the AM market. Supervised ML and natural language processing (NLP) was applied to parse, analyze, and categorize large volumes of federal contracts and grants data. The use of AI and supervised ML models enables analysis of the large volumes of irregular data contained in federal contracts and grants—data that is often inaccessible through regular government reporting processes or required human-intensive analytical approaches. Moreover, beyond simply making usable an expansive body of data sources, the mathematical principles that underlie Govini's AI and ML technologies also increase confidence in the fidelity with which the data are categorized and aggregated to produce a comprehensive and accurate depiction of federal spending over time. All vendors were tagged by capability into one of 27 different sub-technology areas within the AM market. The 27 sub-technology areas can be seen in Appendix Table 1.

In the second phase, the vendor baseline data set was evaluated to identify vendors who have USG prime contracts, subcontracts, OTAs, or grants with active periods of performance (PoP) and available ceiling. An active PoP was defined as a contract with a PoP that ended after September 2023, aligning with the start of a new fiscal year. The combination of an active PoP and available ceiling indicates that this could be an option for a potential contract vehicle to easily access the technology or service provided by that particular vendor.

Analysis

There are approximately 7,800 unique vendors who have historically operated in the U.S. commercial and government AM market from 2017 to 2022, identified through prime contracts, subcontracts, OTAs, grants, academic research publications, and/or patent awards. As seen in Figure 2, the count of vendors in this market has fluctuated over time with a peak in calendar year 2021. This means that there is a wide range of vendors and their associated capabilities and technologies for the Navy to evaluate to integrate into maintenance and production to enhance overall fleet readiness. The dip in FY2022 is a result of lower patent awards and academic research during that time period, which seems in line with an overall decrease in innovation in that time (Data Journalism Team, 2022).

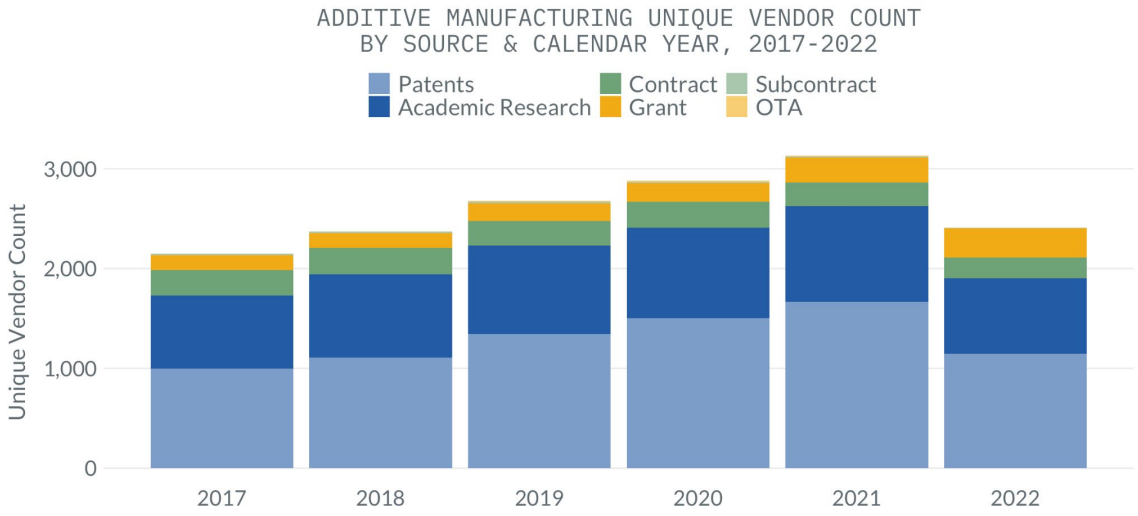


Figure 2: Unique Vendor Count by Source and Calendar Year

Analyzing the vendor location can be a methodology to assess vendors who are easy to partner with for future work. Figure 3 shows the physical location of all vendors in the AM market. Based on the AM technology application, it may be beneficial to work with vendors in geographical proximity to a naval base or laboratory location. There are high concentrations of AM vendors in Southern California, the Pacific Northwest, and Northeastern regions, which coincides with a number of fleet concentration areas, U.S. Navy bases, and naval surface, undersea, and aviation warfare centers.

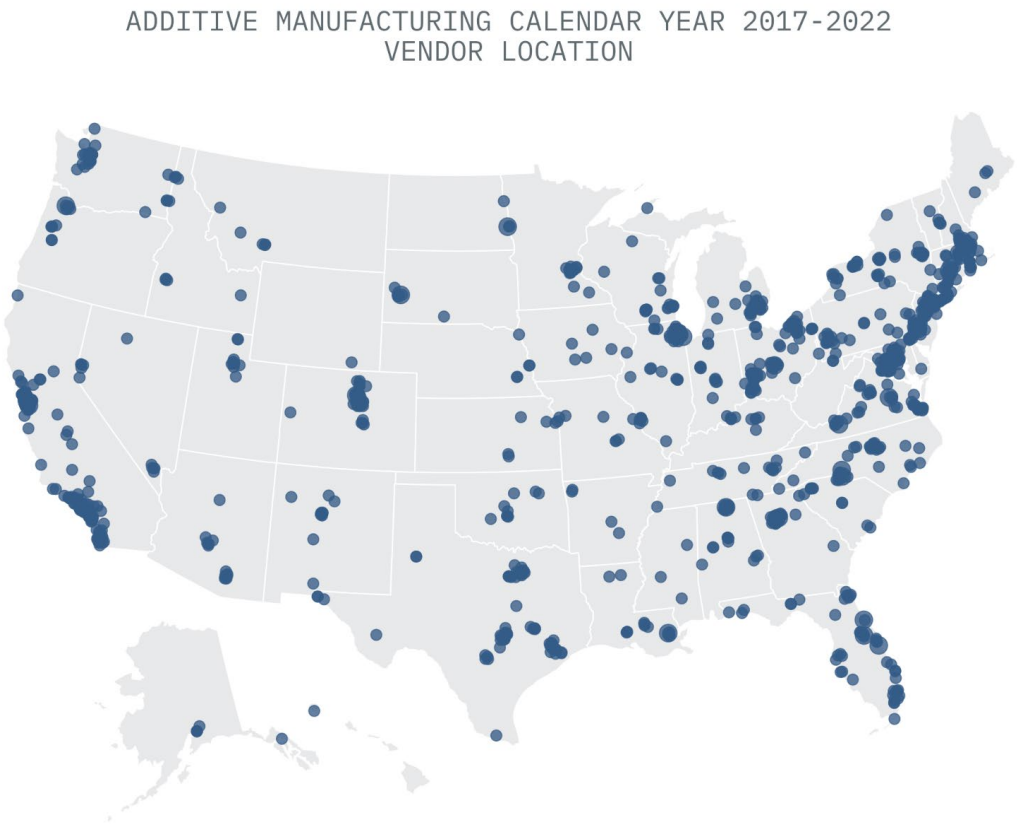
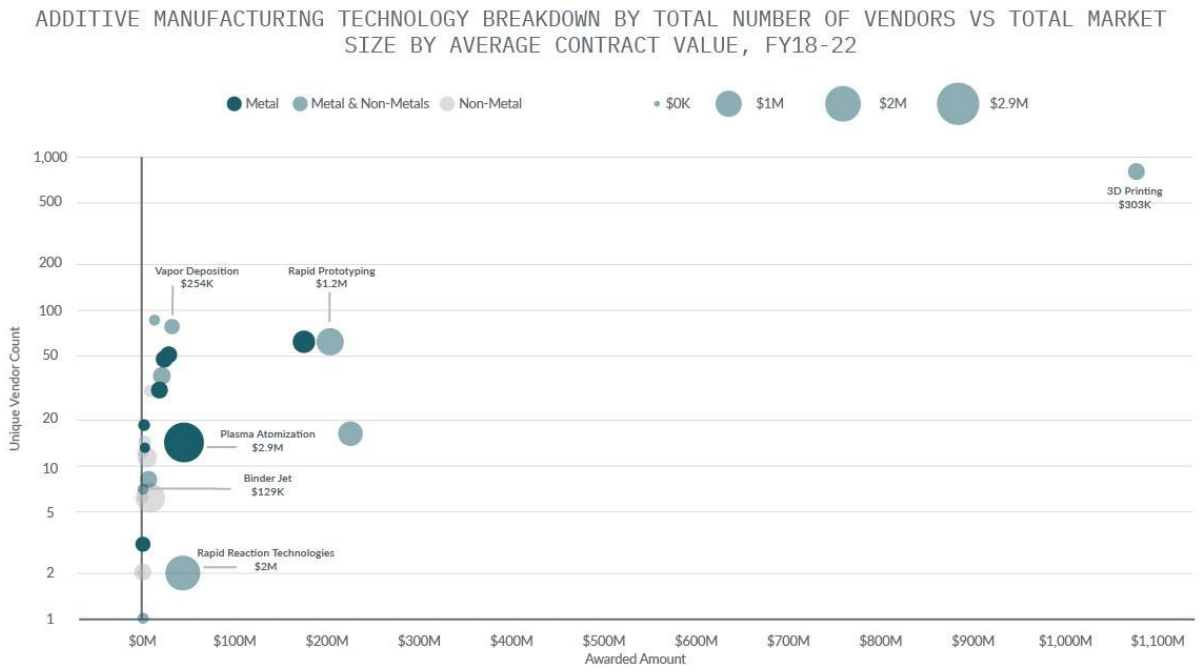


Figure 3: U.S. Map of All Additive Manufacturing Market Vendor Locations Sized by Number of Vendors Associated With Each Latitude and Longitude Grouping

Only 9.3% of the vendors in the entire AM market have been awarded USG contracts since 2018. As seen in Figure 4, the subset of vendors in the USG market provide a variety of AM technologies, including Powder Bed, Plasma Atomization, and standard 3D printing. For 3D printing, there are almost 1,000 vendors who have received a total award amount of approximately $1.1 million. The average award amount for 3D printing is $303,000, which means that there are a lot of small contract awards in this technology market. Govini found that contract award amounts related to Plasma Atomization, which works in metal AM, tend to be larger than those for standard 3D printing, which could be a variety of metal and nonmetal (e.g., plastics, etc.) applications. Broader AM technology groups such as rapid prototyping and 3D printing could allow for more flexibility in the utilization of applicable contracts.



Note. Size of the bubble represents the total average contract size. Color of the bubble represents the material types associated with the additive manufacturing technology area.

Figure 4: Subsegment Technology Areas With the Total Associated Additive Manufacturing Market Size Measured Against the Total Number of Vendors

Currently, a number of these technologies are being evaluated for technical feasibility across the DoN, including laser metal deposition and binder jet technologies. Specifically, the binder jet technology market has a lower on average award amount ($129,500), which places it at 19 out of the 27 defined AM technology areas and material types included in the active AM USG contracts as ranked by average award amount. The binder jet technology market also has a lower total awarded amount, with $1.8 million awarded from FY2018 to FY2022. As this technology becomes more mature, there may be an increase in awards for binder jet technology products and services, which will result in higher total award amounts.

According to subject matter experts in the field, non–binder jet technology for metal material AM appears more promising on producing parts to sustain and repair the fleet than binder jet technologies. Therefore, binder jet technology contract awards were removed from the AM market for the remaining portion of this analysis. Looking at the remaining 26 technology areas (binder jet excluded), there are 134 vendors currently working with the USG and approximately 1,050 vendors that have taken USG investment for work and/or research from FY2018 to FY2022. Figure 5 shows the top contracting agencies across the USG by award amount and the top four vendors each contracting office awarded contracts to—with the vendors ranging from large systems integrators who work in many fields, including AM, to smaller, AM-specific vendors.

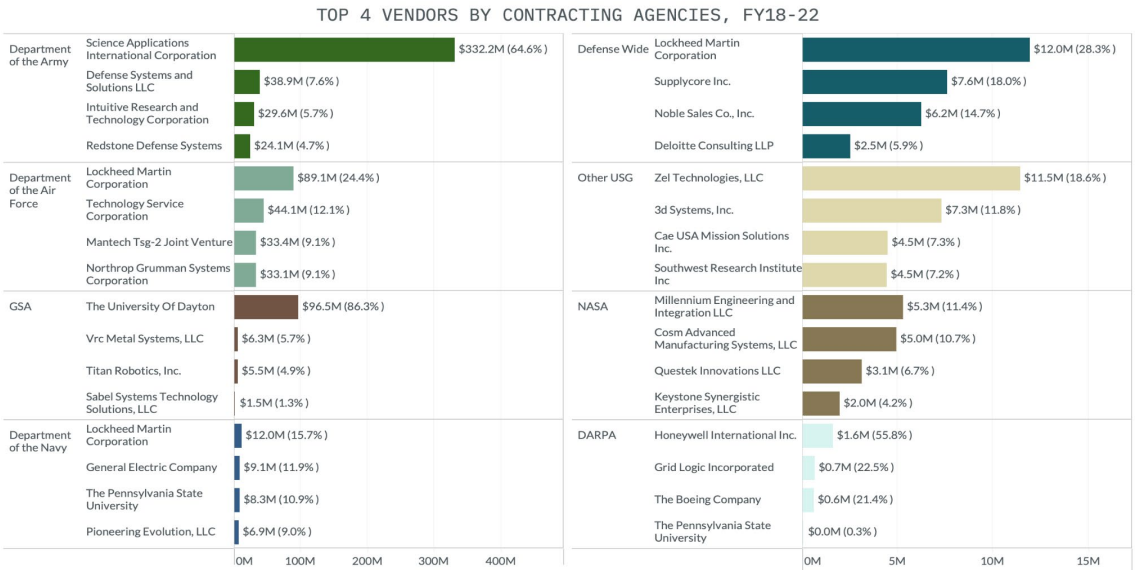
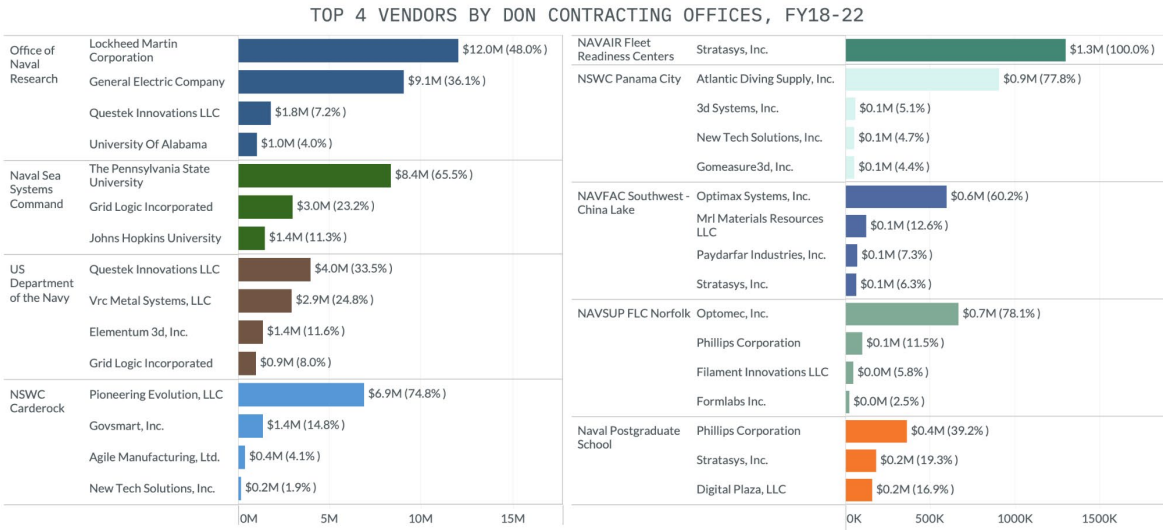


Figure 5: Top 4 Vendors by Sum Awarded Amount and Percentage of Contracting Agency Awarded Amount

Most illuminating, perhaps, is the apparent lack of investment in AM and contracting paths currently available inside the DoN agencies. Figure 5 shows the percent of contract awards the vendor has received from that contracting office for AM-related work. For example, Lockheed Martin has received 15.7% of all AM contract awards from the DoN from FY2018 to FY2022, while they have received 24.4% of all AM contract awards from the Department of the Air Force. The agencies shown in Figure 5 have a high utilization of certain vendors and represent the subset of contracting agencies who it may be ideal to partner with to get quick access to AM technology. Figure 6 shows specific contracting offices within the DoN for a more granular view at U.S. Navy the contracting activity level.



Note: Contracting offices with less than four vendors displayed awarded contracts to less than four vendors in the Additive Manufacturing market from FY2018 to FY2022.

Figure 6: Top 4 Vendors by Sum Awarded Amount from DoN Contracting Office and Percentage of DoN Contracting Office Awarded Amount

Analyzing the investments within the DoN, Figure 6 shows the top four DoN contracting offices by total contract award amount during the time period analyzed for work in the AM market. The offices within the U.S. Navy, Office of Naval Research ($25.1 million), Naval Sea Systems Command ($12.8 million), and NSWC Carderock ($9.2 million) are most likely the best initial starting point for partnering discussions once the specific vendor and technology of interest has been identified because they have the highest cumulative award amount within the AM market. The top vendors utilized by these three program offices are Lockheed Martin Corporation, Pennsylvania State University, and Pioneering Evolution.

As seen in Figure 7, a majority of active contracts across the USG pertain to broader technology areas such as 3D printing and rapid prototyping that can be suited for both metal and nonmetal applications. The largest of these contracts are awarded by the U.S. Department of the Air Force for rapid prototyping technologies. Rapid prototyping and 3D printing contracts may allow a higher degree of flexibility in the type of AM products or services procured when leveraging existing contracts with available ceiling and period of performance.

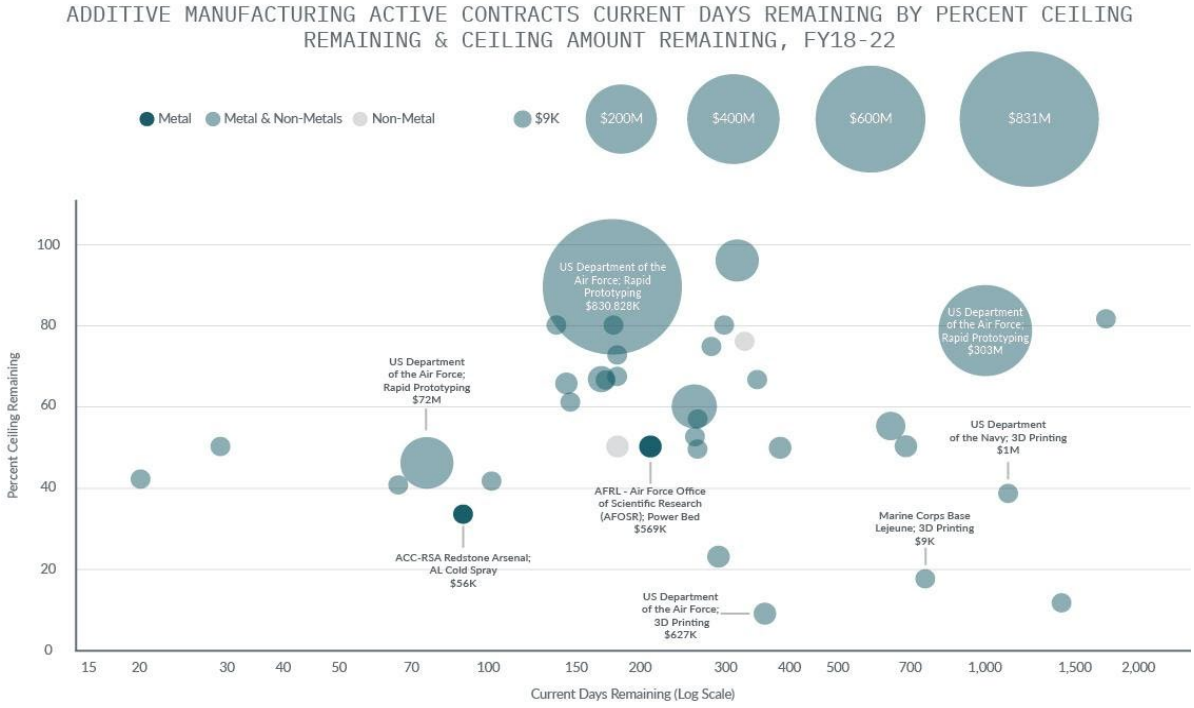


Figure 7: Active Contracts Across the USG by Current Days Remaining, Percent Ceiling Remaining, and Ceiling Amount Remaining

Looking at the available contract ceiling in isolation, which is the maximum amount of money that the USG can fund on a specific contract, is not a good indicator because the contract might have recently been awarded and that could be the reason for the large available ceiling. Figure 7 combines three key metrics—current days remaining, percent ceiling remaining, and ceiling amount remaining—to allow for quicker visibility into potential contracting opportunities with the ideal available ceiling and period of performance. For example, given the time to move money and for the vendor to provide their goods and services, an ideal contract may be those in the top center of Figure 7.

More specifically, for the procurement of a hardware capability, such as the machines needed for non–binder jet manufacturing, the ideal contract to leverage would be a contract with a shorter period of performance and a large available ceiling. Those hardware contracts could potentially be leveraged by other funding offices because of the short duration of the PoP and large contract ceiling. However, for services-oriented contracts, a longer period of performance may be required to ensure the required services can be performed in the remaining time on the contract. This analytical process surfaced 28 target contracts in the AM market. By evaluating this contract subset and associated 22 vendors, U.S. Navy program offices can identify the required capability set to incorporate into ship production and maintenance. These 28 target contracts, 22 vendors, and the associated contracting offices can be seen in Appendix Table 5.

Implications for the Navy

The Navy needs the ability to use AM to produce parts quickly and at the point of need both at sea and ashore in order to keep the fleet ready and sustained. Identifying contracting paths to access key technologies is vital to maintaining fleet readiness and therefore maritime superiority over adversarial nations. Additionally, the data to surface the right vendor with that key technology of interest and the data required for cross-USG analysis to identify those existing contracting vehicles is not easily accessible to Navy analysts. Figure 7 provides a starting point to identify contracting offices across the USG with active contracts for specific key capabilities and can be used by the U.S. Navy to move faster to get the requisite parts manufactured, tested, approved, and installed in the fleet. Automating this discovery and qualification process should allow for quick outreach to the government points of contacts to start the initial process of leveraging the current contracting vehicle. In the future, the U.S. Navy can strengthen those relationships with other offices within the USG to come up with joint contracting strategies to reduce government contracting workload and increase government buying power. The combined demand signal to the vendor can result in lower prices for the technology/service. This could also result in joint investments into key vendors to increase capability needed to support fleet readiness.

Next Steps

In order to further refine the results from this study, the team would conduct initial discussions with U.S. Navy leadership and technical subject matter experts to better understand immediate production and sustainment needs and what technology and applicable use cases have currently been approved by the appropriate technical communities for shipboard usage. This will allow for further refinement of key AM technologies that can be utilized to address those needs. Discussions could also surface the need for quick access to other emerging technologies areas. The methodology used in this study could be applied to another technology area of interest such as unmanned vehicles, materials informatics, or biomanufacturing as well.

Appendix I - Additive Manufacturing Technology Areas

Table 1: Subsegment Technology Areas With the Total Associated Additive Manufacturing Market Size, Associated Material Type, Total Additive Manufacturing Market Size, Total Average Contract Size, and Total Number of Vendors

Rank	Additive Manufacturing Technology Group	Material Type	Total Awarded Amount (FY2018–FY2022)	Average Contract Awarded Amount (FY2018–FY2022)	Unique Vendor Count
1	Plasma Atomization	Metal	$46,904,250	$2,931,516	14
2	Rapid Reaction Technologies	Metal & Nonmetal	$44,465,915	$2,021,178	2
3	Thermoset Manufacturing	Nonmetal	$9,582,114	$1,368,873	6
4	Rapid Prototyping	Metal & Nonmetal	$204,130,732	$1,222,340	63
5	Prototype Integration Facility (PIF)	Metal & Nonmetal	$225,607,965	$964,137	16
6	Cold Spray	Metal	$176,370,955	$683,608	64
7	Photopolymerization	Nonmetal	$6,112,151	$555,650	11
8	Material Jetting	Nonmetal	$2,108,233	$421,647	2
9	Open Manufacturing	Metal & Nonmetal	$7,463,226	$414,624	8
10	Atomic Layer Deposition	Metal	$29,975,864	$389,297	52
11	Powder Bed	Metal	$19,075,809	$381,516	30
12	Nanophotonic	Metal & Nonmetal	$22,953,190	$376,282	38
13	Metal Additive Manufacturing & Printing	Metal	$25,610,036	$346,082	48
14	3D Printing	Metal & Nonmetal	$1,073,783,490	$303,414	804
15	3D Printing	Metal	$849,781	$283,260	3
16	Vapor Deposition	Metal & Nonmetal	$32,479,809	$253,749	78
17	Laser Sintering	Nonmetal	$3,850,277	$167,403	14
18	Stereolithography	Nonmetal	$2,478,892	$137,716	12
19	Binder Jet	Metal & Nonmetal	$1,812,870	$129,491	7
20	Selective Laser Melting	Metal	$3,609,206	$124,455	18
21	Fused Deposition Modeling	Nonmetal	$9,591,697	$112,843	30
22	3D Printing	Nonmetal	$1,182,376	$90,952	6
23	3D Scanning	Metal & Nonmetal	$14,152,701	$80,413	88
24	Electron Beam Melting	Metal	$3,797,163	$79,108	13
25	Adv. Concept Tech Prototyping	Metal & Nonmetal	$434,843	$36,237	1
26	Laser Cutting	Nonmetal	$57,025	$28,513	2
27	Digital Light Processing	Nonmetal	$0	$0	3

Appendix II – Additional Additive Manufacturing Market Details

This section provides more detailed information on the Additive Manufacturing market landscape.

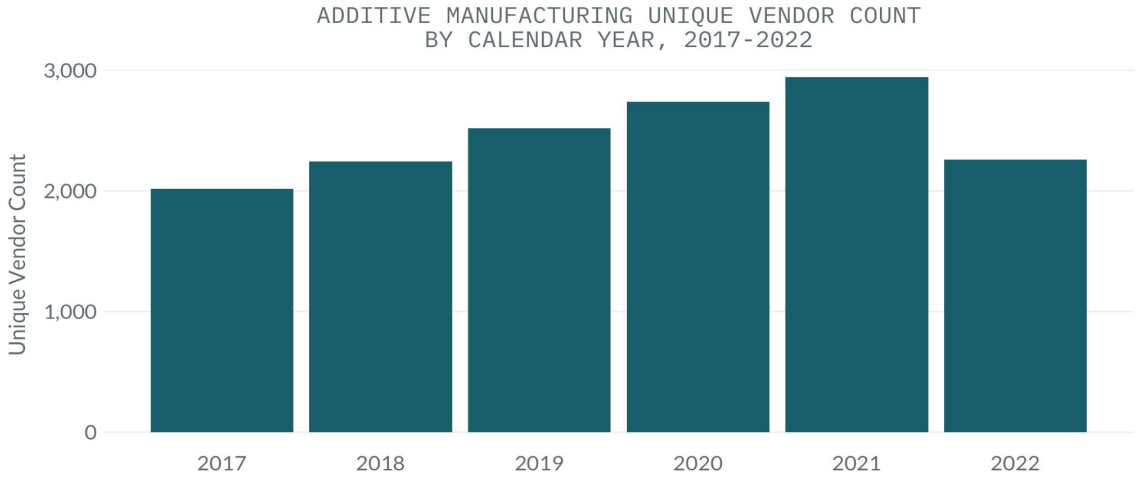


Figure 8: Additive Manufacturing Market Vendor Trend Over Time

Table 2: Top 10 Vendors Based on Award Amount in the Additive Manufacturing Market

Vendor Name	Additive Manufacturing Technology Group	Contracting Office	Total Awarded Amount (FY2018–FY2022)
Lockheed Martin Corporation	Rapid Prototyping	U.S. Department of the Air Force	$98,042,290
Northrop Grumman Systems Corporation	Rapid Prototyping	U.S. Department of the Air Force	$84,747,890
The Boeing Company	Rapid Prototyping	U.S. Department of the Air Force	$80,555,168
Southwest Research Institute	Cold Spray	U.S. Air Force Academy (10 CONS)	$45,745,277
Johns Hopkins University	3D Printing	U.S. Department of the Air Force	$27,180,577
Integrated Solutions for Systems	3D Printing	AFRL RWK - Eglin AFB	$11,714,035
General Electric Company	3D Printing	DLA Aviation (formerly Defense Supply Center Richmond)	$10,000,000
Questek Innovations	3D Printing	DCMA Chicago–Arlington Heights; U.S. Department of the Army	$8,279,027
Titan Robotics	3D Printing	GSA Federal Acquisition Service	$5,500,000
Concurrent Technologies Corporation	Powder Bed	U.S. Department of the Air Force	$5,265,000

Table 3: Top 10 Vendors Based on Available Ceiling Amount on Individual Additive Manufacturing Prime Contract

Vendor Name	Additive Manufacturing Technology Group	Contracting Office	Available Ceiling
Lockheed Martin Corporation	Rapid Prototyping	U.S. Department of the Air Force	$830,827,627
The Boeing Company	Rapid Prototyping	U.S. Department of the Air Force	$302,817,377
Northrop Grumman Systems Corporation	Rapid Prototyping	U.S. Department of the Air Force	$71,994,999
Johns Hopkins University	3D Printing	U.S. Department of the Air Force	$41,067,217
Advanced Technology & Research Corporation	3D Printing	FAS Office of Assisted Acquisition Services–FEDSIM	$33,634,425
Titan Robotics	3D Printing	GSA Federal Acquisition Service	$6,700,000
Mrl Materials Resources	3D Printing	DLA Contracting Services Office–Philadelphia	$3,194,542
Integrated Solutions for Systems	3D Printing	AFRL RWK–Eglin AFB	$1,121,327
Elementum 3d	3D Printing	U.S. Department of the Navy	$999,845
Questek Innovations	3D Printing	U.S. Department of the Navy	$996,599

Table 4: Top 10 Vendors Based on Available Ceiling Percentage on Individual Additive Manufacturing Prime Contract

Vendor Name	Additive Manufacturing Technology Group	Contracting Office	Percent Available Ceiling Remaining	Available Ceiling
Advanced Technology & Research Corporation	3D Printing	FAS Office of Assisted Acquisition Services–FEDSIM	96.1%	$33,634,425
Lockheed Martin Corporation	Rapid Prototyping	U.S. Department of the Air Force	89.4%	$830,827,627
Stratasys	3D Printing	ACC–APG Natick, MA	81.5%	$125,400
Cenmed Enterprises	3D Printing	U.S. Department of the Air Force	80.0%	$83,520
Stratasys	3D Printing	U.S. Department of the Air Force	80.0%	$80,000
Simbionix USA Corporation	3D Printing	National Institute on Drug Abuse	80.0%	$58,000
The Boeing Company	Rapid Prototyping	U.S. Department of the Air Force	79.0%	$302,817,377
Nano Dimension USA	3D Printing	DITCO–Scott: IT Contracting (PL83)	76.1%	$165,549
3d Systems	3D Printing	U.S. Department of Veterans Affairs	75.0%	$59,940
Sun Nuclear Corp.	3D Scanning	U.S. Department of Veterans Affairs	75.0%	$55,152

Table 5: All Vendors Based on Available Ceiling Percentage on Individual Additive Manufacturing Prime Contract for Contracts With More Than $50,000 Available Ceiling and Greater Than 30 Days Remaining in the Period of Performance

Vendor Name	Additive Manufacturing Technology Group	Contracting Office	Days Remaining on PoP	Total Available Ceiling	Percent Available Ceiling Remaining
Questek Innovations	3D Printing	U.S. Department of the Navy	66	$99,925	40.6%
Northrop Grumman Systems Corporation	Rapid Prototyping	U.S. Department of the Air Force	75	$71,994,999	45.9%
Luna Innovations Incorporated	Cold Spray	DCMA Eastern Region; ACC–RSA Redstone Arsenal, AL	89	$55,997	33.4%
Elementum 3d	3D Printing	U.S. Department of the Navy	101	$99,644	41.6%
Cenmed Enterprises	3D Printing	U.S. Department of the Air Force	136	$83,520	80.0%
Mrl Materials Resources	3D Printing	DLA Contracting Services Office–Philadelphia	168	$3,194,542	66.7%
Lockheed Martin Corporation	Rapid Prototyping	U.S. Department of the Air Force	176	$830,827,627	89.4%
Stratasys	3D Printing	U.S. Department of the Air Force	177	$80,000	80.0%
Rpm Innovations	3D Printing	U.S. Department of the Army	181	$86,800	67.4%
Storagenergy Technologies	Stereolithography	ACC–APG Research Triangle Park, NC	181	$549,982	50.0%
Mrl Materials Resources	Powder Bed	AFRL–Air Force Office of Scientific Research	211	$568,820	50.0%
Johns Hopkins University	3D Printing	U.S. Department of the Air Force	258	$41,067,217	60.2%
Goengineer	3D Printing	OL H PZI PZIM–Hill AFB	259	$75,580	52.7%
Stratasys	3D Printing	ACC–RSA Corpus Christi, TX	261	$52,643	56.7%
3d Systems	3D Printing	U.S. Department of Veterans Affairs	279	$59,940	75.0%
Engineering and Software System Solutions	3D Printing	U.S. Department of the Air Force	289	$627,383	23.1%
Simbionix USA Corporation	3D Printing	National Institute on Drug Abuse	296	$58,000	80.0%
Advanced Technology & Research Corporation	3D Printing	FAS Office of Assisted Acquisition Services–FEDSIM	314	$33,634,425	96.1%
Nano Dimension USA	3D Printing	DITCO–Scott: IT Contracting (PL83)	324	$165,549	76.1%
Integrated Solutions For Systems	3D Printing	AFRL RWK–Eglin AFB	357	$1,121,327	8.7%
Sun Nuclear Corp.	3D Scanning	U.S. Department of Veterans Affairs	364	$55,152	75.0%
Questek Innovations	3D Printing	U.S. Department of the Navy	384	$996,599	49.9%
Titan Robotics	3D Printing	GSA Federal Acquisition Service	639	$6,700,000	54.9%
Elementum 3d	3D Printing	U.S. Department of the Navy	684	$999,845	50.0%
The Boeing Company	Rapid Prototyping	U.S. Department of the Air Force	988	$302,817,377	79.0%
Georgia Tech Research Corporation	3D Printing	Federal Highway Administration	1093	$171,618	38.4%
Stratasys	3D Printing	IBC Acquisition Services Directorate	1400	$64,000	11.5%
Stratasys	3D Printing	ACC–APG Natick, MA	1723	$125,400	81.5%

Table 6: Top 10 Vendors Based on Available Ceiling Percentage on Individual Additive Manufacturing Prime Contract for Contracts With More Than $50,000 Available Ceiling and Greater Than 30 days Remaining in the Period of Performance

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Storagenergy Technologies	Stereolithography	ACC–APG Research Triangle Park, NC	181	$549,982	50.0%

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