

Additive Manufacturing: A Selected Bibliography



DTIC-TR-2023-01

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Introduction: Additive manufacturing a form of digital manufacturing relies on 3D models and simulations to produce custom solutions. This digital manufacturing revolution has far-reaching implications for the Department of Defense (DoD) and the defense industrial base.

How this selected bibliography is organized:

This selected bibliography was created using Distribution A technical reports that are currently stored in the Defense Technical Information Center's repository. The summaries are arranged in descending order by topic areas associated with Additive Manufacturing.

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15. SUBJECT TERMS: Additive manufacturing, manufactured materials, evaluations, supply chain					
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Introduction

This bibliography provides an idea of the depth and scope of the DOD's efforts to understand, adopt, and implement additive manufacturing technology into the DoD Digital Engineering Strategy. Each entry includes a title listing, bibliographic citation with abstract and author indexing.

Overarching Documents

Model-Based Systems Engineering for Digital manufacturing Proof of Concept		
Accession Number:	Report Date:	Access Restrictions:
AD1182010	2022-09-02	A - Approved for Public Release.
Author:	Marvis, Dimitri	
Corporate Author:	Georgia Tech Research Corp Atlanta	
Descriptors:	aircrafts, manufacturing, additive manufacturing, fabrication, assembly, aircraft equipment, computer-aided design, composite materials, model-based systems engineering, digital engineering, unmanned aerial vehicles, systems engineering, test and evaluation, yield strength, airframes, computer programming, basic programming language	
Identifiers:	model-based systems engineering (MBSE), trade-off analyses; product lifecycle management (PLM); authoritative source of truth (ASoT); SysML	
New challenges brought by the increase in complexity and connectivity of new products have accelerated the transition from document-centric to model-centric approaches as a means to address some of the current limitations of PLM. Model-based systems engineering, in particular, by providing a common interface between models, data, knowledge and disciplines, is critical to enable a system-level understanding of the designs performance across domains. To demonstrate these qualities across the As Designed and As Built phases of the product lifecycle, this research focused on the development of a methodology aimed at capturing manufacturing and production system considerations in a model-based environment. In doing so, this research demonstrated how model-based systems engineering allows for the connection and integration of product design, manufacturing and production models and data through an authoritative source of truth (ASoT). In particular, manufacturing/production system model for a minimum viable product (UAV wing) are integrated within an existing digital enterprise to demonstrate the requirements validation and verification process, requirement traceability, and finally the ability to conduct tradeoff analyses between design, manufacturing and production concurrently.		

Department of Defense Additive Manufacturing Strategy		
Accession Number:	Report Date:	Access Restrictions:
AD1120846	2021-01-01	A - Approved for Public Release.
Author:		
Corporate Author:	OFFICE OF THE UNDER SECRETARY OF DEFENSE RESEARCH AND ENGINEERING WASHINGTON DC	
Descriptors:	manufacturing, thermal spraying, air force, logistics, additive manufacturing, digital data, digital engineering, supply chain, fabrication, best practices, cybersecurity, department of defense, engineering, lessons learned, materials, national security, risk management, standards, systems engineering, training	
Identifiers:	Not Available	
Technology is changing how systems are manufactured and how production information and data is managed. This digital manufacturing revolution has far-reaching implications for the Department of Defense (DoD) and the defense industrial base. Additive manufacturing (AM), also known as three-dimensional (3D) printing, is a "process of joining materials to make parts from 3D model data,		

usually layer by layer." AM creates the part and material at the same time. This improves production speed and flexibility but requires careful control of the AM process. AM can be used to: build parts that cannot be made any other way; uniquely combine materials; produce obsolete parts; rapidly prototype; create tools and specialized job aids. AM is a powerful tool to enable innovation and modernization of defense systems, support readiness and enhance warfighter readiness. AM is a form of digital manufacturing relying on 3D models and simulations to produce custom solutions. To take the lead in digital manufacturing, the United States will develop standards for digital manufacturing products and processes as well as for the digital environment needed to manage and secure them, as outlined in the Department of Defense's Digital Engineering Strategy. The transformation of the engineering process from design-build-test to a model-analyze-build methodology is enabled by the rapid prototyping and unique manufacturing capabilities of AM.

Department of the Navy (DON) Additive Manufacturing (AM) Implementation Plan V2.0 (2017)

Accession Number:	Report Date:	Access Restrictions:
AD1041527	2017-05-04	A - Approved for Public Release.
Author:	Arcano, Tim, Bouffard, Ben, Marotto, Howie, Wood, Christopher, Freidell, Matthew, Frazier, William, McMichael, Elizabeth, Vitale, Phil, Rettaliata, Justin, Hayleck, Ryan, Kurdian, Armen, Deebel, Mark, Neer, Sean, Bridges, Jason, Fine, Megan, Pluta, Jim, Barrett, David, Wolk, Jennifer, Huang, Paul, Blocksom, Mark, Holzworth, Kristin	
Corporate Author:	OPNAV N4 Arlington United States	
Descriptors:	Additive manufacturing, production, cost effectiveness, naval operations	
Identifiers:		
Additive Manufacturing (AM) is a cross-cutting technology with significant implications for the U.S. manufacturing base and naval warfare. it can shorten the design to production cycle, enable new designs and facilitate cost effective on-demand manufacturing. coupled with digital design and manufacturing, AM will improve warfighting systems in ways never before imagined.		

Research Reports

Model-Based Systems Engineering for Digital Manufacturing: A Proof-of-Concept		
Accession Number:	Report Date:	Access Restrictions:
AD1182010	2022-09-02	A - Approved for Public Release.
Author:	Marvis, Dimitri	
Corporate Author:	Georgia Tech Research Corp Atlanta	
Descriptors:	aircrafts, manufacturing, additive manufacturing, fabrication, assembly, aircraft equipment, computer-aided design, composite materials, model based systems engineering, digital engineering, unmanned aerial vehicles, systems engineering, test and evaluation, yield strength, airframes, computer programming, basic programming language	
Identifiers:	model-based systems engineering (MBSE), trade-off analyses; product lifecycle management (PLM); authoritative source of truth (ASoT); SysML	

New challenges brought by the increase in complexity and connectivity of new products have accelerated the transition from document-centric to model-centric approaches as a means to address some of the current limitations of PLM. Model-based systems engineering, in particular, by providing a common interface between models, data, knowledge and disciplines, is critical to enable a system-level understanding of the designs performance across domains. To demonstrate these qualities across the As Designed and As Built phases of the product lifecycle, this research focused on the development of a methodology aimed at capturing manufacturing and production system considerations in a model-based environment. In doing so, this research demonstrated how model-based systems engineering allows for the connection and integration of product design, manufacturing and production models and data through an authoritative source of truth (ASoT). In particular, manufacturing/production system model for a minimum viable product (UAV wing) are integrated within an existing digital enterprise to demonstrate the requirements validation and verification process, requirement traceability, and finally the ability to conduct tradeoff analyses between design, manufacturing and production concurrently.

Additive Manufacturing and Digital Engineering Strategy Development		
Accession Number:	Report Date:	Access Restrictions:
AD1182995	2022-09-01	A - Approved for Public Release.
Author:	DeLaurentis, Daniel A, Panchal, Jitesh A	
Corporate Author:	STEVENS INST OF TECH HOBOKEN NJ, PURDUE UNIV LAFAYETTE IN	
Descriptors:	additive manufacturing, manufacturing, construction, fabrication, topology optimization, computer-aided design, materials engineering, materials science, assembly, intellectual property, digital engineering, engineers, materials, systems engineering, model-based systems engineering, supply chain, selective laser sintering	
Identifiers:	am (ADDITIVE MANUFACTURING), aircraft components, tdp (technical data package), decision engines	
Additive manufacturing provides an alternative approach for manufacturing products across the supply chain. Some of the benefits of using additive manufacturing are inventory reduction in the supply chain yet increasing supply chain resilience through alternate options, quicker response to surge demands and warfighter readiness, and manufacturing products with complex design while actively reducing the number of serviceable components.		

Critical Evaluation of Construction Industry-Related Additive Manufacturing		
Accession Number:	Report Date:	Access Restrictions:
AD1173324	2022-03-24	A - Approved for Public Release.
Author:	Brunjes, Tyler J.	
Corporate Author:	AIR FORCE INSTITUTE OF TECHNOLOGY WRIGHT-PATTERSON AFB OH	
Descriptors:	materials science, additive manufacturing, construction, manufacturing, fabrication, materials testing, materials processing, mechanics, construction materials, information science, materials, air force, materials laboratories, three-dimensional, civil engineering, additive construction, assembly	
Identifiers:	3D Printing, Scientometric	

Review of construction-related AM literature is used to identify the advantages, challenges, and current trends of the research. Using a scientometric analysis of 522 bibliographic records, this research systematically analyzed construction related AM research to determine the key research areas and trends. Results showed that starting in 2015, the field has been growing at an exponential rate. Recent AM research focused on materials and reinforcement topics, which matched the most notable challenges of AM, which are material rheology, reinforcement, and lacking construction standards. This study provides an insight into AM research and identifies areas requiring more innovation before its commercial acceptance.

Gradient Additive Manufacturing of Energetics Research (GAMER)

Accession Number:	Report Date:	Access Restrictions:
AD1166491	2022-03-30	A - Approved for Public Release.
Author:	van Lingen, Joost,	
Corporate Author:	Netherlands Organisation for Applied Scientific Research	
Descriptors:	additive manufacturing, manufacturing, energetic materials, construction, fused deposition modeling, printing, air force research laboratories, materials, rocket propellants, additives (chemicals), fabrication, assembly, propellants, user interface, literature surveys, tensile testing	
Identifiers:	GAMER (Gradient Additive Manufacturing of Energetics Research), gradient printing, layered printing, hardware adaptation	
Final report is the presentation that was provided to AFRL/RW at the end of the grant funding.		

Best of Both Worlds: Synergistically Derived Material Properties via Additive Manufacturing of Nanocomposites (Postprint)

Accession Number:	Report Date:	Access Restrictions:
AD1154724	2021-07-29	A - Approved for Public Release.
Author:	Koerner, Hilmar, Carrola, Mia, Asadi, Amir, Zhang, Han, Papageorgiou, Dimitrios G, Bilotti, Emiliano	
Corporate Author:	AFRL Materials and Manufacturing Directorate	
Descriptors:	materials science, materials testing, materials processing, material degradation processes, materials laboratories, chemical synthesis, chemistry, manufacturing, additive manufacturing, metallic nanoparticles, fabrication, nanocomposites, ceramic materials, materials, mechanics, assembly	
Identifiers:	transportation sectors, nonmaterial, 3d printing, synergistic	

With an exponential rise in the popularity and availability of additive manufacturing (AM), a large focus has been directed toward research in this topic's movement, while trying to distinguish themselves from similar works by simply adding nanomaterials to their process. Though nanomaterials can add impressive properties to nanocomposites (NCs), there are expansive amounts of opportunities that are left unexplored by simply combining AM with NCs without discovering synergistic effects and novel emerging material properties that are not possible by each of these alone. Cooperative, evolving properties of NCs in AM can be investigated at the processing, morphological, and architectural levels. Each of these categories are studied as a function of the amplifying relationship between nanomaterials and AM, with each showing the systematically selected material and method to advance the material performance, explore emergent properties, as

well as improve the AM process itself. Innovative, advanced materials are key to faster development cycles in disruptive technologies for bioengineering, defense, and transportation sectors. This is only possible by focusing on synergism and amplification within additive manufacturing of nanocomposites.

Analysis on How the Marine Corps has Created Policy and Integrated Additive Manufacturing Throughout the Force

Accession Number:	Report Date:	Access Restrictions:
AD1151092	2021-06-01	A - Approved for Public Release.
Author:	Norako, Vincent R.	
Corporate Author:	Naval Postgraduate School	
Descriptors:	additive manufacturing, fabrication, manufacturing, three-dimensional, computer-aided design, military science, construction, humanitarian assistance, warfare, logistics, printing equipment, supply chain, air force, national security, united states, data analysis, environment	
Identifiers:	marine corps order, 3d printing, programmatic approach	
This joint applied project analyzed the Marine Corps' integration of additive manufacturing (AM) technology throughout the force. Principally, it analyzed the publication Marine Corps Order (MCO) 4700.4 and examined how this document supports AM integration. The primary research question addressed AM's current position within the Marine Corps and what areas could be improved. The most significant area for improvement was cybersecurity concerns. One secondary research question addressed specific risks AM technologies present and how the Marine Corps has or can mitigate those risks. This question supported the primary research question by expounding on the risks of cybersecurity to AM. Another secondary research question was to address what unique opportunities AM technologies provide and how the Marine Corps can fully harness those opportunities. This research question demonstrated AM's benefits beyond maintenance and cost savings, such as humanitarian aid and disaster relief operations and logistics operations within Chinas weapon engagement zone in the South China Sea. Overall, this analysis sought to provide direction and focus to any potential revision of MCO 4700.4 in the future. The data collection was conducted by examining recent articles (approximately less than five years) to determine the state of the technology in the private, public, and military sectors. The analysis remained at the unclassified level to ease distribution of this report.		

Navy Expeditionary Additive Manufacturing (NEAM) Capability Integration

Accession Number:	Report Date:	Access Restrictions:
AD1150790	2021-06-01	A - Approved for Public Release.
Author:	Amodeo, Leslie J., Dick, Brian B., Flynn, Charles P., Nagurney, Rebecca A., Parker, Meagan B.	
Corporate Author:	Naval Postgraduate School	
Descriptors:	additive manufacturing, manufacturing, fabrication, construction, systems engineering, computer-aided design, fused deposition modeling, manufacturing engineering, selective laser sintering, computer programming, human systems integration, environment, assembly, materials, materials science, printing equipment, three dimensional	

Identifiers:	3d printers, navy expeditionary combat command
This capstone report analyzes the current and future use of additive manufacturing (AM) technologies within the Department of Defense (DOD). This analysis provided the technical background necessary to develop the Additive Manufacturing Process and Analysis Tool (AMPAT). AMPAT will help stakeholders identify what AM equipment best serves warfighters and their missions in expeditionary environments. Furthermore, the tool can be used by stakeholders to identify the most advantageous dispersions of AM capabilities across the fleet and make decisions on how those capabilities should be integrated into the greater naval mission and larger DOD enterprise. A systems engineering (SE) approach was implemented to gather information on current and prospective AM methods in order to understand and define the AM system operational requirements. Additionally, an SE process was utilized to analyze alternative software options to build the tool, implement agile software development processes to develop the tool, and verify and validate that the tool met the project requirements. The study found that AMPAT successfully outputs a ranked list of AM systems recommendations based upon user-defined input parameters and weighting values. Recommendations for choosing AM equipment and developing dispersion plans for the fleet include using the AMPAT deliverable to conduct customized, iterative analysis with user-defined inputs that are tailored to specific expeditionary environments.	

Perspective on Nondestructive Evaluation of Additive Manufactured Components (Postprint)		
Accession Number:	Report Date:	Access Restrictions:
AD1113633	2020-09-01	A - Approved for Public Release.
Author:	Jolley, Bryce R., Lindgren, Eric	
Corporate Author:	Air Force Research Laboratory Materials and Manufacturing Directorate Wright-Patterson AFB United States	
Descriptors:	additive manufacturing, materials, quality control, structural integrity, validation, inspection, aircraft equipment, fabrication, damage tolerance, detection	
Identifiers:	NDE (Nondestructive evaluation), EZ SB 19 01, stability, producibility, predictability, supportability, AM (additive manufacturing), nondestructive testing	
Nondestructive evaluation (NDE) has been used for materials and component manufacturing, typically for process quality control or at multiple steps in manufacturing processes. In addition, NDE is used in sustainment of aircraft components to detect defects with a validated capability quantified by probability of detection. U.S. Air Force (USAF) Structures Bulletin EZ-SB-19-01, Durability and Damage Tolerance Certification for Additive Manufacturing of Aircraft Structural Metallic Parts, emphasizes the use of NDE in manufacturing by defining five factors to be evaluated to specify a new material, process, joining method, and/or structural concepts. The factors include stability, producibility, characterization of mechanical or physical properties, predictability of structural performance, and supportability. Included is Section 3.4, Nondestructive Inspection Development, Validation, Verification, and Implementation, which provides instructions to determine the validated capability for all damage types, orientations, and locations for specific regions of interest. Factors that affect NDE capability include where in the manufacturing process the assessment occurs, the nature of the raw feedstock, and the diagnostic information required to ensure the quality of the produced part.		

Metamaterials Using Additive Manufacturing Technologies		
Accession Number:	Report Date:	Access Restrictions:
AD1103255	2020-06-29	A - Approved for Public Release.
Author:	Saunders, Robert	
Corporate Author:	Naval Research Lab Washington DC Washington	
Descriptors:	additive manufacturing, Metamaterials, fabrication, Microstructure, composite materials	
Identifiers:	4d Materials, 4D (four dimensional), am (additive manufacturing), 4d printing, Thermal Metamaterials, Acoustic Metamaterials, Mechanical Metamaterials, Biological Applications, Smart Materials	
The purpose of this document is to provide an overview of current research being conducted in the field of additively manufactured metamaterials. This includes a historical overview of both metamaterials and additive manufacturing as well as suggestions for future research directions.		

Computational Modeling of Additive Manufacturing by Power Bed Laser Fusion: FY19 Engineering Research Technical Investment Program		
Accession Number:	Report Date:	Access Restrictions:
AD1147820	2020-05-14	A - Approved for Public Release.
Author:	Parsons, E. M.	
Corporate Author:	MIT Lincoln Laboratory	
Descriptors:	additive manufacturing, manufacturing, thermal conductivity, heat of fusion, heat transfer, specific heat, latent heat, selective laser melting, selective laser sintering, air force, heat energy, energy, fabrication, laser beams, metal matrix composites, thermal diffusivity, composite materials, lasers, surface tension, temperature gradients	
Identifiers:		
Additive manufacturing (AM) or 3D printing has had a huge impact on numerous sectors at scales ranging from microfabrication to big area manufacturing (size of meters). Many predict that it will soon be recognized as the technology behind the third industrial revolution. It is defined by the ISO/ASTM as the process of joining materials to make parts from 3D model data, usually layer upon layer, as opposed to subtractive and formative manufacturing methodologies. With additive manufacturing, parts of complex geometry can be built with a single machine operation and without any special masks, tooling, dies, or fixtures. Originally used primarily for fabrication of prototypes and models of design concepts, various AM methods are presently capable of producing functional devices, components, and structures constructed from numerous types of materials.		

Towards Certification of Additively Manufactured Safety-Critical Parts for the Department of the Air Force		
Accession Number:	Report Date:	Access Restrictions:
AD1112356	2020-04-01	A - Approved for Public Release.
Author:	Wimer, Jeremy D.	
Corporate Author:	Air Force Fellows Program Maxwell AFB	

Descriptors:	data analysis, materials science, additive manufacturing, manufacturing, neural networks, computational science, data mining, machine learning, materials, mechanical properties, aerospace industry, information science, aircrafts, big data, computer-aided design, computers, fabrication, supply chain, data science, department of defense
Identifiers:	AM (Additive manufacturing), 3d(3-dimensional), PBF (powder bed fusion), DED (direct energy deposition), hip(Hot isostatic pressing)
Additive manufacturing (AM) is a disruptive technology that holds many benefits for the Department of Defense throughout product lifecycles including supporting the digital century-series concept of aircraft acquisition. The variability of parts created by AM is challenging, and the Department of the Air Force lags behind other departments in its adoption of AM. The main barrier to taking advantage of these benefits is the lack of confidence in certifying AM parts for safety-critical flight applications. The airworthiness process relies on process controls, testing, and analysis for risk mitigation and flight certification. The Air Forces current path towards certification has been to closely define and control AM process parameters, lock down that process, and conduct thorough non-destructive testing on individual parts. A better path to certification is to mitigate risks through informed awareness based on sufficient analysis of data created during each parts build process based on the parts criticality. This paper offers a Predict-Built-Test-Validate model as a means to create and analyze a digital passport allowing for certification of parts and informing airworthiness. In-situ data collection, closed-loop control of build process parameters, and machine learning algorithms for defect detection all offer promising methods of collecting data during a build, controlling the process, and ensuring enough information is known about the part to support certification. This paper argues that the Department of the Air Force should not seek to certify individual AM processes or machines, but instead define technical data package requirements and certify processes of collecting and analyzing data whereby the properties of the AM part can be matched with the validated model ensuring it will meet designed performance requirements and be safe for flight.	

Providing Rational for Further Funding Additive Manufacturing Efforts in the Air Force		
Accession Number:	Report Date:	Access Restrictions:
AD1102526	2020-03-06	A - Approved for Public Release.
Author:	Braunberger, Trevor J.	
Corporate Author:	AIR FORCE INSTITUTE OF TECHNOLOGY WRIGHT-PATTERSON AFB OH WRIGHT-PATTERSON AFB United States	
Descriptors:	Logistics, Cost Analysis, military aircraft, selective laser sintering, assembly, computer aided design, fused deposition modeling, manufacturing engineering, advanced manufacturing, laser additive manufacturing	
Identifiers:	3D Printing, Legacy Aircraft	
Extremely long lead times for legacy aircraft replacement parts often exceed 120 days and cost 3 to 4 times the original price drives a search for alternative manufacturing methods such as additive manufacturing. Currently, the method to procuring a legacy replacement for aircraft such as the C-130 is daunting and at times, impossible. Through a comprehensive knowledge collection of organizational data, the Air Force body of knowledge increases and provides actionable data to decision makers which has the potential of dramatically decreasing part wait times and procurement. The proposed, intuitive decision analysis framework mapped out in this research provides relevant direction for potential candidates considering additive manufacturing alternatives within their		

organizations. As result of this study, interested parties now have an abridged guide to costs, expenses, and challenges of setting up an Additive Manufacturing facility within their establishments.

Air Force Additive Manufacturing: Case Studies on Tools, Jigs, and Topology Optimization		
Accession Number:	Report Date:	Access Restrictions:
AD1055245	2017-03-23	A - Approved for Public Release.
Author:	Page, William L.	
Corporate Author:	Air Force Institute of Technology Wright-Patterson AFB OH Wright-Patterson AFB United States	
Descriptors:	additive manufacturing, ORDNANCE DISPOSAL TOOLS, Jigs, Topology Optimization, case studies, mathematical models, air force, Explosive Ordnance Disposal	
Identifiers:	3D Printing, am (additive manufacturing)	
This research explored the application of Additive Manufacturing (AM) to operations for various career fields using case study analysis to investigate to what degree can AM and topology optimization, a mathematical model to optimize the shape of a design, be utilized by various Air Force squadrons in everyday and contingency operations; to what degree can topology optimization be applied to the tools and jigs developed; and how much could topology optimization potentially save the Air Force over a given amount of time? These case studies evaluated nine tools and jigs for Explosive Ordnance Disposal and the Engineering Management Laboratory at the Air Force Institute of Technology. If deemed appropriate by the customer and designer, topology optimization was applied. As the hallmark of a good tool or jig is its usability, a survey was given to rate different aspects of usability for each case study. The scores were then used to identify trends between the case studies. Overall, this research found that AM and topology optimization could be applied to both daily and contingency operations, that topology optimization could be applied to various tools and jigs, and that the application of topology optimization could bring significant cost savings over time.		

Benchmarking DoD Use of Additive Manufacturing and Quantifying Costs		
Accession Number:	Report Date:	Access Restrictions:
AD1051567	2017-03-01	A - Approved for Public Release.
Author:	Crean, Ryan C.	
Corporate Author:	Air Force Institute of Technology Wright-Patterson AFB United States	
Descriptors:	additive manufacturing, supply chain, cost benefit analysis, maintenance, aircrafts, models, costs, Methodology, department of defense, air force, printing	
Identifiers:	AM (additive manufacturing), DOD (department of defense)	
Additive Manufacturing (AM), or three-dimensional (3D) printing as it is commonly referred to, is a rapidly developing technology that has the potential to revolutionize the way that firms develop and produce parts, as well as how they manage their supply chains. AM allows organizations to print prototypes, parts, tools, fixtures, tooling, and a variety of other items at their production location. This can remove long lead times and high inventory levels for one-time or rare items. This research		

examines current AM use within the military services. Additionally, this study details the costs associated with fielding different levels of AM capability, specifically metal printing, production level polymer printing, and desktop level polymer printing. Finally, this research quantifies the cost of producing a metal part using AM. Ten parts with long lead times were chosen for analysis, and the cost calculated for AM production is compared to the price the Air Force currently pays to procure these parts. Topics for future research into of AM will be presented.

Acquisition

Use of Predictive Analytic Tools to Assess Technological Emergences and Acquisition Targets		
Accession Number:	Report Date:	Access Restrictions:
AD1170431	2022-06-03	A - Approved for Public Release.
Author:	Silberglitt, Richard, Wirth, Anna J., Eusebi, Christopher A., Khan, Inez, Leveille, Jasmin, Popper, Steven W.	
Corporate Author:	RAND CORP SANTA MONICA CA	
Descriptors:	quantum computing, information science, databases, air force, artificial intelligence, silicon carbide, additive manufacturing, quantum information science, quantum information, semiconductor devices, statistical analysis, detectors, powder metals, control systems, detection, intellectual property, national security	
Identifiers:	Predictive Analytic Tools	
The United States has been the international leader in science and technology of importance to national security for three-quarters of a century. However, the development by other nations of their own science and technology capabilities, in concert with and fueled by increasing globalization and connectivity of economic and technological development, has increased competition for technological leadership. The authors use patent filings to analyze the current relative positions of the United States and other countries in selected technology areas of interest to the Department of the Air Force: additive manufacturing, artificial intelligence, ceramics, quantum, sensors, and space. Areas of technological emergence were identified by detecting rapid growth in cumulative patent applications in specific technology areas and whether this occurred in the United States or China. The authors also describe and analyze the patent portfolios of U.S. companies that were early filers in these areas, focusing on small or medium-size companies that were not already owned or controlled by foreign entities; this, in turn, enabled identification of companies that had specific leading technological capabilities that could make them attractive for possible foreign acquisition. The authors propose a method to simultaneously identify connected areas of technological emergence and the companies with leading capabilities in these areas.		

Navigating Department of Defense Additive Manufacturing Acquisition Practices		
Accession Number:	Report Date:	Access Restrictions:
AD1164959	2021-12-01	A - Approved for Public Release.
Author:	Mickley, Mitch D., Swank, Piara A., Hagen, Brett A.	
Corporate Author:	NAVAL POSTGRADUATE SCHOOL MONTEREY CA	
Descriptors:	business administration, management personnel, additive manufacturing, air force, organizational structure, three-dimensional, fabrication,	

	manufacturing, construction, data analysis, intellectual property, united states government, government procurement, commerce, governments, computer-aided design, logistics
Identifiers:	3d printing, emerging technology, contracting
The purpose of this research is to examine acquisition practices related to the increased adoption of additive manufacturing (AM) in the Department of Defense (DOD). We explore policies, processes, organizational alignment, and data management to assess AM acquisition in the Air Force. We use a Government Accountability Office (GAO) framework to systematically assess the state of AM acquisitions. Our research includes a DOD spend analysis of AM, policy and guidance analysis, and stakeholder interviews with multiple agencies throughout the Air Force AM ecosystem. We consolidate our findings to develop recommendations that DOD customers can use when seeking 3D-printing requirements. Our conclusion highlights strengths and weaknesses of current acquisitions processes and provides recommendations for further research. While Air Force-centric, our research findings can be adopted to fit acquisition needs specific to all DOD services seeking to meet the call for improved contracting processes outlined in the Department of Defense Additive Manufacturing Strategy.	

Methods Evaluation for Assessing Release of Manufactured Nanomaterials from Polymers, Consistent with the NanoGRID Framework: Advanced and Additive Materials: Sustainability for Army Acquisitions		
Accession Number:	Report Date:	Access Restrictions:
AD1078320	2019-08-01	A - Approved for Public Release.
Author:	Haber, Lynne T., Bednar, Anthony J., Kennedy, Alan J., Ballentine, Mark L., Canady, Richard A.	
Corporate Author:	Army Engineer Research and Development Center	
Descriptors:	composite materials, chemistry, carbon nanotubes, physical properties, risk management, epoxy composites, life cycles, material degradation processes, materials laboratories, materials science, materials testing, particles, polymers, risk analysis, standards, chemical synthesis, engineering, engineers, nanomaterials, polymer matrix composites	
Identifiers:	environmental risk assessment, nanostructured materials-characterization	
This Technical Report (TR) extends on the ERDC NanoGRID (Nanomaterials Guidance for Risk Informed Deployment) program and considers methods needed to assess material released from composites made with manufactured nanomaterials (MN). Specifically, this TR builds from the measurement literature on multi-walled carbon nanotubes released from a matrix to additional application to other MN. The TR informs product development decisions using NanoGRID by facilitating consideration of whether risk characterization is feasible for a given choice of product composition without substantial investment in analytical methods development. In many cases product use can be well characterized and the resulting methods requirements are simple, while in other cases the nature of product use may result in unmeasurable exposures to MN due to the analytical characterization constraints. Understanding these cases prior to product scale-up will enable more accurate cost projections and reduce potential harm of exposures to MN if they are later identified as posing potential health risks. Furthermore, applying the NanoGRID framework to guide evaluation of MN release measurement methods will aid in prioritizing methods evaluation and methods development work in process in ISO TC229 and ASTM E56. The intention of this TR is to clarify risk management uncertainty for product development.		

Additive Manufacturing: Extending Logistics Capabilities		
Accession Number:	Report Date:	Access Restrictions:
AD1177382	2019-05-10	A - Approved for Public Release.
Author:	Rodriguez, Mark A.	
Corporate Author:	Marine Corps Univ Quantico VA	
Descriptors:	additive manufacturing, war colleges, manufacturing, test and evaluation, fabrication, students, assembly, doctrine, logistics, military science, personnel management, united states, warfare, advanced manufacturing, materials, stereolithography, three dimensional	
Identifiers:	Not Available	
Additive Manufacturing is a way to address readiness issues in the Army. I propose some initiatives that will assist in expanding the operationalization of AM that include in-depth training for the junior NCO's and warrant officers at the schoolhouse and providing additional certification programs, enabling fabrication requests to be submitted on GCSS-A, and leveraging private industry to solve obsolescence problems and rapid prototyping request.		

Application of Technology Demonstrations and Prototyping in Middle Tier Acquisitions		
Accession Number:	Report Date:	Access Restrictions:
AD1074470	2019-05-04	A - Approved for Public Release.
Author:	Miller, Douglas S	
Corporate Author:	Defense Acquisition University	
Descriptors:	systems engineering, national security, test and evaluation, air force, aircrafts, congress, additive manufacturing, law, united states government, business administration, contracts, department of defense, governments, lessons learned, management personnel, manufacturing, military acquisition, program management, systems management, united states	
Identifiers:	Not Available	
The background for this research is in support of an effort to expand the body of acquisition knowledge within a specific region of program management dealing with the 2016-2018 National Defense Authorization Act Middle Tier Section 804 rapid prototyping and rapid fielding initiative. Specifically, the research aims to improve understanding of the nature and role of technology demonstrations and prototyping as acquisition tools supporting rapid prototyping and fielding. The research method entails a literature review of classic acquisition, Middle Tier objectives, and how the application of technology demonstrations and prototyping has or has not been applied to previous programs. This review supports a summary analysis intended to assist program managers with a better understanding of the Middle Tier process and how to potentially develop an effective technology demonstration and prototyping strategy. The results are that the services have embraced the Middle Tier authority to quickly field weapon systems given the rapid growth and proliferation of technology along with a continuously evolving threat environment. The research concludes that technology demonstrations and prototyping is generally a value-added endeavor in terms of classic acquisition and with a greater understanding of prototype goals, timing, and integration, program managers will be in a better position to succeed in Middle Tier acquisition. Recommendations include creating a culture of less risk-averse and empowered leadership, aggressively continue the path of Middle Tier acquisition, work with the user community to identify new requirements, encourage		

stable funding, and develop training for the Middle Tier acquisition process. Finally, determine how programs initiated via the Middle Tier will effectively transition to programs of record and address the concern of training and sustainment throughout the life cycle of the weapon system.

The Future of Additive Manufacturing in Air Force Acquisition		
Accession Number:	Report Date:	Access Restrictions:
AD1038118	2017-03-22	A - Approved for Public Release.
Author:	Forest, Benjamin D	
Corporate Author:	Air War College Maxwell AFB United States	
Descriptors:	additive manufacturing, military acquisition, air force procurement, military research	
Identifiers:	Air Force acquisition	
Air Force acquisition experiences frequent criticism for its perceived shortcomings in the areas of cost, schedule, and performance. While not a panacea to the myriad of complex Air Force acquisition challenges, additive manufacturing provides significant potential benefits to cost, schedule, and performance in future Air Force acquisition if implemented methodically across every phase of the acquisition lifecycle. Applied to the Material Analysis acquisition phase, additive manufacturing provides the possibility to enable game-changing system design via lower production costs, enhanced performance possibilities, and rapid replenishment. In the Technology Maturation and Risk Reduction phase, additive manufacturing enables rapid prototype redesign to quickly test modifications to enhance capability and performance. During Engineering, Manufacturing, and Development, additive manufacturing is poised to yield both significant schedule reduction over traditional manufacturing as well as major cost savings via reduction of required materials, unique tooling, specialized production plans, and segments of the workforce. Furthermore, the Production phase of acquisition could be potentially revolutionized by additive manufacturing, enabling concepts such as a virtual aircraft fleet and on-orbit satellite production. Finally, additive manufacturing provides the following promise in Operations and Sustainment: resolving diminishing manufacturing and supply problems, transformation of the warehouse, and expeditionary parts production. While additive manufacturing is not a silver bullet to Air Force acquisition problems, the prospective cost, schedule, and performance benefits cannot be ignored. The Air Force must continue to invest in and explore the technology, with particular attention to the following issues: training and education, data/software rights, standards, research cooperation, process and policies and cybersecurity environment.		

Supply Chain

A Qualitative Assessment of Air Force Logisticians' Knowledge of Advanced Manufacturing Techniques		
Accession Number:	Report Date:	Access Restrictions:
AD1106278	2020-06-01	A - Approved for Public Release.
Author:	Fekete, Robert J.	
Corporate Author:	Air Force Institute of Technology Wright-Patterson AFB OH Wright-Patterson AFB United States	
Descriptors:	advanced manufacturing, additive manufacturing, supply chain management, spare parts, air force aircraft, air force personnel, logistics, air force training, air force equipment, air force operations	

Identifiers:	Defense Industrial Base, National Defense Strategy, Metamorphic Manufacturing, On Demand Manufacturing
Research has shown that the US Air Force and the US defense industrial base have limited capability to produce on-demand aircraft spare parts or piece-parts in support of the 2018 National Defense Strategy, when no stock exists. This purpose of this research was to assess the familiarity that US Air Force logistics professionals have with advanced manufacturing techniques capable of producing on-demand aircraft spares and piece-parts, and to identify the barriers they advanced manufacturing techniques. The responses were qualitatively analyzed, and the resultant themes were presented and discussed.	

Additive Manufacturing for Aerospace Maintenance and Sustainment (Postprint)		
Accession Number:	Report Date:	Access Restrictions:
AD1071917	2019-05-01	A - Approved for Public Release.
Author:	Totin, Ashley, MacDonald, Eric, Conner, Brett P.	
Corporate Author:	Youngstown State University Youngstown United States	
Descriptors:	additive manufacturing, materials, performance tests, assembly, jet propulsion, manufacturing engineering, maintenance, systems engineering	
Identifiers:	Aerospace Maintenance and Sustainment, aerospace fleet, stock out, global supply	
Additive manufacturing (AM) is causing a fundamental manufacturing paradigm shift that is changing how aircraft are now maintained and sustained. Sustaining an aging aerospace fleet is an enormous challenge. The U.S. Department of Defense maintains nearly \$100 billion worth of spare parts and has to balance avoiding excess inventory while simultaneously preventing stock-out. A large 747-type aircraft can have nearly 6 million individual parts produced by a global supply chain of approximately 550 companies, some of which may not exist a decade from now. Sustainment organizations struggle with long lead times, resulting in maintenance delays or grounded aircraft. For example, the Oklahoma City Air Logistics Complex reported lead times as long as 800 days for constant speed drive castings. Meanwhile, at the end of 2016, 29 of all U.S. Marine Corps F/A-18 Hornets were grounded pending spare parts.		

Additive Manufacturing: Extending Logistics Capabilities		
Accession Number:	Report Date:	Access Restrictions:
AD1177382	2019-05-10	A - Approved for Public Release.
Author:	Rodriguez, Mark A.	
Corporate Author:	Marine Corps Univ Quantico VA	
Descriptors:	additive manufacturing, war colleges, manufacturing, test and evaluation, fabrication, students, assembly, doctrine, logistics, military science, personnel management, united states, warfare, advanced manufacturing, materials, stereolithography, three dimensional	
Identifiers:	Not Available	
Additive Manufacturing is a way to address readiness issues in the Army. I propose some initiatives that will assist in expanding the operationalization of AM that include in-depth training for the junior NCO's and warrant officers at the schoolhouse and providing additional certification programs,		

enabling fabrication requests to be submitted on GCSS-A, and leveraging private industry to solve obsolescence problems and rapid prototyping request.

Implication of Additive Manufacturing on United States Air Force Expeditionary Civil Engineer Squadron Supply Chain		
Accession Number:	Report Date:	Access Restrictions:
AD1055270	2017-03-23	A - Approved for Public Release.
Author:	Veitenheimer, Shane R.	
Corporate Author:	Air Force Institute of Technology Wright-Patterson AFB OH Wright-Patterson AFB United States	
Descriptors:	Additive Manufacturing, Supply Chain management, air force, monte carlo method, fabrication, assembly, logistics, united states central command, intellectual property, department of defense, cost analysis, decision making, repair, Explosive Ordnance Disposal	
Identifiers:	Civil Engineer Squadron	
Additive manufacturing is mandated as a technology for the Department of Defense to consider to implement. Previous efforts have shown positive potential for additive manufacturing (AM) for United States Air Force Civil Engineering but do not explore the economic impact. This research examines implementation by investigating a specific Explosive Ordnance Disposal repair part supply chain in the current combat theater of operations. A framework to capture the basic financial savings AM could realize was developed to aid AM decision making. This research established a Scenario Planning and Monte Carlo simulation-based framework to produce an estimated annual cost for a system with various configurations and machine capabilities under varied machine life lengths. The model informs the baseline value of AM replacement and what this represents for an associated machine cost. Further, the research presents potential roadblocks and additional cost areas that would impact an AM decision. The overall results take the next step to understand AMs implementation for the United States Air Force and Civil Engineer Squadrons.		

Driving Innovation to Support the Warfighter: Additive Manufacturing Initiatives Within the Defense Logistics Agency		
Accession Number:	Report Date:	Access Restrictions:
AD1029460	2016-12-01	A - Approved for Public Release.
Author:	Morris, Kelly	
Corporate Author:	Defense Logistics Agency Fort Belvoir United States	
Descriptors:	additive manufacturing, computer aided design, department of defense, spare parts, fabrication, life cycle management, logistics, military acquisition, contracts, procurement	
Identifiers:	Not Available	

The spotlight is on for additive manufacturing (AM) in the commercial sector, but it is also intense for the Defense Logistics Agency (DLA), which hopes to capitalize on the promise of innovation to improve readiness and support to the military. As it tracks AM through the Gartner Hype Cycle, which depicts phases that innovations move through from the initial Innovation Trigger through the Plateau of Productivity, is DLA headed down the trough of disillusionment or up the slope of enlightenment to a productive plateau for AM investments? (See Figure 1.) The productive plateau is where mainstream adoption starts to take off. Criteria for assessing provider viability are more clearly defined and the technology's broad market applicability and relevance are clearly paying off.

Challenges of Enterprise-Wide AM for Air Force Sustainment		
Accession Number:	Report Date:	Access Restrictions:
AD1029462	2016-12-01	A - Approved for Public Release.
Author:	Naguy, Debora	
Corporate Author:	Air Force Life Cycle Management Center Wright Patterson Air Force Base United States	
Descriptors:	laser additive manufacturing, processing equipment, aerospace industry, failure mode and effect analysis, department of defense, supply chain management, quality control, air force facilities, military standards, air force training, cost reductions	
Identifiers:	high tech aerospace components, lightweight design	
No one challenges the massive potential of Additive Manufacturing (AM) for high-tech aerospace components. It is a cost-effective, tool-less production that can address many current Air Force supply chain challenges. It also can reduce weight through lightweight design while potentially improving performance and reducing cost.		

Determining the Degree of the Routinization of Additive Manufacturing in the Air Logistics Complexes		
Accession Number:	Report Date:	Access Restrictions:
AD1053959	2016-03-01	A - Approved for Public Release.
Author:	Woods, Candis A	
Corporate Author:	Air Force Institute of Technology Wright-Patterson AFB OH Wright-Patterson AFB United States	
Descriptors:	Additive manufacturing, computer aided design, supply chain management, fused deposition modeling, selective laser sintering, laser additive manufacturing, fabrication, materials engineering, department of defense, maintenance, printing, software prototyping, life cycles, air force	
Identifiers:	innovation, routinization	
Fiscal constraints have affected the USAFs spending and sustainment of weapons systems that are being utilized beyond their programmed life cycle; therefore, it is imperative that processes be given the critical eye for improvement, innovative approaches, and/or best practice implementation. The AFSC, part of the AFMC, has embarked on a groundbreaking effort to transform operations and leverage industry best practices, while maintaining focus on warfighter support to create The AFSC Way. The AFSC Way is based on a shared leadership model that emphasizes speed, safety, and quality, which gives way to innovative ideas and new technologies in order to achieve Art of the		

Possible results, despite fiscal uncertainty. The quest for continued sustainment has led to the recognition of innovation as a vital ingredient for an organization's survival and profitability in this fiscally constrained environment. Additive manufacturing is one such innovation that the AFSC has adopted and implemented in an effort to maintain or enhance current weapons system sustainment practices. If the AFSC is to realize the potential benefits of additive manufacturing, it must be routinized to some degree into the organizations governance systems. This research seeks to aid in increasing the understanding of what routinization events affect an innovations degree of routinization.

Specifications And Standards

An Exploration of the Additive Manufacturing Materials Roadmap for Army		
Accession Number:	Report Date:	Access Restrictions:
AD1180886	2022-02-15	A - Approved for Public Release.
Author:	Hirschler, Lisa S.	
Corporate Author:	Defense Acquisition Univ Huntsville AL	
Descriptors:	fuselages, additive manufacturing, sheet metal, chemical elements, department of defense, national security, aircrafts, materials, test and evaluation, air force, jet engines, aerospace industry, chemistry, logistics, manufacturing, supply chain, turbines	
Identifiers:	flightworthy, 3d printing, am (additive manufacturing)	
The Army's Advanced Manufacturing Campaign plan directs Army leaders to identify ways to use Additive Manufacturing to augment the supply chain, produce complex parts and improve performance of weapon systems (Department of Army, 2019). This research paper focuses on the Additive Manufacturing (AM) implementation roadmap for Army Aviation. Using AM in aviation is particularly challenging since, parts installed on aircraft must be certified flightworthy as part of the overall certification of the aircraft. For engineers wanting to design additively manufactured flight parts, that's easier said than done. The reason is because there are no industry-standard design (Stratasys, 2019, p. 5). In order to develop the roadmap, three areas of research are explored in this document. The first is the detailing of metal alloys currently used in aviation. The second is the aviation part families composed of each alloy. Finally, the current efforts among Department of Defense (DoD) services to obtain the Intellectual Property necessary to produce airworthy AM parts. This research culminates into recommendations for a roadmap prioritizing the order in which Army Aviation should move forward to pursue the required Intellectual Property. Once the Intellectual Property is obtained, it can be used to develop Additive Manufactured Data Sets (AMTDSs) of the metal alloys for airworthiness certification.		

Data Management and Data Curation for Additive Manufacturing		
Accession Number:	Report Date:	Access Restrictions:
AD1156858	2022-01-01	A - Approved for Public Release.
Author:	Underwood, William, Conrad, Mark, Jansen, Greg, Marciano, Richard	
Corporate Author:	University of Maryland	
Descriptors:	Nov Available	
Identifiers:	Not Available	

This report describes key research issues in additive manufacturing (AM) data management that are important to the US Army and the US Army Combat Capabilities Development Command (DEVCOM) Army Research Laboratory (ARL). It also presents a research plan addressing some of these issues. The ability to manage the metadata and data of an additively manufactured part throughout its life cycle is key to achieving the Army's vision of a more adaptive, agile defense supply base. The Additive Manufacturing Data Management Working Group (AM DM WG) has begun addressing this need by developing a Common Data Dictionary for AM, which is nearing completion and will be published as a standard by ASTM International. In FY21, the authors participated in AM DM WG activities to develop an AM common data model and an AM ontology. They also became acquainted with the powder bed fusion method of AM. The research plan for FY22 includes (1) participating in AM DM WG, (2) prototyping an AM research data management application, and (3) collecting DEVCOM ARL and University of Maryland (UMD) AM product and research data. Our longer-range research plan includes (1) developing a tool to support construction of an AM data package for submission to an AM data repository, (2) prototyping an AM data repository for use by DEVCOM ARL and UMD researchers, and (3) federating the prototype AM repository with other AM data repositories.

Training And Education.

Factors Influencing Cross Utilization Training in Aircraft Maintenance Fabrication		
Accession Number:	Report Date:	Access Restrictions:
AD1177712	2022-06-01	A - Approved for Public Release.
Author:	Vogeler, Aaron L	
Corporate Author:	Air Force Institute of Technology Wright-Patterson AFB OH	
Descriptors:	fabrication, air force, additive manufacturing, manufacturing, students, advanced manufacturing, aircraft maintenance, aircrafts, doctrine, education, maintenance, test and evaluation, training, warfare, x-ray computed tomography, experimental design, knowledge management	
Identifiers:	Cross Utilization Training, Multiskilling	
The goal of this research was to identify areas that affect performance in Cross Utilization Training (CUT) in order to maximize its effectiveness. The researcher collected performance data of 25 personnel of varying demographics at 3 different locations each performing 5 different tasks from the Metals Technology and Non-Destructive Inspection career fields. The researcher used a combination of linear, bivariate, and ordinal regression to assess relationships between demographics, confidence, experience, recency, and the task performance data. For three of the five tasks, confidence, experience, and recency were good indicators of performance.		

Establishing An Additive Manufacturing (AM) Navy Enlisted Classification For The Machinery Repairman To Enable Efficient Use Of AM And Mass Adoption Of The Technology		
Accession Number:	Report Date:	Access Restrictions:
AD1080236	2019-06-01	A - Approved for Public Release.
Author:	Garcia, Gilbert Jr, Edenfield, Bradford L., Yoshida, Kazuma	
Corporate Author:	Naval Postgraduate School Monterey CA Monterey United States	

Descriptors:	additive manufacturing, manufacturing, training, operational readiness, classification, additives (chemicals), life cycle management, job training, fabrication, students
Identifiers:	3D (Three Dimensional), AM (Additive Manufacturing), CPLM (Collaborative Product Life Cycle Management), GMA (Gas Metal Arc), GTA (Gas Tungsten Arc), MM (Machinists Mate), MR (Machinery Repairman), SM (Subtractive Manufacturing)
Additive Manufacturing (AM) technology has been making significant advances in recent years. While industry has already started exploiting it in its daily operations, the adoption and implementation of AM technology across the Department of Defense (DoD) and Department of the Navy (DoN) are still in very early stages. The major value that DoD and DoN plan to achieve are improvements in operational readiness, cost-savings, and increases in warfighting capability. The DoN has yet to identify the elements of a comprehensive training program across the fleet, including the training of operational level users. Should a Navy Enlisted Classification (NEC) be created for the Machinery Repairman (MR) rating to ensure safe and competent use of AM technology? Does creating an NEC support DoD and DoN policies and guidelines for AM implementation? This report examines those questions and provides a rationale and recommendations for the creation of an AM NEC, including a set of critical skills that should be a part of that training. Methodology developed and used in this report could be applied to examine the needs of other rates beyond MR. Recommended future work emphasizes the need to continue updating the training program recommended in this report, keeping it relevant with advances made in AM technology and our growing understanding about DoN applications of this technology.	

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