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An Analysis of Additive Manufacturing Production Problems and Solutions

December 2016

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ABSTRACT

The purpose of this study is to examine challenges and opportunities facing industry and the Department of Defense (DOD) in utilizing additive manufacturing (AM). This research focuses on the challenges and opportunities identified in a June 2015 Government Accountability Office report pertaining to supply chain issues and to advance research methods used to obtain intellectual property and patent rights. Specifically, this research examines supply chain and intellectual property rights methods used in government and private industry to maximize AM capabilities for the benefit of the DOD. Research was conducted by analyzing current technology and processes used in both cradle-to-grave logistics of AM material and private sector approaches to obtaining intellectual property rights for continuous internal use. These methods are analyzed for compatibility with government operations. This report is the final result of our research. This report determined potential solutions the DOD can adopt to effectively resolve challenges faced in producing and obtaining intellectual property rights for DOD-required material.

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I would like to thank those individuals who helped me achieve this career milestone. To our advisors—Cory Yoder and Doug Brinkley—thank you for your insight and support in researching this interesting and relevant topic. Your knowledge in this field is unparalleled and invaluable.

To my family: Janice, thank you for your understanding and support while I spent countless hours working on this project. Mom and Dad, thank you for instilling in me the value of hard work and always supporting me in everything I do. I am forever indebted to you.

—LCDR Ben Muniz

I want to thank all those who made this project a success. First, I want to thank my wife, Gaea. Your love and support through all the long days helped me persevere through this and all of my graduate school projects. I finally caught up with your level of education. To my kids, Gavin and Kylie, I know you missed me when I had to stay late; I missed you, too. To my parents, Steve and Kathleen Peters: thank for you giving me a solid foundation of values that allowed me to go further than I ever thought possible. To our advisors, Professor Yoder and Dr. Brinkley: thank you for giving us the confidence to pursue this project and the freedom to approach it from our unique perspectives.

—LCDR Kevin Peters

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ABOUT THE AUTHORS

Benjamin G. Muniz, Lieutenant Commander, United States Navy, is a 2004 graduate of West Texas A&M University where he received a Bachelors of Business Administration in Management. He joined the United States Navy in 2006, receiving his commission as a Supply Corps Officer through Officer Candidate School, Pensacola, FL.

Following his 2007 graduation from the Navy Supply Corps School, Athens, GA, he served as the Disbursing Officer onboard the USS *Harry S Truman* (CVN 75). In November of 2007, he deployed with *Harry S Truman Strike Group* in support of *Operation Iraqi Freedom.*

In January of 2009 Muniz' volunteered to fill an Individual Augmentee (IA) assignment serving as the J4 Officer in Charge at Iraq Assistance Group- South. During this tour he was responsible for all aspects of logistical support in order to sustain, train and employ advisory ready Military, Border and National Police Transition Teams to assist in the development of credible Iraqi security forces.

LCDR Muniz reported to Commander Naval Air Forces in January 2010 and as the Assistant Navy ERP Lead for Ashore Activities. LCDR Muniz led the type commander's efforts in the development of the R-Supply transition strategy for use across all Naval Air Stations worldwide during the implementation of Navy ERP.

In February of 2012 LCDR Muniz reported to NAVSUP Fleet Logistics Center Sigonella- Site Bahrain as the Business Officer. He was responsible for managing a $6.4M budget utilized in filling product and services requirements to support 92 tenant commands at Naval Support Activity Bahrain, 10 forward deployed ships and 100 units deployed to the 5th Fleet area of responsibility.

LCDR Muniz reported to Explosive Ordnance Disposal Expeditionary Support Unit ONE in December 2012. As Supply Officer accountable for $10M in COSAL and Table of Allowance equipment used to support all West Coast EOD Mobile Units. LCDR Muniz deployed to CENTCOM AOR as the Expeditionary Support Element OIC attached to Commander Task Group 56.1 in support of *Operation Enduring Freedom*.

LCDR Muniz' personal awards include the Joint Service Commendation Medal, Navy Marine Corps Commendation Medal (3), Navy Marine Corps Achievement Medal (3) and numerous unit and campaign awards. LCDR Muniz is a qualified Naval Aviation Supply Officer, Surface Warfare Supply Corps Officer and Navy Expeditionary Supply Corps Officer.

Kevin M. Peters, Lieutenant Commander, United States Navy, graduated from the University of Kentucky in 2001 where he received a Bachelor of Science degree in Business Management. He was commissioned as an Ensign at Officer Candidate School, Naval Air Station (NAS) Pensacola, FL in December 2003. Following commissioning, he completed Basic Qualification Course at the Naval Supply Corps School in Athens, GA and was assigned as the Supply Officer to Commander, Maritime Prepositioning Squadron-THREE (COMPSRON-3). While aboard COMPSRON-3, LCDR Peters earned his qualification as a Surface Warfare Supply Corps Officer and supported Operation Unified Assistance during a tsunami relief mission in The Maldives.

LCDR Peters' other tours at sea include duty as Supply Officer, USS MINNEAPOLIS-ST. PAUL (SSN 708) where he completed a 6-month independent deployment to the SIXTH Fleet Area of Responsibility. While onboard MINNEAPOLIS-ST. PAUL, he earned his qualification as a Submarine Warfare Supply Corps Officer, completed the homeport shift from Norfolk, VA to Pearl Harbor, HI and decommissioned the ship. Most recently, LCDR Peters was assigned aboard the aircraft carrier USS CARL VINSON (CVN 70) serving as division officer in Hotel Services (S-5) and Materiel (S-8) divisions. While onboard CARL VINSON he completed two deployments to the FIFTH Fleet Area of Operations, was the recipient of the Battle "E" award in 2013, and earned his qualification a Naval Aviation Supply Corps Officer.

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LCDR Peters has completed two Individual Augmentation (IA) deployments to the Southern Philippines in support of Joint Special Operation Task Force-Philippines (JSOTF-P). In 2008 he served as the JTF 515.1 Logistics and Administration Officer onboard USNS STOCKHAM (T-AKE 3017). In 2015, he served as the Deputy Logistics (J4) Officer at Camp Navarro, completed the transition from JSTOF-P to the PACOM Augmentation Team-Philippines (PAT-P) and served as the first PAT-P Director of Logistics.

LCDR Peters is currently earning his Masters of Business Administration (MBA) degree in Materiel Logistics Management at the Naval Postgraduate School in Monterey, CA. Kevin and his wife, Gaea, live in Monterey, CA and are proud parents of son, Gavin, and daughter, Kylie.

In addition to his three warfare qualifications, his personal awards include the Joint Service Commendation Medal, Navy and Marine Corps Commendation Medal (three awards), the Navy and Marine Corps Achievement Medal (four awards), and various unit and campaign awards.

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LIST OF ACRONYMS AND ABBREVIATIONS

2D	Two-Dimensional
3D	Three-Dimensional
4D	Four-Dimensional
ABS	Acrylonitrile-Butadiene-Styrene (Terpolymer)
ACWT	Average Customer Wait Time
AM	Additive Manufacturing
BBP	Better Buying Power
CAD	Computer-Aided Design
CAE	Computer-Aided Engineering
CNC	Computer Numerical Control
CRADA	Cooperative Research and Development Agreements
DARPA	Defense Advanced Research Projects Agency
DDM	Direct Digital Manufacturing
DFARS	Defense Federal Acquisition Regulation Supplement
DOE	Department of Energy
DOD	Department of Defense
DMS&T	Defense-Wide Manufacturing Science and Technology
FAR	Federal Acquisition Regulation
FDM	Fused Disposition Modeling
GAO	Government Accountability Office
IP	Intellectual Property
NAMII	National Additive Manufacturing Innovation Institute
NASA	National Aeronautics and Space Administration
NAVSUP	Naval Supply Systems Command
NAVSUP GLS	Naval Supply Systems Command Global Logistics Support
NDE	Non-Destructive Examination
NSN	National Stock Number
OEM	Original Equipment Manufacturer
PBF	Powder Bed Fusion
PLM	Product Lifecycle Management
RP	Rapid Prototyping

R&D	Research and Development
RDT&E	Research, Development, Test & Evaluation
SECDEF	Secretary of Defense
SLA	Stereolithography
SLS	Selective Laser Sintering
SM&R	Source Maintenance & Recoverability
SMA	Supply Material Availability
STEAM	Science, Technology, Engineering, Arts, and Mathematics
STL	Standard Tessellation Language
UPS	United Parcel Service
USC	United States Code
USD(AT&L)	Under Secretary of Defense for Acquisition, Technology, & Logistics

I. INTRODUCTION

The technologies known as additive manufacturing (AM) have matured to a commercial level and are now a viable option to support current and future Department of Defense (DOD) materiel readiness requirements. The maturation and introduction of this technology as a production source faces a wide array of challenges, as expected with evolving technology and its application into the general assembly lines and repair facilities. The initial use of the AM capability within industry and the DOD has revealed a number of challenges that require expeditious resolutions; some of these challenges were expected with the introduction of this new technology, but new, unexpected challenges have appeared as the use of AM has increased. This research focuses on the challenges of supply chain management and intellectual property (IP) rights. Both private industry and the DOD are facing these challenges as the use of AM gains momentum. To realize the full benefits of this technology and permit further growth and adaptation of this technology, private industry and the DOD must address the supply chain challenges and resolve intellectual property rights issues.

This paper addresses the necessary actions to overcome the material limitations and intellectual property rights issues impeding government from realizing the benefits of using AM.

A. RESEARCH OBJECTIVES

The purpose of this research is to identify methods that are currently being used or are feasible to eliminate the challenges hindering the adoption and optimal production capacity of AM throughout the DOD enterprise. Additionally, this report identifies the current federal acquisition regulations related to the procurement of intellectual property rights involved in AM. An analysis of these regulations assists in determining potential methods of satisfying the regulations while encouraging industry to authorize use of the applicable rights for government production of protected property. The first part of this research discusses elements relevant to supply chain management of AM material and production. The second part of this research paper identifies the federal regulations currently governing the protection of intellectual property rights related to government procurement and usage. The goal of each section is to focus on viable solutions necessary to overcome the challenges currently hampering effective and efficient adoption of AM in the DOD.

B. RESEARCH QUESTIONS

To further advance the use of AM within the federal government, solutions to the current challenges related to supply chain management and intellectual property rights need to be resolved. In an effort to provide recommended solutions to these issues, this research project aims to answer the following questions.

1. Primary research question

- How can federal acquisition procedures be adapted to overcome intellectual property challenges that AM technology can be used to increase supply chain efficiency?

2. Secondary research questions

- How can the DOD utilize AM to improve supply chain efficiency?
- What intellectual property challenges does AM present?
- How can federal acquisition procedures be adapted to overcome the challenges?

C. RESEARCH VALUE

Previous research related to AM in the private industry and the federal government highlighted organizations that utilize this technology to produce components or parts within their production plants or in restricted pilot programs within the federal government. This research advances current research related to AM by providing recommendations on how to solve the issues identified in the 2015 U.S. Government Accountability Office (GAO) report titled *3D Printing: Opportunities, Challenges, and Policy Implications of Additive Manufacturing*, specifically related to supply chain deficiencies and intellectual property rights. In addressing these challenges, this report recommends solutions to the supply chain management and intellectual property issues identified here with the intention of providing realistic solutions in order for the government to increasingly adopt AM technology efficiencies where most practical.

D. METHODOLOGY

Research was performed utilizing a multi-phase approach. Initially, past and current material consisting of books, articles, government publications, federal regulations, and case studies pertaining to AM were reviewed to become familiar with the topic and better comprehend the challenges identified in the June 2015 GAO report. Then, current practices in private industry and in the federal government were analyzed for relevant information and potential application to current challenges. Lastly, interviews were conducted with industry and government subject-matter experts to address the latest processes being utilized or researched for future application to resolve supply chain management issues and overcome the barriers hindering the effective permissions of intellectual property rights between private industry and government agencies.

E. REPORT STRUCTURE

This report contains six chapters. The report begins with history and background information about AM in Chapter II. Chapter III contains a review of the literature illustrating the current state of supply chain management and intellectual property in the world of AM. The research analyzed in this chapter served as the springboard for the study. Chapter IV analyzes the supply chain management challenges impeding rapid adoption and efficiencies in AM. Chapter V identifies the regulations hindering private industry from engaging with the federal government to accelerate using this technology within government agencies. Chapter VI offers a summary of the study, conclusions, and recommendations to overcome the supply chain management and intellectual property rights issues obstructing maximum efficiencies and utilization of AM. This chapter also provides areas for further research.

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II. BACKGROUND

This chapter covers the background of additive manufacturing (AM) technology, intellectual property rights, and supply chain management. It lays the foundation for this research into the challenges the DOD must overcome to realize all the benefits of AM. Adapting and overcoming intellectual property rights is one of the major challenges identified by the GAO in its report *3D Printing: Opportunities, Challenges, and Policy Implications of Additive Manufacturing* from June 2015 (GAO, 2015a). Supply chain management improvements, specifically, the ability to quickly manufacture customizable repair parts in remote locations, is one of the benefits identified by this report. This GAO report covers many other challenges and opportunities, but this research focuses on intellectual property rights and supply chain management.

A. HISTORY OF ADDITIVE MANUFACTURING

This section presents a brief history of AM, including an abbreviated account of AM in its infancy. The section focuses mainly on the period from the mid-1980s to present. Since its early years, AM has evolved into a viable technology for research institutions and private industries alike.

AM is a method by which digital three-dimensional (3D) design data are used to construct an object by adding layers of the respective material upon each other until the object is finished (“Additive Manufacturing,” 2016). The term *additive manufacturing* includes multiple technologies such as “3D Printing, Rapid Prototyping (RP), Digital Direct Manufacturing (DDM), layered manufacturing, and additive fabrication” (AM Basics, n.d.).

To create a 3D-printed object, the company uses 3D computer-aided design (CAD) software to produce a digital model divided into thinly cut cross-sectional layers. The printing process consists of adding these layers upon each other with the respective material beginning at the bottom of the object. The layers build upward until the final layer is added to the top, creating the final 3D object (3D Printing, 2016).

The origins of AM date back to 1860 when Francois Willeme patented a method for creating a photosculpture. This was done by placing the object in a circular room where 24 cameras spaced at even intervals concurrently captured pictures of the subject. These photos were then traced by a cutter attached to a pantograph that would simultaneously cut the wood. The final sculpture was made by compiling each layer of wood (Bourell, Beaman, Leu, & Rosen, 2009). Figure 1 shows Willeme sitting in a room specially designed to simultaneously capture the photos necessary to create his 3D sculpture.

Figure 1. Human Photosculpture in Willeme Studio.
Source: Bourell et al. (2009).

In 1892, J. E. Blanther patented the process to create topographical maps. He utilized a process of piling a succession of wax plates onto each other that were cut according to the shape of each layer in the overall object. Papers were inserted between opposing positive and negative forms resulting in the contoured map (Bourell et al., 2009). This was the precursor to what would be developed into modern AM.

The creation of AM or, as it is commonly known today, 3D printing, can be traced back to 1984 with the invention of stereolithography by Charles Hull. Stereolithography was a more advanced printing method that used ultra-violet (UV) light rather than the wax used in Blanther's original process (Geng, 2015). Hull's ingenuity occurred while he was using UV lights in his day job putting thin cut layers of veneers on furniture. After dabbling with the process for about a year, Hull created a process using the material photopolymer, which is a liquid that solidifies under light and shape and can be outlined and layered. In 1986, Hull advanced his technology through his new company 3D Systems, which would sell the first stereolithography in 1988 (Wohlers & Gornet, 2014). This invention would catapult AM for the next 30 years at a rate of advancement far exceeding that of the previous 120 years since Francois Willeme developed his photosculpture technique.

In the years between 1988, when Chuck Hull's stereolithography was first made available for public purchase, until 1996, many incremental accomplishments further advanced the commercialization of AM. In 1991, the following AM technologies were commercialized: laminated manufacturing (LOM), solid ground curing (SGC), and fused deposition modeling (FDM; Wohlers & Gornet, 2014). These achievements were all based on the principle of AM but used different materials and composition methods to develop the final object.

Commercially available 3D printers came on the market when 3D Systems began selling 3D printers in 1996. The first version, the Actua 2100, added layer-by-layer wax deposits via an inkjet printer (Wohlers & Gornet, 2014). Other corporations followed suit and sold various models utilizing the same process but with different materials. The increased interest led to companies allocating more of their budgets to research and development (R&D), resulting in a more rapid fielding of devices with newer technologies and capabilities hitting the industrial market in shorter time. In 1999, 3D Systems released Actua 2100's successor, the Thermojet. This version was less expensive and faster than its predecessor (Wohlers & Gornet, 2014).

The beginning of the century brought new technology and capabilities to the AM technology industry. Multiple companies continued to make incremental gains, but the highlight in the first part of the 21st century was Z Corporation's first commercially available multi-color 3D printer, the Z420C (Wohlers & Gornet, 2014). Figure 2 illustrates some of the milestones in AM.

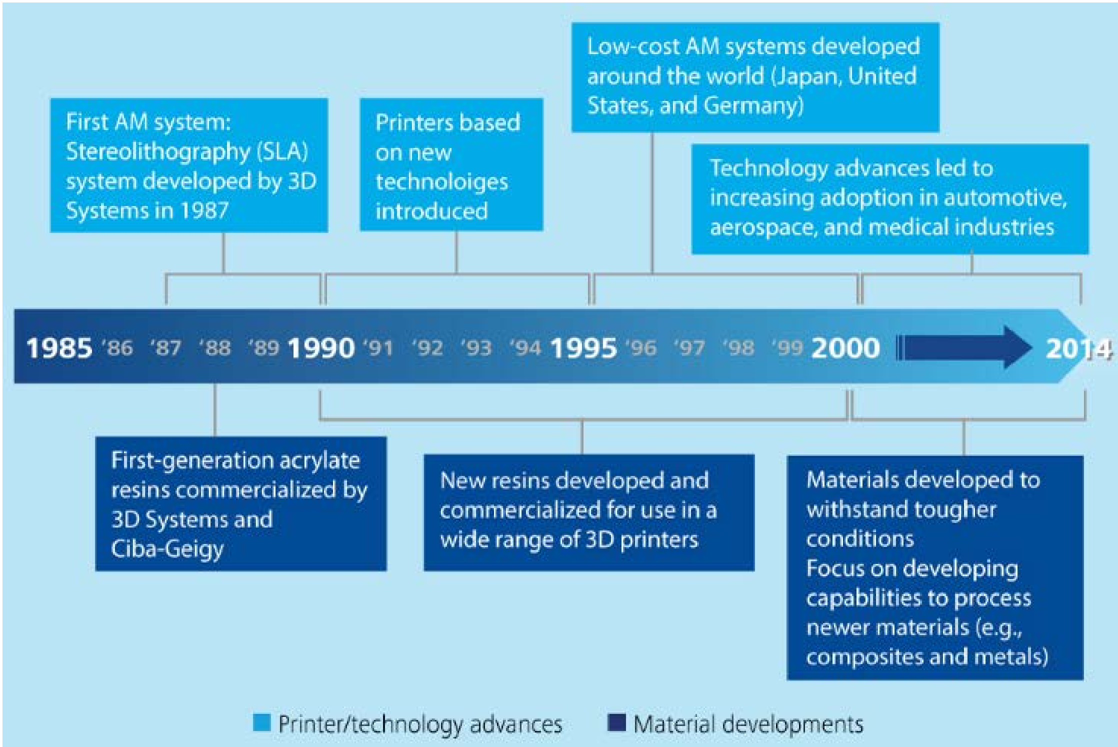

Figure 2. The Development Milestones of Additive Manufacturing since 1985. Source: Marchese, Crane, & Haley (2015).

In the last decade, 3D printing has experienced rapid growth in the aerospace and medical industries. In 2010, Optomec won a Navy contract to produce the laser-engineered net shaping (LENS) method to repair aircraft engines (Wohlers & Gornet, 2014). The following year, manufacturers of hearing aids embraced this technology industry-wide for the fabrication of custom-fit pieces (Wohlers & Gornet, 2014). Shortly thereafter, the dental industry began adopting AM to produce custom-fit orthodontic pieces (Wohlers & Gornet, 2014). These industries began to take interest in the capabilities of direct metal processing and its capabilities when joined with mechanical properties such as wrought alloys, which are more commonly used in industry. Due to its familiarity, this combination quickly gained support as one of the leading materials used in AM (Wohlers & Gornet, 2014).

This same year, the fused disposition modeling (FDM) patent expired and allowed for cost-effective equipment constructed on the RepRap open source project to become widely accessible. This has resulted in low-cost personal systems generating very strong consumer interest, and the same can be expected when Standard Tessellation Language (STL) and laser sintering technology patents expire (Wohlers & Gornet, 2014).

Most recently, the first flight-critical aircraft part constructed using AM was tested on a MV-22B Osprey test flight in July 2016. The link and fitting assembly is a critical component that secures the aircraft's engine nacelle to the aircraft wing. This was the first time a part produced by AM was used in a non-prototype environment and was considered essential to flight safety (Naval Air Systems Command Public Affairs, 2016).

The last three decades have illustrated tremendous growth in AM technology. Beginning with its initial creation to its current use in the most demanding capacities, the technology will continue to evolve as patents expire and the cost associated with AM continues to decrease.

B. FEDERAL GOVERNMENT INVESTMENTS IN ADDITIVE MANUFACTURING

There has been widespread interest in AM technology within the federal government. In addition to the DOD, the Department of Commerce, Department of Education, Department of Energy, National Aeronautical Space Administration (NASA), and the National Science Foundation (NSF) have all started projects to explore AM processes.

In May 2012, under President Obama's plans to develop AM technologies, the DOD announced a new program called National Network for Manufacturing Innovation (NNMI). The goal of the program is to develop a "range of structural and functional materials with defense and energy applications" (Lindman, 2012, p. 1) to reduce the cost of products and promote U.S. economic competitiveness. The administration's proposal includes up to $1 billion in funding (Lindman, 2012).

One of the programs under the NNMI is the National Additive Manufacturing Innovation Institute (NAMII), better known as "America Makes." Based in Youngstown, OH, American Makes is a public–private partnership of 65 organizations including companies, universities, community colleges, and nonprofits. Its goal is to foster a highly collaborative environment to accelerate AM technologies. NAMII was started with a $30 million federal grant; however, America Makes is expected to become financially self-sustaining in 2017. It is currently managing over $87 million in AM projects and recently opened its first satellite office in El Paso, TX (America Makes, n.d.).

The Navy is leaning forward in implementing AM technology. In 2013, the Print the Fleet project was started to develop procedures for printing, certifying, and delivering parts. The environment on a ship out to sea provides even more challenges such as humidity and ship movement. Other challenges involve the so called "digital supply chain" of the software required to run these machines. So far, only small items like oil caps have been printed, but the Navy is working on making larger items like aircraft wings and small drones. In addition to other benefits, the Navy is hoping to reduce the risk to the physical supply chain (Harper, 2015).

C. THE PROCESS OF ADDITIVE MANUFACTURING

The AM process takes a CAD-based 3D model through an eight-step process that ultimately results in the physical object. The complexity of the part may involve different levels of AM. Simple items may only utilize graphic models of the AM process, while more complex items may involve AM at multiple stages throughout the manufacturing process. Items in the initial stage of the product development cycle may require only a few steps within the AM process, since a rough part may be acceptable compared to an item in the later stages of development, which requires a complete and finalized part. Figure 3 depicts the general AM process as documented in *The Additive Manufacturing Process* (Gibson, Rosen, & Stucker, 2010).

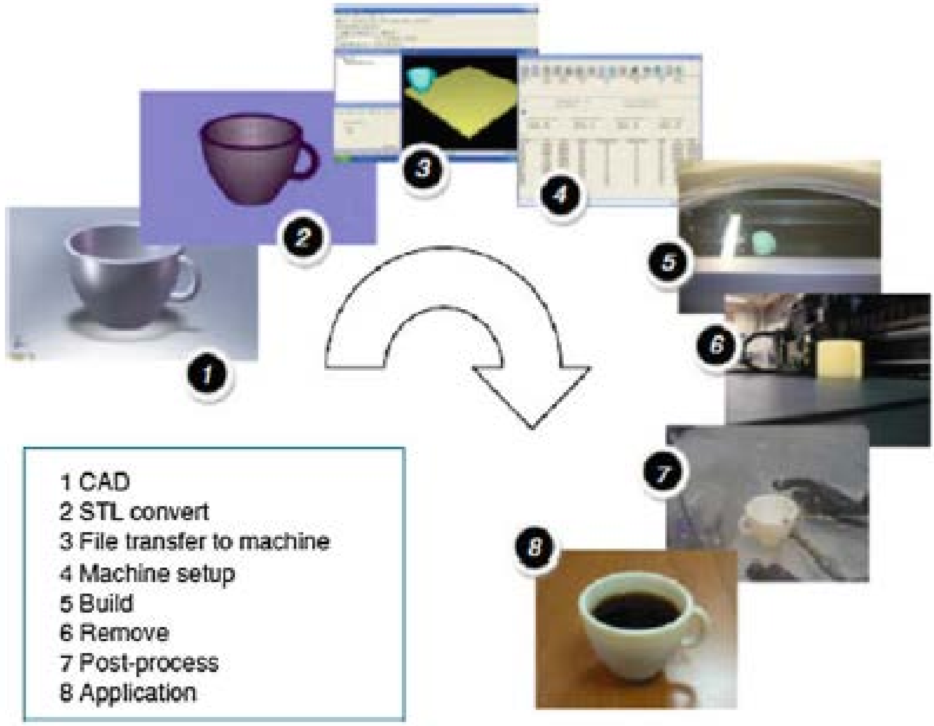

Figure 3. Additive Manufacturing Technologies: Rapid Prototyping to Direct Digital Manufacturing. Source: Gibson et al. (2010).

Step 1: CAD

Products developed through AM are created beginning with a software model containing the exterior geometry. Regardless of the software used, the critical output is a 3D solid or external image. Another viable option is to reverse engineer an item or part using a laser or scanning device.

Step 2: Conversion to STL

This step requires converting files to STL, which is the current standard and can be produced by a majority of CAD systems. The STL file is required because it contains the dimensions of the closed exterior surface and is necessary to calculate the layers.

Step 3: Upload to AM Machine and STL File Manipulation

The STL file must be uploaded to the AM machine. Necessary manipulation of the file may be performed at this time to ensure details such as size, position, and angle.

Step 4: 3D Printer/Machine Setup

Configure the AM machine setting to ensure it accounts for restrictions, power source, layer width, precision degrees, timing, and other configurations.

Step 5: Build

The AM machine builds the object via an automated process similar to paper printers. Limited oversight needs is required to make sure the printer has adequate material and to address possible software malfunctions.

Step 6: Removal

The object printed must be removed upon completion of build. Aside from simply removing it, safety interlocks in place to prevent the printer from overheating or from moving parts. These locks must be released.

Step 7: Post Processing

Upon removing the object from printer, it may need to be cleaned, unbraced, or subjected to final manual touchups.

Step 8: Application

The 3D-printed object may now be functional. In some cases, it may require additional manipulation such as priming, painting, texturing or finishing necessary to realize the final intended end use state. At this point, it can be used or assembled into the component of which it is a part for complete functionality.

D. INTELLECTUAL PROPERTY RIGHTS LAWS AND REGULATIONS

The authority to reproduce items by the government and private industry is subject to numerous federal laws and regulations ensuring the integrity of intellectual property rights. Intellectual property as defined by Defense Acquisition University (DAU) is the "intangible creation of minds—inventions, literary and artistic work, unique business names and so forth" ("Intellectual Property," n.d.). One form of intellectual property rights pertinent to the protection of inventions and applicable to the government's ability to refabricate items through AM is access to technical data (TD). Technical data is "recorded information of a scientific or technical nature" which consists of material such as "product design or maintenance data" ("Data Rights," 2016).

As directed in the Defense Federal Acquisition Regulation Supplement (DFARS) 227.7103-1, the "DOD policy is to acquire only the technical data, and the rights in that data, necessary to satisfy agency needs." This is often a due to the high cost associated with procuring the copyright permissions. In rare cases, the government will fund 100% of the costs to create the desired product and will obtain "unlimited rights" enabling full use of the data. Even if the government funded 100% of the software, it does not own the data but has only received the specified licensing rights to use the technical data or software. The rights the government is authorized per data package is typically dependent on the percentage of funding the government contributes and is documented in the contract.

Standard licensing rights received by the government for computer software authorized by the licensor are classified as unlimited, limited, government purpose, restricted or specifically negotiated rights (DFARS 227.7103-5). The following are explanations for these different types of data rights as documented in the DFARS:

- **Unlimited Rights:** The rights of the government to utilize, release, duplicate, produce derivative works, issue copies, in any form and/or reason, and to authorize others parties as the government sees fit (DFARS, 2016, Sect. 227.7103-5).
- **Limited Rights:** Authorization for the government to have up to full use of proprietary technical data internally, but must request authorization to disclose the data to nongovernment agencies (DFARS, 2016, Sect. 227.7103-5).
- **Government Purpose Rights:** The rights to utilize, copy, or release technical data strictly for government purposes use, and allow others to utilize for the sole interest of the government. Prohibits the use of data for commercial application (DFARS, 2016, Sect. 227.7103-5).
- **Restricted Rights:** Rights obtained and used by the government pursuant to the terms of the contract for data developed solely with private funds (DFARS, 2016, Sect. 227.7103-5).
- **Specifically Negotiated License Rights**: Specific rights agreed to by the contractor and government that are distinct from the rights normally authorized in a standard license. (DFARS 227.7103-5)

Regardless of the data rights obtained by the government, it must utilize these rights with a concern for the financial effect they have on a business, in addition to the government's future supply source. In many cases, proprietary information is what delineates one contractor from other contractors in the industry and provides the competitive advantage required to prosper in a free market. On the other hand, a competitive advantage may develop into a monopoly, which eliminates competition. The government must find the middle ground when acquiring technical data to effectively incentivize industry to advance technological growth while at the same time maintaining an adequate industry base to ensure effective competition ("Data Rights," 2016).

U.S. laws in the form of statutes, in addition to federal and DOD regulations, provide guidance to ensure all parties' interests are protected in the execution of government procurements involving intellectual property including technical data. Additionally, each military branch promulgates service-specific guidance governing the respective branch's AM policies.

1. Federal Statutes

Federal statutes are laws passed by Congress and promulgated in various forms, one of which is codified law also known as the United States Code (Library of Congress, n.d.). These laws serve as the foundation from which federal and DOD regulations are created. The DOD is governed by Title 10 of the U.S.C.; therefore, all DOD acquisitions are subject to the terms of this code. Title 38 of the U.S.C. serves as the directorate for laws pertaining to patents. Although the these two codes provide the majority of policy pertaining to the DOD and patents, other codes that touch patent law within their respective Titles are discussed later in the chapter.

2. Rights in Technical Data

In accordance with Title 10 of U.S. Code Section 2320, the secretary of defense (SECDEF) is required to establish policy ensuring the protection of government, contractor, and subcontractor rights relevant to the technical data of goods and technologies as established by law. These policies are required to be included in the DOD's version of the FAR, known as the Defense Federal Acquisition Regulation Supplement (DFARS; 10 U.S.C.

§ 2320). This supplement also identifies the rights of the government, contractor, and subcontractor based on the extent of the funding contributed by each of these parties to the technical data or proprietary information. The government is authorized unlimited rights to the technical data in cases where the research and development is supported solely with appropriated funds. On the other hand, the contractor or subcontractor may limit the government's rights or ability to share data with nongovernment agencies when technical data is created at the sole expense of the contractor. Under this law, program managers are mandated to analyze the technical data needs of all elements relevant to major weapon systems and incorporate acquisition strategies to enable effective sustainment through the life cycle of the weapon system. This principle is also required under Section 2548 of U.S.C. Title 10.

DOD contracts that contain stipulations regarding the delivery of technical data must comply with 10 U.S.C. Section 2321. This policy requires the SECDEF to mandate the validity of these stipulations within three years after the latter of the payoff date or delivery date on which the technical data is provided to the government. The government may dispute the release restriction should sufficient reasons exist and compliance with the restriction would impede the practical competitive acquisition of the item containing the technical data at a later date. The government may not challenge stipulations of the technical data after six years unless an extenuating circumstance such as those identified in 10 U.S.C. Section 2321(2)(A) exist. If a written challenge is issued by the government based on one of these circumstances, the contractor or subcontractor has 60 days to reply explaining the basis for their assertion. Upon receipt of the contractor's response, the contracting officer has 60 days to make a decision regarding the legitimacy of the assertion. The contracting officer will make a determination regarding the validity of the assertion in 60 days as well, if the contractor does not provide a justification to their restriction.

A contractor or subcontractor can submit a claim in writing to the contracting officer contesting the decision made regarding the validity of a restriction, which shall be handled in accordance with Title 41, Chapter 71.

Pursuant to U.S.C. Title 41, Chapter 71, Section 7103, if the contracting officer's challenge to a restriction is upheld, the restriction must be revoked and the contractor may be required to reimburse the government for the cost associated with challenging the restriction. The opposite would apply if the challenge to the restriction is not sustained.

a. Patents—Bayh-Dole Act

Policy established in U.S. Code Title 35, Chapter 18, defines the manner in which the patents system must be used for inventions created with the use of federally financed research. This act serves to protect inventors against misuse or impractical access to their inventions while affording the government adequate rights to realize the benefits for the inventions it partially or wholly funded. In accordance with 35 U.S. Code Section 202, a contractor is required to reveal invention to the government for which it has created using federal funding in a reasonable time. Failure to do so may result in the government receiving title to the invention. A contractor must notify the government in writing if they will exercise their right to retain title on the inventions within two years form the initial notification of the invention. The government is authorized nonexclusive, nontransferable and paid-up rights for government use of the invention. However, the government is prohibited from authorizing the licensing of the invention to third parties for inventions in which the contractor has elected to retain rights without obtaining written approval from the head of the company. Noncompliance of this policy by any party may result in action by the Office of Federal Procurement Policy and ultimately the U.S. Court of Federal Claims.

b. Cooperative Research and Development Agreements

Cooperative Research and Development Agreements (CRADA) are an authorized type of contract under 15 U.S.C. 3710 that allows the government to enter into an agreement with a private institution and provide resources necessary to perform specialized research aligned specific to the federal agency's mission. This type of contract allows government researchers to collaborate with nonfederal government agencies and share technical expertise in a wide spectrum of disciplines. CRADA ensures the protection of rights for both parties and is applicable to inventions made under this agreement. Private agencies are afforded the opportunity to maintain licensing rights equivalent to exclusive licenses under the condition the government is entitled to nonexclusive, nontransferable, irrevocable, paid-up license in return for their cooperation of the CRADA. Under this type of agreement, both parties are prohibited from divulging trade secrets or any proprietary information relevant to the terms of the agreement for up to five years if necessary. CRADA initiatives are exempt from the FAR and DFARS.

Under U.S.C. Title 35, Chapter 18, Section 203, the federal government may exercise “march-in” rights, which oblige the contractor to authorize the appropriate rights and licenses to other nongovernment agencies under practical conditions when the agency holding the title has not taken or is not expected to take further action to realize useful application of the invention.

c. Infringement

U.S.C. Title 35, Chapter 28, Section 271 defines patent infringement as when a person “without authority makes, uses, offers to sell, or sells any patented invention within the United States or imports into the United States any patented invention during the term of the patent.” A product that is developed through a patented process must either experience “material change by subsequent process” or become an unnecessary part of another product to no longer be protected by propriety law.

U.S.C. Title 28, Chapter 91, Section 1498 entitles the owner of a patent to recover “reasonable and entire compensation for such use and manufacture” for patent infringement when a patented invention is produced or employed by or for the government without proper licensing rights or legal permission. Compensation includes administrative and legal cost incurred in pursuit of recovering damages resulting from the patent infringement. Compensation for patent infringement is pursued in the U.S. Court of Federal Claims.

The intellectual property principles that apply to AM are no different from any other technology, but the scale and scope of violations as well as the pool of potential infringers is much, much larger (Hornick, 2015).

3. Federal Regulations

Federal regulations are derived from U.S. Code and provide the common and permanent rules that govern the executive branch of the U.S. federal government. These regulations serve as the administrative law ensuring that the same standards are followed by all agencies in the executive branch of government. Agencies are required to adhere to these codes when creating regulations specific to their operations. The DOD adheres to the FAR and the DFARS in the execution of its acquisitions.

a. Federal Acquisition Regulation

The FAR (2016) is the principal regulation that provides consolidated, simple, uniform acquisition guidance and processes for adherence by all executive agencies executing procurements, including those containing intellectual property.

FAR 27.102 sets rules, processes, solicitation requirements, and contract clauses related to patents and data. This section of the FAR provides the following general guidelines for contracts pertaining to patented inventions.

- Agencies shall use commercial inventions developed under government contracts to the maximum degree possible (FAR 27.102).
- In most cases, companies providing commercial inventions release the government against legal responsibility for infringement of patented item (FAR 27.102).
- The agency shall remain cognizant and limit requests of privately funded intellectual data. When applicable, the agency shall only procure rights critical to meet mission requirements (FAR 27.102).

FAR 27.3 prescribes regulations for patent rights of inventions made in the execution of an R&D-type government contract or subcontract. This part specifies the government's objectives to utilize the patent system to endorse government-funded inventions, persuade commercial industry to participate in government-sponsored R&D efforts, support free competition while building momentum for government and commercial collaboration, ensure the best interest of the government by garnering adequate rights for these inventions, and being considerate of the public's access to inventions and reducing oversight costs for patent management. Additionally, this subpart provides detailed policy concerning the contractor's right to elect patent title, government's license, government's right to obtain title, march-in rights and contracts clauses, which are provided in Appendix A.

b. Defense Federal Acquisition Supplement

The DFARS provides agency-specific policies and deviations from the FAR applicable strictly to the Defense department. Pursuant to CFR Chapter 2, Title 48, the

DFARS is distributed under the consent and subject to the authority, guidance, and governance of the secretary of defense. The director of Defense Procurement and Acquisition Policy, Office of the Under Secretary of Defense (Acquisition, Technology, and Logistics; OUSD[AT&L]DPAP), maintains approval authority for deviations from the instruction related to acquisition procurement integrity covered in DFARS 203.104 and data rights discussed in DFARS 227.4.

DFARS 227.71 provides the DOD with specific guidance for the rights in technical data. Aside from mandating that the DOD procure only the minimum required essential data, this section also asserts the government license rights that authorize the DOD to use, amend, duplicate, publish, or disclose within the government, but prohibits disclosure to a third party without the contractor's written consent for noncommercial items (DFARS 227.71). The following are three elements pertinent to the procurement of technical data:

- Contracting officers are mandated to work with technical data subject-matter experts (SMEs) and end users to ensure technical data contained in solicitation adhere to all applicable regulations, specifically DFARS 227.7103-1 (DFARS 227.71).
- Government requirements personnel must be considerate of commercial firm's investment to privately funded inventions while also considering the government's life cycle costs, specifically acquiring and protecting data. The government must also give special consideration to whether the item, parts, or methods are inherent to the product therefore available on a basis of form, fit, or function (DFARS 227.71).
- The contracting officer shall ensure that specific information relative to the technical data is included in the solicitation and contract award including type, quantity, format, deliverables (on individual CLIN), costs, schedule, and delivery locations for technical data deliverables (DFARS 227.71).

This section of the DFARS also contains specific information regarding licensing rights, as explained earlier in this chapter. Lastly, it explains contract clauses pertinent to the DFARS, which are provided in Appendix B.

c. *Additional Guidance*

Each department of service within the DOD has developed branch-specific guidance for the acquisition of data and or inserted guidance into existing references (DOD Open Systems Architecture Data Rights Team, 2013). These documents are as follows:

- Army Guide for the Preparation of a Program Product Data Management Strategy (DMS)
- Acquiring and Enforcing the Government's Rights in Technical Data and Computer Software Under Department of Defense Contracts, Air Force Space and Missile Systems Center
- Naval Open Architecture Contract Guidebook for Program Managers
- The Navy Marine Corps Acquisition Regulation Supplement

E. SUPPLY CHAIN MANAGEMENT

After the Industrial Revolution, companies specialized in one specific area of production. Focus was placed on maximum efficiency at a single value-added step such as assembly or delivery. Terms used to describe these efforts include "logistics" and "operations management." It was not until the late 1980s that the emphasis on the efficiency of the total supply chain was developed.

Michael Hugos (2011), author of *Essentials of Supply Chain Management*, describes a supply chain as "the companies and business activities needed to design, make, deliver, and use a product or service" (p. 2). Every business is a stakeholder in numerous supply chains. The globalization of trade has put an increasing importance on companies to be aware of the impacts they have on the supply chains and how they add value to maintain a competitive advantage in these markets.

The term *supply chain management* was first used in the 1980s to describe actions to influence the activities of the supply chain to achieve desired results (Hugos, 2011). It differs from logistics in that logistics describes the activities within the scope of one company and supply chain describes the networks that synchronize their actions to deliver goods and services (Hugos, 2011). This idea started to take gain widespread acceptance in the early 1990s when large manufacturing companies began to vertically integrate by acquiring their suppliers and retail operations. Supply chain management incorporates the concepts of Total Quality Management (TQM), Lean Six Sigma, and other production improvement methods.

Although each company faces a unique set of challenges, the issues essentially remain the same in most cases (Hugos, 2011). According to Hugos (2011), the following are five critical elements all supply chains must collectively consider:

- **Production:** What should be produced and when?
- **Inventory:** What should be kept in inventory and how much?
- **Location:** Where should manufacturing and distribution facilities be located?
- **Transportation**: How should goods be moved from manufacturer to consumer?
- **Information:** What data should be obtained, and how should it be utilized? (Hugos, 2011)

The answers to these questions determine the ability of a firm to effectively serve its customers (Hugos, 2011). The solutions to these issues largely depends on the strategic values of the company. A low-cost leader's supply chain looks much different from one focused on high customer-service levels.

The DOD has many challenges when it comes to supply chain management. There have been dozens of published studies, including two by the GAO in 2015, that criticize the DOD for keeping what the GAO describes as "excess inventories." Many of these studies point to the lower inventory practices of the private sector and recommend that the DOD adopt these practices to achieve huge inventory savings. There are many valid reasons for the DOD to keep inventory levels higher than for-profit organizations. The underlying reason for the higher inventories is that the DOD measures success differently than commercial companies. Commercial for-profit companies reward employees for profit-generating activities. Failure to meet goals risks lower profit and goodwill. The DOD is focused on a military mission supported by unit readiness. The risk of not meeting these goals could mean destruction of government assets, death of Americans, or losing a critical battle. The DOD rewards managers for meeting metrics related to Supply Material Availability (SMA), Average Customer Wait Time (ACWT), number of backorders, and number of orders shipped (Kang, 1998). Almost no one is rewarded for budget minimization at the expense of readiness. This incentivizes higher inventories at all levels. Because of this focus on readiness, the DOD will never achieve the efficiency of its commercial counterparts; however, there are still efficiencies to be gained in the DOD supply system that will allow for inventory cost savings. Simply training managers on commercial practices without regard for the differences in mission, structure, and inventory management culture will lead to confusion and contradictory objectives (Kang, 1998).

F. SUMMARY

AM has been used in one form or another since 1860. In the last few decades, computer technology, precision tooling, and new techniques have made AM a commercially viable option for some manufacturing applications. As the complexity of manufacturing increases, the intellectual property rights laws and regulations struggle to provide adequate protection for creators to encourage innovation. Federal and DOD regulations threaten to slow or stop implementation of this new technology due to their rigid requirements. An area in which AM is poised to make an impact is supply chain management, which is the integrated consideration of all stakeholders related to the value-added steps from raw materials to final customer. AM introduces a tool that has the potential to solve some supply chain management challenges of transportation, customization, and manufacturing complexity.

III. LITERATURE REVIEW

The first half of this chapter centers on the acquisition aspect of intellectual property and looks into the policies and instructions the DOD has implemented to ensure that its workforce executes the procurement of intellectual property in a lawful and consistent manner across all branches of service. The chapter includes explanations of the first policies promulgated by the DOD in the initial stages when the agency transitioned from conducting a majority of R&D internally to reaching out and procuring it from the commercial industry. This section also takes a closer look into key elements of the DOD's Better Buying Power (BBP) initiative, which utilizes the most practical methods to increase the department's overall buying power, while acquiring the most technologically advanced weapon systems for the warfighter. The DOD developed instructions that provide the most detailed guidance to manage intellectual property, which are revised as necessary to accommodate for the changes in how the government and industry effectively collaborate. The first half of this chapter concludes with a discussion of the DOD's requirement to incorporate an intellectual property strategy into a program's acquisition life cycle.

The second half of this chapter presents the latest developments in the evolution of AM technology and new methods that companies are using to incorporate AM into their supply chain for cost, speed, and quality benefits. An in-depth review describes current uses of AM in private industry and the DOD.

Some sources use the term *direct digital manufacturing* (DDM) to describe all technologies that turn a digital file into a solid object. This term is especially used in contexts where traditional manufacturing and AM are integrated into the same production line to support a large and complex bill of materials (Sasson & Johnson, 2016).

3D printing is the process of making three-dimensional items by laying down consecutive layers of material from a digital model absent of molds, casts, or patterns. It is also known by its more technical term *additive manufacturing*, which is used throughout this document. The commercialization of AM technology happened in the mid-1980s and was first used as a prototyping tool (GAO, 2015a). It is now growing in popularity for highly customized, low-volume production of end use items.

A. INTELLECTUAL PROPERTY POLICIES AND INSTRUCTIONS

The DOD implemented guidance concerning the acquisition and management of intellectual property to ensure government and commercial business interests were protected. These policies and instructions are derived from the congressionally mandated laws discussed in Chapter II and provide more detailed direction for the appropriate application of policies in order to attract commercial industries to do business with the government.

1. Office of the Under Secretary of Defense for Acquisition, Technology, and Logistics Policies

The turn of the century saw the DOD relinquish its position as the primary source of R&D to the private industry. The agency realized it would be better served by working with private industry to produce the most technologically advanced military weapon systems. Transitioning from a strictly internal production to cooperative efforts or outright procurement has required the DOD to overcome its stigma of unreasonable and stringent negotiating positions it is perceived to maintain when negotiating for intellectual property rights with corporate industries (Pittman, 2001).

The under secretary of defense addressed this issue in his September 5, 2000, memorandum initiating training and policy concerns related to the manner in which the DOD handles the acquisition of intellectual property (USD[AT&L], 2000). In his message, he acknowledged the value that companies place on their IP and the fact that the most innovative technologies are now funded primarily by commercial industry. The guidance requires the DOD to foster an atmosphere where corporations are incentivized to share their research and do business with the DOD. This will enable the major weapon systems to sustain technological growth throughout the product’s life cycle. The under secretary encourages the acquisition workforce to execute the laws and regulations applicable to intellectual property in a fashion that invites the private sector to engage in business with the government by allowing flexibility incorporated in laws and regulations that are often overshadowed by the overwhelming use of contract clauses. Establishing an approachable culture with the commercial sector will enable the DOD to leverage their capabilities into its weapon systems while protecting the intellectual property that is the core of their business foundation. The memorandum goes as far as to waive contractual requirements that are perceived to compromise commercial intellectual property rights and are counterproductive to legitimate and reasonable business processes (Under Secretary of Defense for Acquisition, Technology, and Logistics [USD(AT&L)], 2000).

Early the following year, the under secretary of defense issued a memorandum reforming the intellectual property rights of contractors in which he instructed the deputy under secretary of defense (Acquisition Reform) (DUSD[AR]) to publish a user-friendly guide for the proper management of intellectual property within the department (USD[AT&L], 2001). The objective of this effort was to clarify the acquisition process for contracting activities handling intellectual property contracts to entice the commercial industry to fill government requirements. A Rapid Improvement Team created for this effort determined that contracting regulations allowed the contracting officer to contract only for the necessary data rights, use performance-based acquisition strategies, apply flexible terms in patent right contracts, and stress detailed licensing rights. These efforts served as the foundation of future policy revisions necessary for the DOD to effectively leverage cutting-edge technology produced by the commercial industry (USD[AT&L], 2001).

In June 2010, the DOD implemented the Better Buying Power initiative to leverage the department's buying power and increase commercial productivity by instituting targeted acquisition guidelines to generate greater return on investments. One of the two critical points in Better Buying Power 1.0 highlighted by the under secretary of defense was the need to seek industry's participation and ideas as the leading contributor to DOD weapon systems. Their involvement would help the DOD achieve the productivity growth commensurate with private industry and allocate the cost savings to other critical warfighter needs (USD[AT&L], 2010).

Better Buying Power 2.0 was released in November 2012 and expanded guidance promulgated in BBP 1.0 (USD[AT&L], 2012). Two areas of concentration in this version of BBP highlighted the DOD's procurement and management of intellectual property by increasing programs to take full advantage of industry's R&D. The ineffective communication structure between the DOD and industry hindered these efforts. In an attempt to remedy this obstacle, the DOD created the Defense Innovation Marketplace webpage detailing the department's objectives and included a requirement in the DFARS requiring large military contractors to provide figures of their independent R&D plans as criteria for allowability. These two initiatives were meant to provide the platform for the DOD and industry to further engage in dialogue allowing for increased leverage of existent and emerging technology. This version of BBP also emphasized the need for effective intellectual property strategies to support the procurement of open system architecture, which will allow for competitive alternatives and reduce constraints placed on the DOD by vendor-lock (USD[AT&L], 2012).

The most recent version of Better Buying Power was released in April 2015 (USD[AT&L], 2015). BBP 3.0 continued many of the focus areas from the two previous versions but added a new element of stressing innovation and technical excellence in weapon system acquisition to maintain an advantage over adversaries. An integral part of BBP 3.0 is to "incentivize productivity in industry and government" (USD[AT&L], 2015), including by "removing barriers to commercial technology utilization." In order to promote increased and efficient innovation, the DOD needs to adopt more commercial technologies that mature at a faster rate than current complex military weapon systems. Accomplishing this goal will entail eliminating or modifying certain barriers currently impeding the adoption of commercial technology to include certain policies and regulations. Another point of emphasis in BBP 3.0 is to "incentivize innovation in industry and government" by "increasing the use of prototyping and experimentation, emphasizing technology insertion and refresh in program planning and providing draft technical requirements to industry early and involve industry in funded concept definition" (USD[AT&L], 2015, p.14). Utilizing prototypes will expedite the incorporation of the latest technology into weapon systems for operational testing and eventually experimental testing in an operational environment. When employed, this initiative will streamline the acquisition process while providing the flexibility to incorporate improvements through the fielding process. Incorporating technology insertion into the program planning of an acquisition will allow the government to keep pace with the speed of technological advances maintained in the commercial sector. This objective will also allow for more practical refresh or modernization cycle timeframes by taking advantage of other BBP 3.0 initiatives, as well as earmarking future year funding. Exchanging initial technical requirements with industry prior to the request for proposal will enable the government to solicit a more advanced requirement by incorporating information obtained early on from industry. Given ample notice, industry can dedicate resources to research solutions for government requirements and provide advice to incorporate in the initial draft requirements. This will also give industry the necessary time to assist the government while developing technology to include in their proposal upon the request for proposal being issued. Ultimately, exchanging initial technology requirements increases effectiveness of the planning and acquisition process by better shaping and developing requirements (USD[AT&L], 2015).

2. Department of Defense Instructions

The DOD has established instructions to provide amplifying guidance for program managers and contracting officials to use when acquiring weapon systems containing intellectual property.

The DOD developed the DOD 5010.12M, *Procedures for the Acquisition and Management of Data*, to provide a consistent process for the procurement and administration of technical data needed from private firms when conducting business with the DOD (Assistant Secretary of Defense for Production and Logistics [ASD(P&L)], 1993). The instruction aims to deliver a standard protocol for streamlining data requirements for inclusion in agency contracts. This instruction complements mandates in DFARS 227.4.

Objectives specifically applicable to the procurement of technical data rights necessary for optimal effectiveness of AM are outlined in this instruction. Procedures defined in this instruction set criteria for defining required data that must be incorporated in the contract to effectively meet DOD mission-critical requirements. The contracting official should concede to commercial data where reasonable, utilizing the least invasive methods of obtaining data, controlling data requirements from contractors, ensuring the cost for obtaining the data is appropriate for the value resulting over the life span of the weapon system, ensuring technical data already available via depositories is used to the greatest extent possible, and adhering to all applicable government regulations regarding the choice, procurement, and application of technical data (ASD[P&L], 1993).

This instruction also outlined the functions of data procurement and management to ensure the proper policies, applications, and processes are standardized throughout the DOD.

Key functions and management processes relevant to AM are the protection of technical data, verification that the data procured is the minimal data needed to fulfill the government's critical needs, distribution of technical data to the appropriate depository or lead government organization, and verification of the data's appropriateness for its projected use (ASD[P&L], 1993).

Although another key element of data procurement is the timely creation of the data, this point currently has limited applicability to AM as the technology is still maturing (ASD[P&L], 1993). Even though the data might be available, a 3D printer capable of printing the component may not exist at this time. This may allow contractors to deliver the appropriate 3D file at a future date when the vendor can validate that a 3D printer is available in the market that can successfully create the object.

The DOD 5010.12M ensures the DOD procurement and management of all intellectual data critical to the support of current and future weapon systems is incorporated into the business process for effective life cycle management.

The DOD Instruction 5000.02, *Operation of the Defense Acquisition System*, "establishes policy for management of all acquisition programs" (DOD, 2015, p. 1) in consideration of other applicable government laws and policies. This instruction was recently revised in 2015 to update the previous version's guidance, necessary to effectively accomplish agency goals consistent with the updated laws relevant to acquisition management including technical data. These updates have influenced various DOD acquisition initiatives, specifically Better Buying Power. As the procurement pendulum maintains momentum for procuring weapon systems from commercial industries, these instructions have increased their breadth to mandate that data management strategies include an intellectual property strategy. This strategy is a statutory requirement that begins as part of the acquisition strategy during procurement and transitions to the sustainment plan once it reaches the operational phase of its life cycle (DOD, 2015). Figure 4 illustrates the acquisition life cycle and highlights the point where the Intellectual Property Strategy should be implemented.

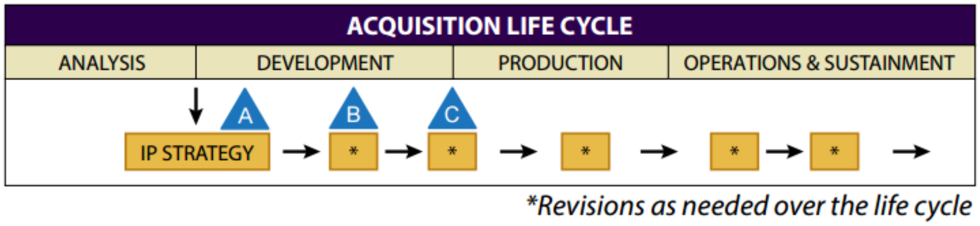

Figure 4. Acquisition Life Cycle Major Milestones.
Source: DOD (2013).

The program manager is required to develop and maintain an intellectual property strategy to ascertain and administer the whole gamut of intellectual property challenges from cradle to grave for each Acquisition Category (ACAT) I and II program. The intellectual property strategy must define the program manager's requirements for intellectual property, and when feasible, competitively procure IP and accompanying license rights. These rights must support competitive and economical procurement and life cycle support as mandated in the DFARS for major weapon systems and related subsystems. Although the intellectual property strategy falls under the program manager, it entails the input from subject-matter experts within the integrated product team consisting of multiple disciplines relevant to the weapon system in development (DOD, 2015).

The DOD (2015) recommends considering the following principles when preparing a strategic approach to IP administration:

- Prepare for sustainment and competition throughout the life cycle of the weapon system.
- Incorporate the intellectual property strategy with all the strategies and plans relevant in the weapon systems acquisition life cycle. This evolving document will be ineffective if used as a "stand alone" document.
- Invest in IP and license rights in the initial stages of the acquisition to ensure effective intellectual data (i.e., 3D files) are started as early as the development phase.
- Only acquire the minimum IP required to meet the government's needs and make sure not to request rights that have already been procured or are not critical to supporting the weapon system through the acquisition life cycle.
- Evaluate IP and licensing requirements prior to contract award and validate their conformity to terms specified in the contract upon delivery (DOD, 2015).

The increased reliance on commercially fielded weapon systems has revolutionized the manner in which the DOD must execute major weapon system acquisitions. These policies and instructions are the backbone to ensure a standardized and effective acquisition process is used across the DOD. This will enable the necessary revisions to be promulgated across the department and, more importantly, communicate to industry a clear set of objectives and rules the government abides by in its acquisition contracts.

B. BENEFITS

Hod Lipson is a professor of engineering at Columbia University in New York City. He has worked extensively on food printing and bio-printing. He co-authored the award-winning book, "*Fabricated: The New World of 3D Printing*." Lipson said, "With 3D printers, the cost of manufacturing complexity goes to zero. Complexity is now free" (Ehrenberg, 2013, p. 22). Some of the primary benefits that AM brings to the manufacturing world are the ability to reduce the time to design functional parts, produce parts that are more complex than is possible with conventional manufacturing, produce parts with better performance, and produce highly customizable, for parts manufacturing on ships out to sea and at remote forward operating bases (GAO, 2015a). The hope is that this will reduce the mountains of repair parts that are currently required to support military campaigns overseas.

AM also has the potential to replace globalization with localization. Instead of producing items in low-cost labor countries, manufacturers can use 3D printers to produce items at the same low cost without the need for long-distance shipping and high inventories (Hammes, 2015).

3D-printing technology reduces barriers to entry for manufacturing. It has the potential to allow anyone to make anything. Suddenly, former customers can become competitors. As mass customization becomes common, the demand for mass-produced physical parts will fall. This is known as the democratization of manufacturing (Hornick, 2015).

AM has three distinct advantages over subtractive manufacturing: product customization, design flexibility, and minimization of material waste (Cotteleer, Holdowsky, & Mahto, 2014). These advantages help support companies who are using just-in-time manufacturing and lean manufacturing. Although there has been little tangible evidence to support a massive investment, it is believed that AM could become a disruptive technology (Cotteleer et al., 2014).

C. TECHNOLOGY TYPES

AM does not describe a single technology or process but rather a class of different systems that generally use the layer-by-layer method of manufacturing. The different processes fall into seven categories of AM (GAO, 2015a). Each type of AM has a different method of building the 3D object. Table 1 describes the technique used in each process.

Table 1. Categories of AM Technologies. Source: GAO (2015a).

Table 1: Types of Additive Manufacturing Processes

Process name	Description
Binder jetting	A liquid bonding agent is selectively deposited to join the powder materials.
Directed energy deposition	Focused thermal energy, such as a laser, is used to fuse materials by melting as the materials are being deposited to form an object.
Material extrusion	Materials are heated and selectively dispensed through a nozzle.
Material jetting	Materials, such as photopolymers or wax, are selectively dispensed through a nozzle.
Powder bed fusion	Thermal energy selectively fuses regions of a powder bed.
Sheet lamination	Sheets of materials are cut and stacked to form an object.
Vat photopolymerization	The use of certain types of light, such as ultraviolet light, to selectively solidify liquid photopolymers.

Source: GAO analysis of ASTM International data. | GAO-15-505SP

These seven categories contain subcategories of technologies that may include a variety of materials, print speeds, dimensional precision, and surface finish.

D. PROTOTYPING VERSUS END USE

Before AM, creating the tooling required to build a prototype took weeks. For the last few decades, "rapid prototyping" using methods such as SLA, SLS, and FDM cut this time to a few days (Bak, 2003). Manufacturers are always seeking a cost-effective and quick way to produce low-volume prototypes with similar properties to Acrylonitrile-Butadiene-Styrene (ABS) injection molded parts. Vantico Ltd. has created an SLA material with strength, heat resistance, and elongation properties very close to ABS (Bak, 2003).

As AM processes have improved, manufacturers have started to see potential in using these machines for rapid production, not just rapid prototyping (Bak, 2003). In order for AM processes to make the jump into functional part production, it must meet the prime production metrics of cost, cycle time, and quality (Bak, 2003). Rick Dove, president of Extrude Hone Corporation's ProMetal Division, has learned that "3D printing can generate more pounds per hour because raster scan technology allows us to run virtually unlimited conversion streams" (Bak, 2003). Their tests have proved that production costs can be as low as $30 per pound.

E. USES IN INDUSTRY

AM technology offers significant benefits in terms of customization, resource efficiency and complexity reduction. These benefits appeal to some industries more than others. The following sections discuss specific cases where the aerospace, automotive and medical industries have found success in using AM to solve their unique manufacturing challenges.

1. Aerospace

The aerospace industry has been an early adopter of AM technologies. Aerospace prototype and production can be very expensive. Also, slow-moving inventory adds huge expenses to operations. One of the key reasons for the aerospace industry's interest is the reduced waste in expensive alloy. Reducing the "buy to fly" ratio of materials yields significant savings in these high cost raw materials. The Royal Air Force (RAF) is expected to save over $2 million by using 3D-printed parts on the Tornado fighter (Miller, 2014).

In 2013, NASA began testing rocket engine parts that were 3D printed (Miller, 2014). In late 2014, NASA sent the first 3D printer to the International Space Station (ISS) and began printing tools in zero gravity. In 2013, NASA began testing rocket engine parts that were 3D printed (Miller, 2014). On January 15, 2016, NASA printed the winning design for the Future Engineers Space Tool Challenge (Rainey, 2016). This is the first proof of concept that NASA can print required tools in zero gravity, on demand, instead of adding them to the next resupply mission at an estimated cost of $10,000 per pound. NASA continues a series of Future Engineers 3D Space Design Challenges in partnership with the American Society of Mechanical Engineers (ASME).

2. Automotive

In the wake of the 2008 Great Recession, GM, Ford, and Chrysler faced major financial troubles. All three accepted government bailouts under the Trouble Assets Recovery Program (TARP). During this time, all costs were securitized. One area that was viewed as overly expensive was tooling. Tooling costs are the expenses incurred in the creation of tools required for the performance of the production line. The tooling required for short-run or prototype parts was especially costly on a per part basis. Also, the automotive companies realized that manufacturer recalls due to low-quality production parts significantly increased the life cycle costs of vehicles. Using AM technologies for tooling purposes improves quality due to the fewer opportunities for human error. Due to the gains in time, cost, and quality, AM has been used extensively for automotive tooling purposes.

GM has partnered with 3D Systems to use SLS and SLA machines for rapid prototyping (RP; Helsel, 2015). The RP plant in Warren, MI, produces over 20,000 parts per year (Helsel, 2015). Recently, translucent materials have been added. This allows engineers to use parts that mimic the properties of the injection molded production parts when testing light housings and other similar fixtures (Helsel, 2015). Today, RP parts are used in all wind tunnel tests. Parts too large to be printed in one piece are broken into multiple components and glued together. Figure 5 shows a 40% size model of a GM truck being prepared for wind tunnel testing. Most of this model was created using 3D printing (Helsel, 2015).

Figure 5. A 3D-Printed 40%-Size Model of a GM Truck Created for Wind Tunnel Testing. Source: Helsel (2015).

AM technologies have found many uses in the automotive industry. AM allowed designers to check parts for fit and finish before investing in expensive tooling. Most new car shapes that are wind tunnel–tested are from AM parts, especially items like side mirrors and front panels. Many automotive manufacturers use additively manufactured components on their cars. In 2007, Hyundai used powder bed fusion (PBF) to manufacture flooring pieces for their concept car, QarmaQ (Gibson et al., 2010). Bentley uses PBF to create specialized parts that are ultimately covered in wood veneers or leather. Other automotive companies use AM to replicate discontinued parts for antique cars (Gibson et al., 2010). Although AM will never match the speed and low cost of injection molding, it does have useful application in small quantity, specialized, and prototyping situations.

3. Medical

The medical industry has found many practical uses for AM technologies. Accurate models of intricate body parts can be easily printed for use in student education and surgery planning, especially in areas like facial reconstruction (Mahon, 2016). The highly custom and low-volume nature of prostheses make them ideal for the AM process (Mahon, 2016). Other items that are routinely printed include drugs, small medical supplies, bone, and even soft tissues like ear cartilage and blood vessels (Mesko, 2015). The DOD has started experimenting with technology to print human cells in order to form living tissue. This could be used to treat severe burns that are too large to be covered with skin harvested from other parts of the body (Mesko, 2015).

F. SUPPLY CHAIN BENEFITS

Major transportation suppliers have realized the value and potential of the mass customization that 3D printing can provide. United Parcel Service (UPS) has partnered with German software company Systems, Applications, and Products (SAP), to create a network of distributed on-demand manufacturing solutions. The goal is to bring together industrial-strength 3D printing with existing supply chain models. Customer orders can be manufactured and shipped in the same day. This is a cost-effective solution for slow moving parts, expensive tooling, and rapid prototyping for entrepreneurs who do not have access to 3D printers ("UPS to Launch," 2016). In addition to this remote manufacturing and shipping integrated service, customers can 3D print their creations inside hundreds of UPS store locations.

G. CHALLENGES AND LIMITATIONS

The GAO identified three major challenges: "(1) ensuring product quality, (2) limited design tools and workforce skills, and (3) supporting increased production of functional parts" (GAO, 2015a, para. 2). AM will never completely replace conventional manufacturing. In many cases, conventional processes will usually be quicker and more cost effective for mass production of parts in high demand (GAO, 2015a). AM will most likely be used in cases where conventional manufacturing cannot achieve the properties required (GAO, 2015a). Current certification processes involve destroying several parts out of batch to ensure the quality of those parts (GAO, 2015a). This does not lend itself well to AM processes. Non-destructive testing methods must be expanded before AM can compete for the same quality certifications currently given to traditionally manufactured items.

Most AM machines are currently sized between a desktop printer and small car. This limits the ability to build large products (GAO, 2015a). With current AM technology, it can take hours or even days for a printer to complete one part (GAO, 2015a). If AM technology ever hopes to compete with conventional manufacturing, these print times must be significantly reduced.

AM faces many challenges in becoming the disruptive technology that some have predicted. Four areas that could affect the growth of AM are (1) intellectual property, (2) national security, (3) product liability, and (4) environmental, health, and safety concerns (GAO, 2015a).

In order for AM to fully realize its potential, a new generation of workforce must be trained on how to effectively operate and implement this technology. The AM design, print, and certify process involve all of the STEAM disciplines, that is, science, technology, engineering, arts, and mathematics (GAO, 2015a).

With all the benefit that AM is promising, it has some dirty little secrets (Gilpin, 2015). Lyndsey Gilpin, author of the book *Follow the Geeks,* lists some examples include Gilpin's article "The Dark Side of Printing: 10 Things to Watch":

- Many 3D printers are energy intensive and use over 50 times more electricity than injection molding.
- 3D printers may pose health risks similar to burning a cigarette.
- 3D printers rely too heavily on plastics and other non-biodegradable materials.
- 3D scanning and printing introduces a new set of IP infringement and licensing concerns.
- The Undetectable Firearms Act contains a provision that permits 3D printed guns if they contain a piece of metal large enough to be detected by metal detectors.
- Responsibility of manufacturers may disappear when a 3D printer is used to make an untested product that harms someone.
- Bio-printing introduces new ethical and regulatory issues.
- Assembling chemical compounds on a 3D printer may make it possible for home assembly of drugs: legal and otherwise.
- Corporations will face substantial economic and legal complications as 3D printers produce objects that cannot be controlled.
- As printing forks, plates and other items that come in contact with food become more common, the risk of ingesting unhealthy compounds increases (Gilpin, 2015).

In order for 3D printing and other AM technologies to become safe for consumer use, each of these issues must be addressed. Additionally, the quality of 3D-printed products is often crude and requires substantial finishing compared to computer numerical control (CNC) produced parts.

H. FUTURE PLANS

Many organizations see great potential in the ability of additive manufacturing (AM) to become the preferred method of future manufacturing. For example, the European Space Agency plans to use AM to build a base on the moon. Printers will be used to mix lunar soil with a binding agent and deposit it on top of inflatable molds (Ehrenberg, 2013). The Gartner research firm, a leader in predicting strategic technology trends, forecasts that full implementation of personal use 3D printing will happen around 2025 (Hornick, 2015). McKinsey & Co also sees the promise of additive manufacturing: The global management consulting firm projects that "3D printing could have potential economic impact of $100 billion to $300 billion per year by 2025" (Hornick, 2015, p. 1).

I. PRIVATE USE PRINTERS

3D printers are the industrial robots that enable the digital models to come to life. 3D printer sales are accelerating. Worldwide printer sales in 2015 were projected to be 244,533 units. Sales are expected to double every year through 2019. Currently, printers costing less than $1,000 apiece make up 25.5% of the market. This portion is expected to grow to over 40% by 2019 (Grunewald, 2015). Over 120 companies worldwide market and sell 3D printing machines. XYZ printing from Taiwan leads the pack with 17% of the market share by volume (Kira, 2016). Statasys's MakerBot previously dominated the market but lost market share to smaller companies partly due to expiring patents (Zaleski, 2015). A myriad of patents related to 3D printing technologies such as FDM, SLA, and SLS have expired in the last few years (Heller, 2015). This has increased the competition in the 3D printer market and driven prices down. Table 2 lists the top five personal desktop 3D printers by unit volume.

Table 2. Top Five Vendor 3D Printer Market Share by Unit Volumes, Global Desktop/Personal Printers, YTD 2015 (Q1–Q3).
Source: Heller (2015).

YTD 2015 Rank	Company	Brand	Units	Q1-Q3'15 YTD Global Share
1	XYZprinting	Da Vinci	28,300	17%
2	3D Systems	Cube/Cubify	20,290	12%
3	Stratasys	MakerBot	15,426	9%
4	Ultimaker	Ultimaker	14,734	9%
5	M3D	The Micro	14,436	9%

J. CONTROVERSY

As Gilpin (2015) pointed out, not all uses of 3D printing are legal, ethical, or safe. In addition to making it easier to violate intellectual property rights, 3D printers can be used to manufacture items that are illegal to possess under current laws. Cody Wilson, a gun-rights activist in Arkansas, has developed printable firearms and makes the files widely available through his website at no charge. He had made an AR-15 rifle grip and a 30-round magazine. Handcuff keys can easily be printed and have been proven to work effectively (Ehrenberg, 2013).

Amos Dudley is a student at New Jersey Institute of Technology who found himself in the rare situation of being broke and having access to high-tech scanning and 3D printing machines (King, 2016). After learning some basics of orthodontics, he was able to take a mold of his teeth, scan the mold, manipulate the file, and 3D print a series of teeth-straightening molds for himself. He spent less than $60 on materials for something that costs up to $8,000 from companies such as Invisalign, Damon, and ClearCorrect (King, 2016). Although do-it-yourself dentistry may not catch on, this case proves what is possible with current 3D printing technology.

3D scanning technologies and peer-to-peer files sharing already exist around the world. AM is making it easier for counterfeiting to rapidly expand to every industry. The mass appeal of new AM technologies may be tarnished by this criminal activity (GAO, 2015a).

K. INPUTS

Manufacturing is the conversion of raw materials into finished products. Most of the focus is placed on the characteristics of the final product or output. However, in order to ensure the entire manufacturing process remains efficient, there must be equal analysis of the inputs. High tech AM devices require three main inputs: energy, raw materials, and digital files. These inputs are discussed in the following sections.

1. Energy

Traditional manufacturing processes have historically been energy intensive. Thus, these facilities are located in well-developed areas where electricity is readily available at a low cost. Since AM technology allows for manufacturing at sea or in remote areas where energy is limited, energy efficiency is a highly desired feature. A 2011 study at Loughborough University found that capacity utilization and energy efficiency varied widely across different AM platforms (Baumers, Tuck, Wildman, Ashcroft, & Hague, 2011). In some cases, AM allows for an item previously constructed of multiple subcomponents to be contemporaneously produced as one piece. Calculating the total energy consumption of multiple subcomponents is difficult due to the dispersed and varied methods used to achieve the end item. The parallel nature of AM allows for an unprecedented level of transparency with regard to energy inputs into a complex item (Baumers et al., 2011).

2. Raw Materials

AM began with malleable materials such as those polymers used in FDM. These materials are sufficient for prototyping and novelty uses; however, as the technology has proven its value for more critical systems, performance of materials becomes more important. Most DOD AM pilot projects are prohibited from using AM parts in any safety-related system due to the lack of confidence in material reliability. Since traditional destructive batch testing is not possible with AM parts, new non-destructive examination (NDE) methods must be developed to quickly validate the post-production quality of printed parts without affecting their integrity. Tracking raw materials from the mine to the hands of the consumer will be applied to AM manufacturing inputs. This type of tracking has been in widespread use by companies that make ships, airplanes, nuclear reactors, and other items that require a high degree of material reliability confidence.

As manufacturers increasingly demand that parts be additive manufactured, the two-dimensional (2D) method of combining four standard colors (cyan, magenta, yellow, and black) into any shade cannot be applied to the 3D manufacturing world. For metallic components, this means the interrelationship between additive process, source material, and metallurgical mechanism must be established.

3. Digital Files

Digital files are essential to the AM process. These files are what provides the flexibility and portability of AM processes. The following sections discuss different elements of the data files.

a. Data Acquisition

There are three main types of 3D file data acquisition: 3D CAD software, 3D scanning, and 2D extrapolation. Computer-aided design (CAD) software has been used since the early 1970s, and most software packages can easily be converted to an AM printer–readable format. A variety of 3D input tools are commercially available, including both mounted and hand-held scanners. Modern non-contact scanners use laser range finding, Light Detection and Ranging (LIDAR), or triangulation methods of determining distances. These scanners detect the size, shape, and color of a physical object, which are used to create a point cloud. 3D scanners are especially useful when reverse engineering is required. For older designs that have no digital data, this may be the only way to obtain a 3D file. 2D extrapolation is the process of adding a third dimension (depth) to an existing 2D file. This method is commonly used for print raised letters of a symbol or logo. It is also used for very simple shapes such as turning a circle into a sphere. Most 3D software packages have a feature for converting 2D images to 3D files for AM purposes.

b. Visualization versus Printing

In addition to AM printing, 3D files can be used for visualization. This allows designers and future users to visualize a design before it is created in the physical world. Some companies are beginning to leverage virtual reality systems to allow designers to virtually “walk through” a design to help them verify that it meets their requirements. For these visualization purposes, modeling and rending steps are required to bring realism to the design. Designs that go straight to a printer do not require modeling and rendering to be applied.

c. *3D Data*

There are over 140 different file types for storing 3D data, and none has been widely adopted as the industry standard. There is an array of problems associated with 3D data acquisition, representation, storage, and retrieval. All 3D data sets contain content from three different categories: geometry, appearance, and scene (McHenry & Bajcsy, 2008). Geometry is the set of points that represents the shape of the object. Appearance is the texture and color of the surfaces achieved through rendering. Scene is the layout with regard to a camera angle and lighting. Not all file types contain information from all three categories.

The STL file format gained popularity among the rapid prototyping industry. ("What Is an STL File," 2015). This format approximates surfaces with a series of triangles, and a majority of current CAD systems in use are capable of generating STL files. The advantage of an STL file is that it is a simple file format and can be read by nearly any CAD software; however, it does not describe any other characteristics of the object. Also, more densely packed triangles are required to describe non-triangle shapes, leading to very large file sizes.

The .obj file type, developed by Wavefront Technologies, is another type of 3D format that, unlike STL files, can contain polygons. 3D Manufacturing Format (3MF) is an open source file type developed by Microsoft to overcome all the shortcomings of the STL file format. 3MF contains all the information of a 3D model in a single file, including basic Cartesian coordinates, material, texture, color, and printer instructions (Raghavan, 2016).

All printers convert these user formats into machine-readable format after the information is sliced and sorted for the best possible print. All of these machine-readable print files are proprietary formats based on each printer make and model. Most printers are using proprietary software although some interoperability efforts have begun. As printers start to become more common, a format war could ensue. This would further complicate federal government acquisitions and prevent major consolidation of 3D file management.

d. Software

In order to produce high quality 3D objects, sophisticated software must be used to control the printer. A 3D file contains all the information of the object, but the software is required to break the image down into pieces and give detailed instructions to the printer in order to take the correct actions in the correct order. Although 3D CAD has been around since the dawn of computers, different software is required for the different steps of creating a 3D object including modeling, scanning, rendering, and printing.

IV. ANALYSIS OF ADDITIVE MANUFACTURING RELATED TO SUPPLY CHAIN

A. INTRODUCTION

This is the first of two chapters that present an analysis of the information gathered during the personal interviews with industry and government leaders. In this chapter, the common challenges from both public and private organizations are identified. The chapter also recommends solutions for achieving full implementation of AM technology into the U.S. military supply chain.

B. CHALLENGES

During the interviews, three themes emerged:

1. Developing the digital supply chain
2. Building trust in the system
3. Protecting intellectual property

The first two challenges are addressed in the following sections. The intellectual property concerns and recommended solutions are addressed in Chapter V.

1. Digital Supply Chain

Additive manufacturing (AM) falls into the broader category of digital manufacturing. Digital manufacturing has been in existence since the late 1950s with the advent of computer numerical control (CNC) manufacturing. A supply chain is typically described as the real physical materials that are mined, processed, assembled, stored, shipped, used, and disposed. However, one of the most important pieces of AM is the digital information that is created, stored, transmitted, and eventually received by the AM printer. Without this digital input, the printer cannot produce what the user needs. At every step of the process, the digital information must be accessible to authorized users and protected from unauthorized users. The challenges of the digital supply chain can be thought of in the same ways as the challenges of the physical supply chain, with a few key differences.

Liz McMichael is the NAVAIR AM Digital Thread Integrated Planning Team (IPT) lead. She oversaw the first successful flight demonstration of a flight-critical aircraft component created using AM. This project was completed in only 18 months from conception to first flight. She emphasized the challenge of starting the road to AM processes by saying, "we (the DOD) don't buy 3D data" (personal communication, August 17, 2016). In order to build a baseline data set, she explained, we must first get the data, then manage it, protect it, and pay for what we use (Liz McMichael, personal communication, August 17, 2016). This is going to require a fundamental shift in the DOD's acquisition strategy. This topic is discussed further in Chapter V.

Andre Wegner is the founder and chief executive officer (CEO) of Authentise, Inc. His company has created a suite of software solutions to enable AM users to store their designs, stream them directly to printers, and monitor production (Molitch-Hou, 2016). His suite of software was developed under the backbone of 3Diax (Molitch-Hou, 2016). 3Diax incorporates user-customized modules using Application Program Interfaces (API) (Molitch-Hou, 2016). This arrangement allows organizations to seamlessly integrate 3Diax solutions into their existing information technology (IT) infrastructure. Figure 6 shows an outline of some of the modules available via 3Diax.

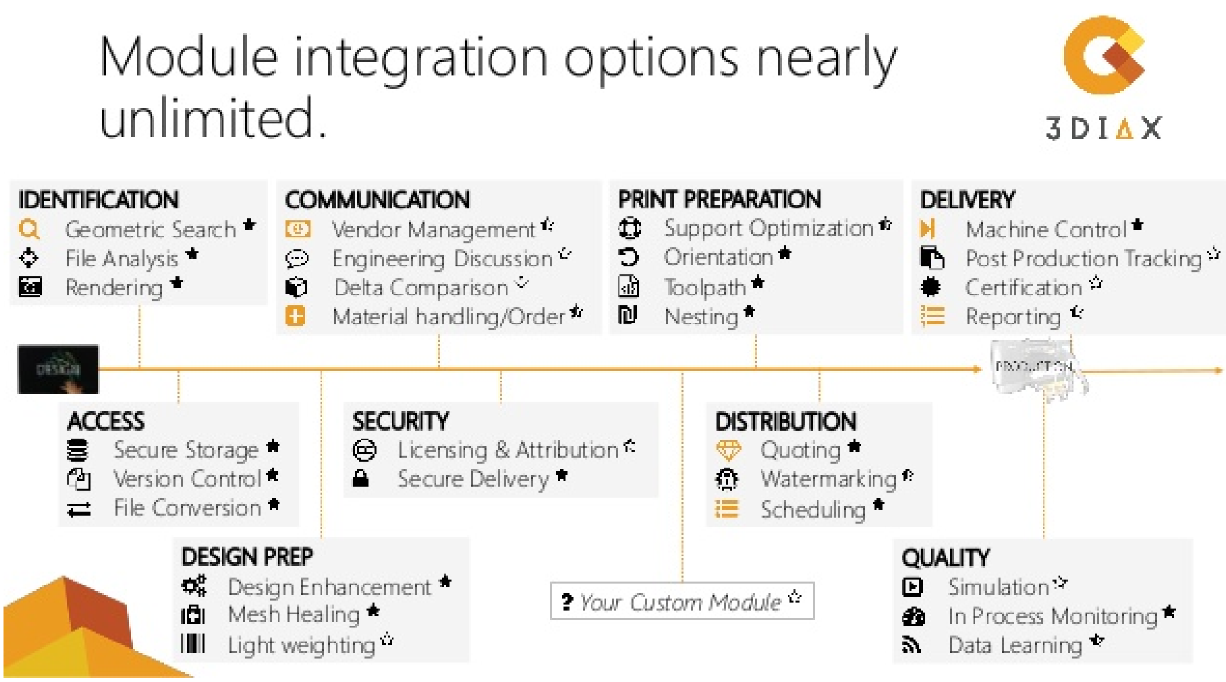

Figure 6. An Outline of the Various 3Diax Software Modules. Source: Molitch-Hou (2016).

2. Building Trust

There is a natural aversion to change, and AM technology is no different. Current AM-produced items are small plastic prototypes that lack the strength and other necessary attributes of their traditionally manufactured counterparts. In order for the DOD to reap all the benefits of AM, it must build awareness and trust in the AM process and the items it produces.

The DOD currently ensures trust in critical items through programs such as the Defense Standard (MIL-STD), Defense Specification (MIL-SPEC), Submarine Safety (SUB-SAFE), and Level I programs. Currently AM printers and users cannot provide the assurance provided by these programs. Jan Vandenbrande is a program manager at the DARPA Science Office. He was previously employed at Boeing were he experienced the company's meticulous tracking of materials from cradle to grave. This process allows high-tech parts to be certified for use without NDE of every item. This method can also be used for AM produced parts. He said,

> In thirty years, we will be at a stage where you can certify the process. So in other words, you can certify that this manufacturing plan, which in the case of 3D printing would mean, if you print it out this way with this material and you know, you turn all the knobs right, this part will perform to the specifications that you want. The process is actually certified so that you don't actually have to test every part. Some NDE will be required to make sure there is no threat in the process, but many parts in an airplane, for example, are certified by the way you make them rather than certifying each individual part. That's a lot faster. It means you can produce and crank out things much faster than having to inspect everything. Inspections takes a lot time and is very expensive. So, I expect that in thirty years we should be able to have a certifiable thing that if you print it, you can trust it. (Jan Vandenbrande, personal communication, August 18, 2016)

Until the DOD reaches the point where the AM process can be certified, AM parts will each be subjected to individual NDE by a trained technician. This will initially limit the types of parts that can be produced by AM but remains an important stepping-stone on the road to building trust in AM parts.

C. RECOMMENDATIONS

Based on all the information presented, there are specific actions the DOD can take to encourage the expeditious implementation of AM technology into the supply chain. The follow sections discuss five recommendations to achieve this goal.

1. Push Printers Forward

In order to build the necessary awareness and trust in the benefits of AM technology, the printing capability must be pushed as close as possible to the end users. A natural fit for the Navy is the Aircraft Intermediate Maintenance Department (AIMD) onboard aircraft carriers and large deck amphibious ships. AIMD already provides intermediate level (I-level) maintenance, inspection, testing, and calibration for aircraft and support equipment. AIMD also includes the miniature/micro miniature electronics repair (2M) which is capable of transistor level repair of circuit cards. The skills required for AIMD personnel naturally transfer to AM technology.

Aviation Electronics Technician First Class (AT1) Jonathan Lukesh has had the collateral duty title of 3D printing controller and technician onboard the USS Essex (LHD-2) for more than a year (Jonathan Lukesh, personal communication, August 2, 2016). With the support of his chain of command, he taught himself to operate the uPrint SE Plus 3D printer and SolidWorks CAD software to begin printing eyewash dust caps, USB port protectors, aircraft models for tabletop planning, and other non-critical items (Jonathan Lukesh, personal communication, August 2, 2016). In 2015, he was able to print a gear for the H-53 helicopter stick position test equipment (Jonathan Lukesh, personal communication, August 2, 2016). This part allowed the aircraft to be properly calibrated and resume flights operations. Although this part was not flight critical, it is the first known demonstration of an AM manufactured part directly affecting the readiness of naval aviation assets. Figure 7 shows photos of the original side-by-side with the AM printed part.

Figure 7. 3D-Printed Replica Next to the Original Part TE-779 Test Fixture Used for Testing H-53 Stick Position Sensors
Source: Lukesh, personal communication (2016).

Although the original part was made of brass, the only AM material available onboard the USS Essex was ABS plastic which proved sturdy enough for this application (Jonathan Lukesh, personal communication, August 2, 2016). AT1 Lukesh received a personal award for his efforts and the USS Essex continues to look for ways that AM can uniquely solve shipboard equipment problems (Jonathan Lukesh, personal communication, August 2, 2016).

2. Build the Database

As Navy ships and other forward fighting units begin to acquire AM capability, they will need a way to identify whether the required items are capable of being produced locally. To do this, the Navy must begin to build the database of items that are AM capable. The DOD must first identify the classes of supply that will be targeted for conversion to AM production.

Figures 8 and 9 show the ten classes of supply as defined in Joint Publication 4-0 (Joint Chiefs of Staff, 2013). Class IX and Class II are the areas that contain the most promise for DOD AM applications. These items present some of the challenges of customization, but are small, light, and complex enough to be solved by AM. Although some research has been conducted with AM of specialty foods, the DOD is not currently pursuing AM for Class I supplies.

Class	Symbols	Subclass	Common-User Logistics (CUL) Capability
I. **Subsistence:** Food		A - Nonperishable dehydrated subsistence that requires organized dining facilities C - Combat rations includes meals, ready to eat (MREs) that require no organized dining facility; used in combat and in-flight environments. Includes gratuitous health and welfare items R - Refrigerated subsistence S - Non-refrigerated subsistence (less other subclasses) W- Water	Fully suited to CUL
II. **General Support Items:** Clothing, individual equipment, tentage, organizational tool sets and tool kits, hand tools, material, administrative, and housekeeping supplies		A - Air B - Ground support material E - General supplies F - Clothing and textiles G - Electronics M - Weapons T - Industrial supplies (e.g., bearings, block and tackle, cable, chain, wire, rope, screws, bolts, studs, steel rods, plates, and bars)	Limited CUL suitability
III. **Petroleum, Oils, Lubricants (POL):** Petroleum (including packaged items), fuels, lubricants, hydraulic and insulating oils, preservatives, liquids and compressed gasses, coolants, deicing, and antifreeze compounds, plus components and additives of such products, including coal		A - Air W- Ground (surface) P - Packaged POL	Excellent CUL candidate (with some limitations)
IV. **Construction/Barrier:** Materials that support fortification, obstacle and barrier construction, and construction material for base development and general engineering		A - Construction B - Barrier materials	Fully suited for CUL
V. **Ammunition:** Ammunition of all types (including chemical, radiological, and special weapons), bombs, explosives, mines, fuses, detonators, pyrotechnics, missiles, rockets, propellants, and other associated items		A - Air W - Ground	Limited, primarily to small arms, selected larger munitions

Figure 8. Classes, Subclasses and Common User Logistics Suitability. Source: Joint Publication 4-0, p. II-5 (2013).

Class	Symbols	Subclass	Common-User Logistics (CUL) Capability
VI. Personal Demand Items: Nonmilitary sales items		A - Personal demand items not packaged as ration supplement sundry packs (RSSP) M- Personal and official letter and packaged mail. Does not include items in other classes such as spare parts P - RSSP	Fully suited for CUL
VII. Major End-Items: A final combination of end-products ready for intended use; e.g., launchers, tanks, racks, adapters, pylons, mobile machine shops, and administrative and tracked vehicles		A - Air B - Ground support material (includes power generators, fire-fighting, and mapping equipment) D - Administrative and general purpose vehicles (commercial vehicles used in administrative motor pools) G - Electronics J - Tanks, racks, adapters, and pylons (US Air Force only) K - Tactical and special purpose vehicles (includes trucks, truck-tractors, trailers, semi-trailers, etc.) L - Missiles M - Weapons N - Special weapons X - Aircraft engines	Not suitable for CUL
VIII. Medical Material/ Medical Repair		A - Medical material (including repair parts special to medical items) B - Blood and fluids	Fully suited for CUL
IX. Repair Parts (less medical special repair parts): All repair parts and components, including kits, assemblies, material power generators sub-assemblies (repairable and nonrepairable) required for all equipment; dry batteries		A - Air B - Ground support material, power generators, and bridging, fire-fighting, and mapping equipment D - Administrative vehicles (vehicles used in radio administrative motor pools) G - Electronics K - Tactical vehicles (including trucks, truck-tractors, trailers, semi-trailers, etc.) L - Missiles M- Weapons N - Special weapons T - Industrial supplies (e.g., bearings, block and tackle, cable, chain, wire, rope, screws, bolts, studs, steel rods, plates, and bars) X - Aircraft engines	Not suitable for CUL except for common items; requires special coordination to ensure proper support
X. (code as zero '0'): Material to support military programs, not included in classes I through IX	CA	None	Fully suited for CUL

Figure 9. Classes, Subclasses and Common User Logistics Suitability, Continued. Source: Joint Publication 4-0, p. II-6 (2013).

To code items as AM capable, the DOD must incorporate this information into the existing supply information using the item's unique National Stock Number (NSN) and Source, Maintenance, and Recoverability (SM&R) code. The SM&R code is a five-character code that identifies the item's "(1) reparability, (2) maintenance level authorized to remove and replace the item (organizational, intermediate, depot), (3) maintenance level authorized to repair the item and, if it cannot be repaired, the maintenance level authorized to dispose of the item" (NAVSUP, 1998). Since there are dozens of AM processes, the code that identifies

AM capability cannot be binary. It must also identify the printer types and other special considerations to be taken when producing these parts.

3. Consolidate and Share Knowledge

The DOD has multiple efforts across the different services; all focused on advancing the improved combat capability and cost savings that AM has the potential of delivering. Currently there is no department-wide method to systematically track these efforts (GAO, 2015b). In 2015, the GAO recognized this deficiency and recommended an Office of the Secretary of Defense lead be designated (GAO, 2015b). This person would have the responsibility of developing and implementing an approach for tracking activities and resources to speed adoption across the department.

AM is a new technology fighting for limited Research, Development Test & Evaluation (RDT&E) dollars in the military budgets. Figure 10 shows the projection of the Navy's projected declining RDT&E budget through 2021. In order for the military to maintain its asymmetric technological advantage, it must find ways to make the most of this limited funding.

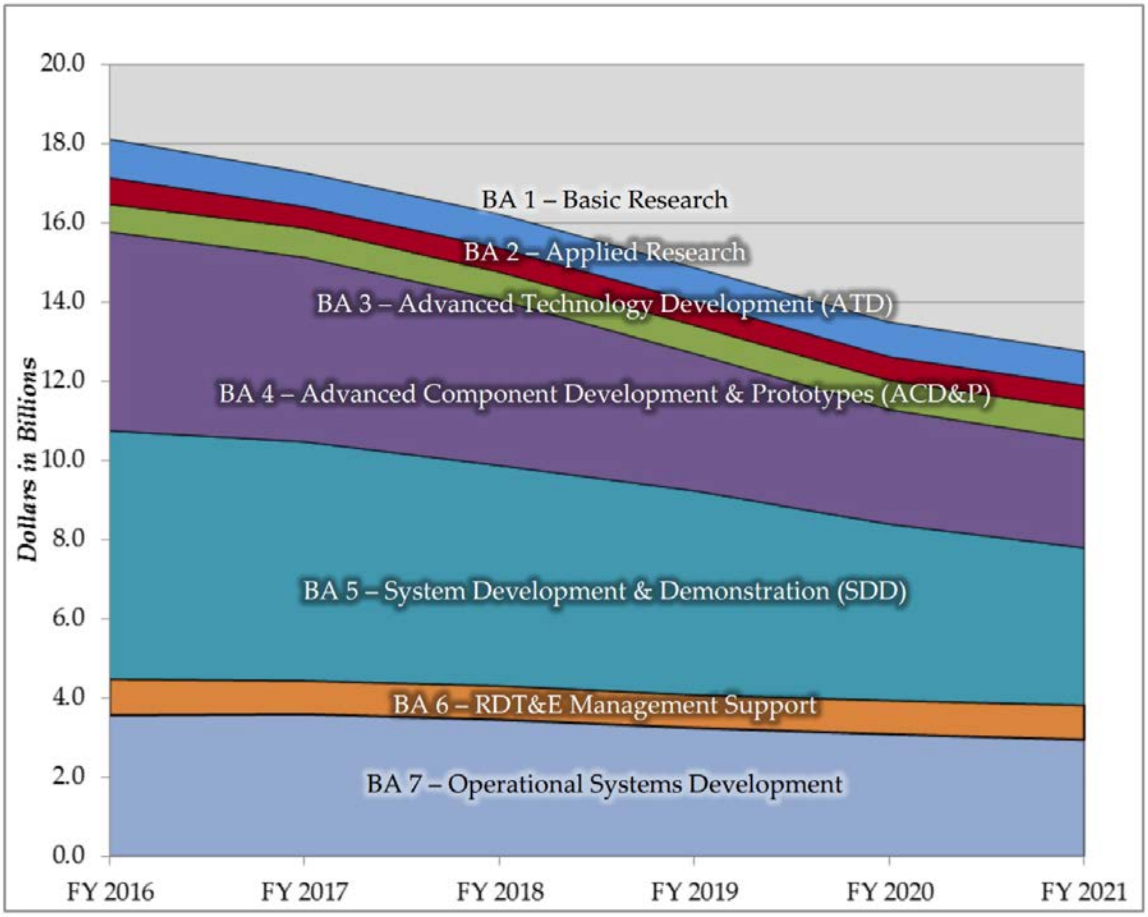

Figure 10. Department of the Navy Projected RDT&E Budget. Source: Assistant Secretary of the Navy (2016).

The public–private partnership of America Makes puts it in a unique position to help the DOD maximize research and development dollars. America Makes is building the roadmap using four main pillars: Processes, Materials, Design, and Value Chain (America Makes, n.d.). It connects members of government, academia, and industry by:

- Fostering a highly collaborative infrastructure for the open exchange of additive manufacturing information and research.
- Facilitating the development, evaluation, and deployment of efficient and flexible additive manufacturing technologies.
- Engaging with educational institutions and companies to supply education and training in additive manufacturing technologies to create an adaptive, leading workforce.

- Serving as a national Institute with regional and national impact on additive manufacturing capabilities.

- Linking and integrating U.S. companies with existing public, private, or not-for-profit industrial and economic development resources, and business incubators, with an emphasis on assisting small- and medium-sized enterprises and early-stage companies (start-ups). (America Makes, n.d.)

Currently each of the services maintains separate RDT&E budgets and often fund the same type of research. If the services fund their research through organizations like America Makes, they will be able to eliminate duplication, multiply their efforts by adding private funding, and achieve the synergy of the public–private partnership to quickly integrate AM technology into the acquisition process.

4. Train the AM Workforce

AT1 Lukesh admitted that he had no Navy training applicable to AM technology (Jonathan Lukesh, personal communication, August 2, 2016). All of the skills he learned came from reading manuals and watching YouTube videos (Jonathan Lukesh, personal communication, August 2, 2016). Successful AM operators must be proficient in the use of CAD software, engineering design, 3D visualization, and post-production NDE. For the DOD to achieve success with the distributed manufacturing nature of AM, it will need to start providing these skills during the training pipeline.

5. Vertically Integrate

Since AM is in its early stages of development, most manufacturers have focused on reproducing traditionally manufactured parts at a lower cost, closer to the user, and with improved characteristics. The DOD is producing today's designs using tomorrow's tools. As the DOD demonstrates AM success in this early phase of AM technology development, the scope must expand to include more stages of the product life cycle management (PLM). This will include items designed for AM production and items able to be recycled into different items using AM technologies.

Diane Ryan is a manager at the Siemens Product Lifecycle Management Software Digital Factory Division (personal communication, September 1, 2016). Her company develops software and other technology solutions for the design, analysis, testing, manufacture, and validation of products (Diane Ryan, personal communication, September 1, 2016). Her team has the ability to incorporate various customer-defined design considerations including intellectual property, data security, compliance, transportation, interoperability, and post processing (Diane Ryan, personal communication, September 1, 2016). As the DOD begins to use AM to share production responsibilities with the original equipment manufacturers (OEMs), it must also consider these other factors and how to include them into the total PLM solution.

D. SUMMARY

The DOD must overcome major supply chain management challenges to support today's warfighter. AM technology will never become the panacea for all DOD problems; however, AM provides some exciting opportunities to overcome those challenges. The ability to produce complex designs with improved characteristics for low-volume production, mass customization, and critical applications with a fraction of the time, money, and material will quickly surpass any challenges along the way. In order to take full advantage of this new technology, the DOD needs to come up with ways to duplicate all the assurances that go into traditionally manufactured parts in an expeditionary environment. Despite the current limitations of AM technology, progress is being made every day.

The exiting news is that many members of the military are pushing forward with AM technology. The DOD must move quickly to maintain the country's technological advantage over its adversaries; however, technology moves faster than bureaucracy does. As Liz McMichael stated, "The risk with AM is not that we will go too fast; the risk is that we won't go fast enough" (personal communication, August 17, 2016).

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V. ANALYSIS OF ADDITIVE MANUFACTURING RELATED TO INTELLECTUAL PROPERTY

This chapter provides an analysis of the federal acquisition procedures used in the procurement of intellectual property for additive manufacturing (AM) based on interviews and documented research. This chapter also identifies potential methods for addressing industry's concerns regarding the protection of intellectual data when selling the proprietary information associated with weapon systems to the DOD. Finally, this chapter discusses an alternative method of doing business with the government for organizations reluctant about FAR directives and clauses that require turning over complete authorization of data rights to the government.

A. ACQUISITION STRATEGY

As stated in Chapter III of this research, DODI 5000.02 requires the program officer to establish an intellectual property strategy to manage the full range of intellectual property related to a weapon system program throughout its life cycle. Although this requirement establishes the need for a strategy, it stops short of mandating the procurement or terms and conditions for future procurement at a pre-negotiated price or in a competitive environment prior to contract award. The absence of this type of stringent data enables the program management office to delay or defer the acquisition of technical data, including intellectual property rights and deliverables, to a future date in order to increase the chances of awarding a contract, especially in a fiscally constrained environment (DOD, 2013).

For the DOD to incentivize the commercial industry to conduct business and afford the government the opportunity to take full advantage of the potential cost savings and logistics and readiness benefits provided by AM, the government will have to change its acquisition approach and begin to contract for the technical data. Advancing the government's current requirement of establishing an acquisition strategy to mandating the contractual requirement for technical data has only recently become a viable option as the DOD previously did not have the systems to manage the data. Furthermore, the government was not capable of utilizing this data because it lacked interfaces with OEM. The demand for data in the digital representation was not necessary until 3D printing became a practical option to satisfy small-scale manufacturing requirements. The government must contract for all the data necessary to utilize the digital representation of an object and ensure the government receives the deliverables contained in the contract. In cases where the companies maintain certain rights to the data, the government still needs to have access to this data, and it must have a strategy in place to obtain access to the data should it be required a later date (Liz McMichael, personal communication, August 17, 2016).

The government can position itself to obtain access to the technical data it needs at any time in the product's life cycle by using an option-based acquisition strategy. This is executed by including access to a company's PLM system in the original contract. The PLM system is essentially a repository that contains complete product information, including the digital representation or digital threads that are critical data required to create a 3D part (Liz McMichael, personal communication, August 17, 2016). One possibility of an option-based acquisition strategy is to contract for access to a vendor's PLM through a subscription. This would enable the DOD to access the digital information stored online or on the OEM's network at the time of the DOD's choosing for a predetermined price agreed to in the contract (McGrath & Prather, 2016). This would require a fundamental change to the OEM's business model. Contrary to earning money per part produced and sold, the recommended subscription model would enable the vendor to generate passive revenue per part printed (Liz McMichael, personal communication, August 17, 2016).

Figure 11 illustrates the flow of funding that companies would receive when customers purchase technical data. This diagram depicts the technical data being transferred from the rights holders to a third-party repository such as Authentise, then being transmitted to the customer's 3D printer upon payment for the digital thread.

Figure 11. Authentise's 3D Print Licensing Platform Allows Pay-to-Print Design Distribution. Source: Authentise (n.d.).

Another variation of this model is to utilize the flexibility in the model to only contract for technical data and data rights necessary to achieve the government's mission without acquiring the maximum level of data rights. This option enables the government to secure fair and reasonable prices during the acquisition phase while reducing the costs, resulting in a practical option in a difficult fiscal environment (McGrath & Prather, 2016).

The last and most restrictive, yet most affordable, option that this model permits is for the government to rent necessary data for use in a limited capacity for a specified duration of time and scope at predetermined rates (McGrath & Prather, 2016).

Figure 12 illustrates the network structure required for the government to obtain intellectual data using an OEM's PLM system. As opposed to the model shown in Figure 11, this system directly connects the government to the OEM's system without using a third party-repository.

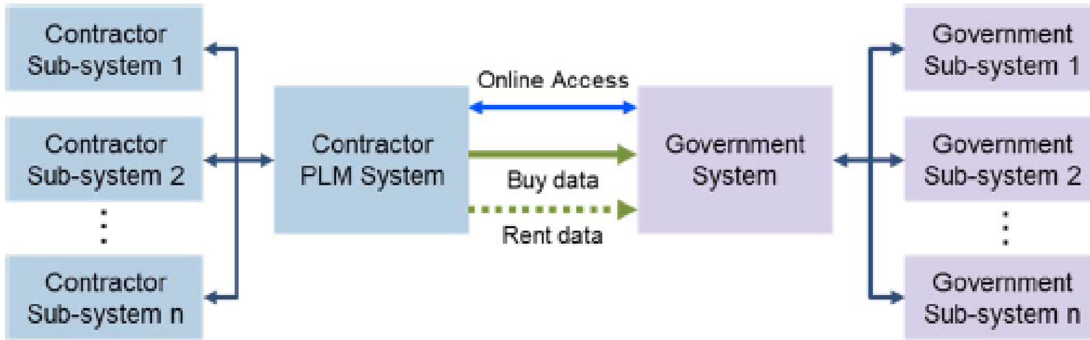

Figure 12. Modes of Data Flow between Government and Contractor System. Source: (McGrath & Prather, 2016).

Industry experts involved in the design and delivery of 3D printing strategies agree that any intellectual property owners involved in manufacturing should consider the direction AM is headed and need to consider incorporating a secure central repository capable of managing intellectual data into their manufacturing strategy. Wegner (personal communication, July 28, 2016) believes the government can address eliminating the backlog of unavailable parts due to shuttered manufacturers by lobbying Congress to establish a rule mandating that any future government contract requires suppliers to submit designs into a centralized database that will manage the distribution of the data in the event the company can no longer supply the data.

Ultimately, the pre-negotiated option model using a vendor's PLM system or third-party repository introduces a viable option to facilitate the management of this disruptive technology while securing a passive source of revenue for private sector firms and still complying with current government regulations. The next section addresses industry's concerns regarding the protection of their proprietary data when distributing it outside their firms through a PLM or third-party repository.

B. DATA PROTECTION

For the government to convince industry to provide the necessary technical data through a repository, it must ensure the integrity and protection of the intellectual property. This issue can be looked at through two lenses, the lens ensuring integrity of the data for functionality purposes and the lens focused on preventing theft of the data as proprietary information critical to a firm's profit and competitive advantage in the industry. This section is focused on the latter as this chapter of this paper is dedicated to the establishment of an environment where firms are confident their intellectual property is transmitted securely to a DOD network.

This secure transmission and storage of data is a cause of concern for some OEMs and has resulted in their reluctance to do business with the government for manufacturing contracts with AM capacity. The smaller field of vendors who are onboard consists of those who are willing to adjust their business model and adapt to the changes this disruptive technology is affording their end users. The dichotomy favors those willing to cooperate and may create a transformation of weapon system suppliers to those receptive of distributive manufacturing with the government (Liz McMichael, personal communication, August 17, 2016).

Recent technological advances have resulted in processes that protect intellectual property form counterfeiting. InfraTrac developed an anti-counterfeiting solution that uses a chemical fingerprint, which is authenticated quickly and economically. The technology works by comparing a scanned part's chemical makeup to the original part's unique identifier, a layered mathematically coded pattern, using a pocket spectrometer. Placing the object under the pocket spectrometer provides the part's internal ID that contains the material make-up for comparison to the item's official tag. The use of the spectrometer reveals the chemical make-up, which is then compared to the original model's file for authenticity. This procedure is non-destructive and cannot be detected by the naked eye, as the chemical identifiers are transparent until exposed to infrared light (Molitch-Hou, 2015).

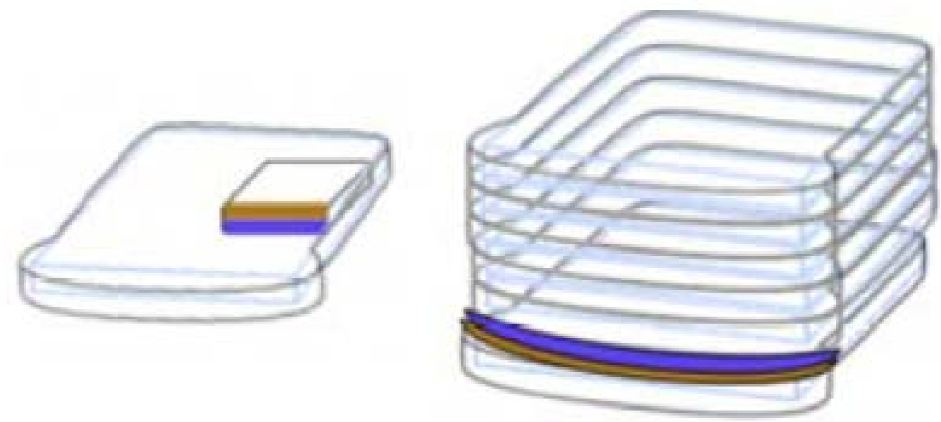

Figure 13. A Depiction of InfraTrac's Chemical Fingerprint Embedded in a 3D-Printed Item to Prevent Counterfeiting. Source: Molitch-Hou (2015).

This technology is compatible with a majority of 3D printing materials currently used even in complex metals, such as those used in building aircraft parts. An added benefit of this technology is its simplicity of use, only requiring about an hour of training and providing instant authentication results. This technology effectively prevents patent infringement by disrupting an object from being scanned due to the inability of scanners to detect the invisible taggant, or chemically encoded fingerprint, required to complete the scanning of an object, thereby eliminating the potential to reverse engineer an item (Molitch-Hou, 2015).

As 3D printing evolves, so too will the technology required to protect company's intellectual data. Whether it is a more complex process such as software safeguarding the transmission of data over a network, or a simple process such as the one using a chemical fingerprint, proprietary information must be protected to ensure a company's legal rights to profit from their intellectual property.

C. ALTERNATIVE PROCUREMENT METHOD

Pursuant to 10 U.S.C. 2371, the DOD has the flexibility of using Other Transactions Authority (OTA) in certain instances for prototype projects that specifically correlate to weapon systems being procured or created by the agency or one of its service components. OTA is defined as "authority to enter into transaction other than contracts, grants or cooperative agreements" (USD[AT&L], 2000, p. 8). This authorization applies specifically to procurement contracts and is not subject to the FAR, DFARS, or other policies governing procurement actions.

The DOD can use this flexible tool to incentivize civilian corporations to do business with the government as it reduces the bureaucracy that discourages firms from doing business with the government. According to Mr. Wegner, the numerous reporting requirements and all the red tape involved in doing business with the government is just too painful. The headache and hassle of dealing with the government on the bureaucratic side discourages companies from even entertaining the idea of dedicating resources to government contracts and instead focus their efforts within industry where it's easier to make money (personal communication, July 28, 2016)

The flexibility this tool provides requires officials using this authority to possess "a level of responsibility, business acumen, and judgment that enables them to operate in this relatively unstructured environment" (USD[AT&L], 2002, p. 8). Individuals using authority must act judiciously to ensure that appropriate levels of risk are accepted by all stakeholders in the agreement and implement safety measures to guard the DOD's interest. In accordance with the OTA guide, published in 2002, this authority may be used only when

> (A) there is at least one nontraditional defense contractor participating to a significant extent in the prototype project; or
>
> (B) no nontraditional defense contractor is participating to a significant extent in the prototype project, but at least one of the following circumstances exists:
>
>> (i) at least one third of the total cost of the prototype project is to be paid out of funds provided by the parties to the transaction other than the federal government.
>>
>> (ii) the senior procurement executive for the agency determines in writing that exceptional circumstances justify the use of a transaction that provides for innovative business arrangements or structures that would not be feasible or appropriate under a procurement contract. (USD[AT&L], 2002, p. 9)

The intent of this authority is for contracting officials to seek fixed-price agreements in prototype projects that entice non-traditional contractors to extensively participate as a key contributor to the prototype project. This authority incentivizes non-traditional contractors to do business with the government, as it is not subject to the Truth in Negotiation Act or Cost Accounting Standards (CAS), which can present significant overhead costs and entry barriers for businesses seeking an opportunity to attract government business. In return, the government benefits by tapping into new technological capabilities that may serve as solutions to capability gaps within the DOD.

OTA provides immunity for government contractors from 10 U.S.C. 2320-21, but government officials must still consider other applicable laws relevant to intellectual property and protect the firm's and government's interest from being compromised to external threats such as espionage. Contracting officials should seek guidance from their Intellectual Property Counsel as applicable intellectual property laws extend beyond those in Title 10.

The agreements entered into by the government should holistically consider the total life cycle costs of the project and procure the appropriate level of data rights to use the technology produced by the prototype project to satisfy the government's requirement. The government should use applicable U.S. Code as a baseline comparison to the level of technical data, "but may negotiate rights of a different scope when necessary to accomplish program objectives and foster government interests" (USD[AT&L], 2002, p. 18). This flexibility requires the inclusion of intellectual property clauses in the agreement detailing the terms and conditions pertaining to the technical data throughout the life cycle of the weapon system. This clause, in addition to a disputes clause, serves as the reference in determining the legitimacy of claims and to which stakeholders they apply. In considering the life cycle benefits of the project, the agreement should state the method of access and who may access the technical data throughout the life cycle. This includes instances in which the government contractor neglects to complete the project or advance its development as well as instances in which the technology is obsolete in the commercial market, but is still in use by the government.

D. SUMMARY

In summary, this chapter highlighted the importance of executing an acquisition strategy that mandates the acquisition of access and delivery of technical data to a centralized database necessary for the government to produce parts via an AM process. Additionally, anti-counterfeiting technology necessary to protect the intellectual property was prescribed as a solution to industry's concerns related to patent infringement. Lastly, OTAs were introduced as a procurement method for the government to use when acquiring weapon systems with firms reluctant to do business with the DOD due to complications related to government bureaucracy.

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VI. CONCLUSION

As this paper has described, AM technology is an exciting new tool for the DOD. Supply chains of the future must incorporate this technology. Andre Wegner predicts, "By 2027, so in about ten years, 10% of everything we make will be made digitally by 3D printers, and not at the point of use, but digitally closer" (personal communication, July 28, 2016). Therefore, it is the responsibility of military leaders to lean forward and develop solutions to overcome these challenges in order to obtain the immense benefits that AM will deliver.

A. SUMMARY OF RECOMMENDATIONS

This research focused on the 3D technologies and printers that are currently in existence and serve as a reliable option for producing parts. Some manufacturing experts claim that 3D printing is simply one iteration of computer-aided manufacturing that started with computer numerical control (CNC) machining. The broad group of techniques that uses a machine-readable file to direct computer-controlled equipment is collectively called *digital manufacturing*.

1. Supply Chain Challenges

AM presents some exiting solutions to difficult military supply chain problems. AM has the potential to radically change the way warfighters are supplied in the future. To make this quantum leap forward, the DOD should consider the following recommendations.

a. Supply Chain Recommendation 1: Push Print Capability Forward

There are already AM pilot programs onboard ships, aviation maintenance squadrons, and deployed Army forward operating bases. This ability to print close to the end user is what is required to achieve the flexibility and speed advantages of AM.

b. Supply Chain Recommendation 2: Build the Database

Commands with AM machines will require the information necessary to identify AM-capable parts. As pilot programs and other research prove AM capability, these items require classification as AM eligible. The existing NSN and SM&R codes may satisfy this goal. This information must interface to the digital supply chain of files to deliver them to the machines.

c. Supply Chain Recommendation 3: Consolidate and Share Knowledge

As the GAO recommended, the DOD needs a lead to manage and direct AM research information and resources. The public–private partnership of America Makes will also aid in synergizing efforts with private-sector partners.

d. Supply Chain Recommendation 4: Train the AM Workforce

In order to use this high-tech machinery, the DOD must train the AM workforce of tomorrow. This means adding CAD software, 3D visualization, NDE tests, and other AM-specific skills to the training pipeline.

e. Supply Chain Recommendation 5: Vertically Integrate

As AM technologies prove their benefit to the DOD supply system, the scope needs to expand to incorporate total product life cycle management. This will expand benefits and efficiencies to include all phases, from requirement to disposal.

2. Intellectual Property Challenges

This portion of the research focused on finding a solution that addresses the challenges specific to acquiring the technical data necessary for the government to manufacture parts via AM. In order to accomplish this, industry must have confidence in the government's ability to securely transmit and safeguard the data, and the government must have a procurement method that offers more flexibility than the traditional acquisition process, which favors the government's interest over industry's.

a. Intellectual Property Recommendation 1: Acquisition Strategy

The DOD needs to contract for the technical data required to utilize 3D printing during the initial weapon system acquisition. Procuring the technical data rights via a subscription method is a realistic and practical option for the DOD. Contracting for access to a vendor's PLM system will result in a new business model where companies are paid per part printed rather than per part produced. This distributive supply chain will reduce manufacturing costs and generate passive income. 3D technology is becoming mainstream and the growth of this technology will force companies to adapt to their business model or become obsolete.

b. Intellectual Property Recommendation 2: Data Protection

The DOD needs to continue to explore additional methods of ensuring that private industries' intellectual property is safeguarded so firms trust the DOD's handling of data. Additionally, the DOD needs to update its information technology networks in order to meet the technical requirements demanded by AM.

c. Intellectual Property Recommendation 3: Alternative Procurement Method

The DOD needs to utilize alternative procurement methods such as OTA to encourage firms who are reluctant to do business with the government because of the bureaucracy and concern over DOD acquisition regulations. OTAs deserve special consideration in cases where firms have a critically required innovative capability and the DOD requires the expedience and flexibility to acquire the weapons system and the technical data associated with it. This procurement method is a viable option and currently the most practical to further AM adoption and advance DOD AM capabilities.

B. AREAS FOR FURTHER RESEARCH

Although we strived to conduct an exhaustive analysis of AM problems and solutions, the topic is too large for the time allotted for this graduation requirement. Thus, we have included areas for further research. All of these would be valuable projects for future Naval Postgraduate School students.

Much of the research compared the differences between new AM techniques and traditional subtractive manufacturing methods. New machines are being developed that can accomplish both methods at one time. This is called *hybrid manufacturing*. Hybrid manufacturing brings with it an entire new level of complexity of materials science, engineering, and testing methods. A company called DMG Mori is the current industry leader in the development of hybrid manufacturing machines (Diane Ryan, personal communication, September 1, 2016).

Just as 3D printing technology is becoming pervasive in manufacturing, a new technology called four-dimensional (4D) printing is being developed. In this context, the fourth dimension is time, as these objects are non-rigid or spacio-temporal (McAlpine, 2016). Inspired by nature, these objects can change shape based on variations in humidity, temperature, or other environmental stimuli (McAlpine, 2016). This discovery represents a new combination of biological science, materials science, and mathematics (McAlpine, 2016). This is a brand-new technology with no current commercial applications, but one that could provide great advantages to the DOD in the future. Further research is required to investigate the full potential of 4D printing for the military.

This paper mentioned the digital supply chain and its importance to AM. These 3D CAD files are created, stored, protected, and distributed to AM-capable machines. The integrity of this flow of information is crucial to the quality of AM products. This mandatory input to the process has profound impacts on the ability of the military to leverage this new set of manufacturing technologies. An entire MBA project could discuss the challenges and opportunities regarding the digital supply chain.

AM technologies now include woven materials including carbon fiber–reinforced plastics. Boeing uses carbon fiber–reinforced plastics extensively on the 787 Dreamliner. One unique advantage to woven materials is the ability to include conductive wire on the outermost ply for lighting strike protection (Brosius, 2007). Woven materials may have other characteristics that prove advantageous for the DOD.

This research mainly considered parts adaptable to the AM printers ranging from the desktop to workbench size. However, AM technology exists for much smaller and larger scale items. The smallest known devices print on a nanoscale. Researchers at the Department of Energy’s Oak Ridge National Laboratory have created a method called Focused Electron Beam Induced Deposition (FEBID; Hall, 2016). It is currently only useful for the advancement of research. This type of AM process focuses much more heavily on the materials than the process. Currently, the upper size limit of AM is limited to the size of the print bed. Large-scale printing is currently in development that possesses the ability to direct dispense liquid concrete to create guard shacks, shelters, and other livable spaces. This technology could benefit the Navy's Construction Battalions (CBs) who routinely deploy to build temporary and permanent structures for deployed forces.

This research project focused on the strategic-level challenges and solutions for incorporating AM technology. Future graduate students may choose to pursue the same topic on an operational or tactical level, such as screening a list of COSAL consumables for characteristics that make it legally eligible for AM technologies. This could result in an authorized list of consumable items eligible for reproduction by engineering, printing, and testing without violating patent infringement statutes. This would lead to parts that may use AM as an alternate procurement method. NAVSUP GLS has previously expressed interest in sponsoring such projects.

AM has the potential to bring manufacturing jobs back to the United States. The low cost of entry of AM makes it accessible to many more people and small businesses than traditional machining. A future NPS student could conduct an economic study on the impact of AM technology on the U.S. job market.

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APPENDIX A. FAR CLAUSE MATRIX

FAR Part 27 provides contract clauses applicable to intellectual property in government contracts. The FAR clauses provided in this appendix include relevant background information, the intent and application of the clause, and clause requirements (USD [AT&L], 2001).

FAR Clause Matrix

FAR 52.227-1: Authorization and Consent

Statutory Reference	28 U.S.C. 1498 (a)
Regulatory Reference	FAR 27.201-2(a)
Principal Objective	To extend the Government's limited waiver of sovereign immunity for U.S. patent infringement to its contractors.
Applicability	All contracts except contracts for commercial items or when performance and delivery will be made outside the United States.
Requirements	The clause authorizes the contractor to use patented inventions in performing a contract without independent exposure to patent infringement from third parties. The Government authorizes and consents to all use and manufacture, for performance of a contract or any subcontract, of any invention covered by a U.S. patent embodying the product, the delivery of which is accepted by the Government under the contract.

FAR 52.227-2: Notice and Assistance Regarding Patent and Copyright Infringement

Statutory Reference	None
Regulatory Reference	FAR 27.202-2
Principal Objective	To notify the Government of a patent infringement lawsuit that the Government must defend.
Applicability	Supply, service, or research and development contracts above the simplified acquisition procedures threshold except when performance and delivery will be made outside the United States.
Requirements	The contractor promptly notifies the contracting officer upon notice or claim of patent or copyright infringement based on the performance of the contract.

FAR 52.227-3: Patent Indemnity

Statutory Reference	None
Regulatory Reference	FAR 27.203-1(b), 27.203-2(a), or 27.203-4(a)(2) as applicable
Principal Objective	Ensures that the Government purchases items that otherwise incorporate commercially available components, free and clear of any patent claims or liability.
Applicability	All contracts except those for research and development (using Alternate I of FAR 52.227-1), supplies or services not previously sold in the commercial marketplace, work to be performed outside the United States, contracts using simplified acquisition procedures, or architect-engineer work.
Requirements	The contractor must indemnify the Government against liability, including costs, for infringement of any U.S. patent arising out of the manufacture or delivery of supplies or performance of services under a contract.

FAR 52.227-4: Patent Indemnity—Construction Contracts

Statutory Reference	None
Regulatory Reference	FAR 27.203-5
Principal Objective	Ensures that the Government is not exposed to any patent infringement claims or liability under construction contracts (consistent language with 52.227-3).
Applicability	Fixed-price contracts for construction, dismantling, demolition, or removal of improvements.
Requirements	The contractor agrees to indemnify the Government against liability, including costs and expenses, for infringement of any U.S. patent.

FAR 52.227-5: Waiver of Indemnity

Statutory Reference	28 U.S.C. 1498(a)
Regulatory Reference	FAR 27.203-6
Principal Objective	To waive indemnification by the contractor and authorize the use and manufacture, solely in performing a contract, of any invention covered by a U.S. patent identified in the contract.
Applicability	Contracts for which a written approval from the agency head or designee is obtained. Must be in the Government's interest and must be solely for performance of the contract.
Requirements	The Government authorizes the contractor to use and manufacture, solely in performing the contract, any invention covered by the U.S. patents identified herein; and waives indemnification by the contractor with respect to such patents.

FAR 52.227-6: Royalty Information

Statutory Reference	None
Regulatory Reference	FAR 27.204-2
Principal Objective	To obtain royalty payment information in proposals in order to conduct cost/price analysis, ensure the royalty is proper, and ensure the Government is not paying a royalty to which it otherwise has a license.
Applicability	Negotiated contracts.
Requirements	Requires the offeror to disclose, as part of its proposal, the amount of royalty paid, patent numbers, and a brief description of the component on which a royalty is paid. Also, if requested by the contracting officer before the execution of the contract, the offeror shall furnish a copy of the current license agreement and an identification of applicable claims of specific patents.

FAR 52.227-7: Patent—Notice of Government Licensee

Statutory Reference	None
Regulatory Reference	FAR 27.204-3(c)
Principal Objective	To advise offerors, through the solicitation, when the Government intends to pay a patent royalty for items to be procured under the contract.
Applicability	Contracts for which the Government has agreed to pay a patent royalty.
Requirements	Sets forth the patent information, royalty rate, and owner and licensee information.

FAR 52.227-9: Refund of Royalties

Statutory Reference	None
Regulatory Reference	FAR 27.206-2
Principal Objective	To ensure that the Government does not overpay royalties.
Applicability	Negotiated fixed-price contracts for which the contracting officer believes it is questionable whether substantial amounts of royalties will have to be paid.
Requirements	Establishes requirements for royalty payments to ensure they are properly chargeable.

FAR 52.227-10: Filing of Patent Applications—Classified Subject Matter

Statutory Reference	None
Regulatory Reference	FAR 27.207-2
Principal Objective	To prevent classified information from entering the public domain.
Applicability	Contracts that may result in a patent application containing classified subject matter.
Requirements	The contracting officer must approve the filing of a U.S. patent application that includes disclosure of any contract subject matter classified as "confidential" or higher.

FAR 52.227-11: Patent Rights—Retention by the Contractor (Short Form)

Statutory Reference	35 U.S.C. 202-204 and 37 C.F.R. 401
Regulatory Reference	FAR 27.303 (a)
Principal Objective	To ensure that inventions developed by small business firms and domestic nonprofit organizations, with federal funding, are utilized for the public benefit.
Applicability	Contracts for experimental, developmental, or research work with small businesses and nonprofit organizations.
Requirements	♦ The contractor must disclose an invention within two months after the inventor identifies it in writing to contractor personnel responsible for patent matters. ♦ Where the Government obtains the title and the contractor has a nonexclusive domestic license, the license may be revoked or modified by the Government to the extent necessary to achieve expeditious practical application. ♦ For inventions where the contractor acquires title, the Government has the right to require the contractor to grant a nonexclusive, partially exclusive, or exclusive license to

	a responsible applicant. ♦ The contractor flows down the same rights to the subcontractor and will not, as part of the consideration for awarding the subcontract, obtain rights in the subcontractor's subject inventions. ♦ The contractor agrees that it will grant exclusive rights to subject inventions in the United States only to those manufacturing substantially in the United States.

FAR 52.227-12: Patent Rights—Retention by the Contractor (Long Form)

Statutory Reference	35 U.S.C. Sec. 202, 204, and 210(c), Presidential Memorandum 2/18/83, and Executive Order 12591
Regulatory Reference	FAR 27.302(f), 27.302(g), 27.303(b), 27.303(d)(1)(ii), and 27.304-1(g)
Principal Objective	To ensure that inventions developed with funding from DoD, the Department of Energy, and the National Aeronautics and Space Administration by large, for-profit businesses are utilized for the public benefit.
Applicability	The contractor is other than a small business firm or nonprofit organization and the effort is for experimental, research, or developmental work.
Requirements	♦ The contractor must disclose inventions within two months after the inventor discloses in writing to contractor personnel, or within six months after the contractor becomes aware that an invention has been made, whichever is earlier. ♦ Where the Government obtains the title and the contractor has a nonexclusive domestic license, the license may be revoked or modified by the Government to the extent necessary to achieve an expeditious practical application. ♦ The contractor will flow down the same rights to the subcontractor and will not, as part of the consideration for awarding the subcontract, obtain rights in the subcontractor's subject inventions. ♦ The contractor agrees that it will grant exclusive rights to subject inventions in the United States only to those manufacturing substantially in the United States. ♦ If the contractor has not commercialized a subject invention within a reasonable time, the Government has the right to require the contractor to grant a nonexclusive, partially exclusive, or exclusive license to a responsible applicant. If the contractor refuses such a request, the Government has the right to grant such a license itself.

FAR 52.227-12: Patent Rights—Retention by the Contractor (Alternate I)

Statutory Reference	35 U.S.C. 202(c)(4)
Regulatory Reference	FAR 27.303(b)(2)
Principal Objective	To honor U.S. treaties and agreements with foreign govem-ments and international organizations.
Applicability	The contractor is other than a small business firm or nonprofit organization and the effort is for experimental, research, or developmental work.
Requirements	The Government has the right to sublicense foreign govern-ments, their nationals, and international organizations pursu-ant to specifically identified treaties or international agreements.

FAR 52.227-12: Patent Rights—Retention by the Contractor (Alternate II)

Statutory Reference	35 U.S.C. 202 (c)(4)
Regulatory Reference	FAR 27.303(b)(2)
Principal Objective	To honor U.S. treaties and agreements with foreign govem-ments and international organizations.
Applicability	Long-term contracts where the contractor is other than a small business firm or nonprofit organization and the effort is for ex-perimental, research, or developmental work.
Requirements	♦ The Government has the right to unilaterally amend the contract to identify specific treaties and international agreements entered into after the effective date of the contract to effectuate the granting of licenses and other rights to relevant organizations. ♦ The contracting officer has the discretion to modify the clauses in FAR 52.227-11, 52.227-12, and 52.227-13 to make it clear that the rights granted to the foreign gov-ernment or international organization may be additional rights beyond a license or sublicense if so required by the applicable treaty or international agreement.

FAR 52.227-13: Patent Rights—Acquisition by the Government

Statutory Reference	41 U.S.C. 418a (d) and 35 U.S.C. 202(a)(i)
Regulatory Reference	FAR 27.303(c) FAR 27.302(i)2
Principal Objective	To provide for contracts to be performed outside the United States by large, for-profit companies.
Applicability	The contractor is foreign and the effort is for experimental, research, or developmental work.
Requirements	♦ The contractor agrees to assign to the Government the entire right, title, and interest to each subject invention. ♦ The contractor's domestic license may be revoked or modified to the extent necessary to achieve an expeditious practical application of the subject invention.

FAR 52.227-14: Rights in Data

Statutory Reference	41 U.S.C. 418 (a)
Regulatory Reference	FAR 27.409(a), 27.302(i)1, 27.303(c), and 52.227-13
Principal Objective	For the Government to have unlimited data rights to data first produced under a contract.
Applicability	Not applicable to DoD. (See FAR 27.400).
Requirements	♦ Sets forth rights in data for contracts where data will be produced, furnished, or acquired (with some notable exceptions). ♦ For data other than software, the contractor grants to the Government, and others acting on its behalf, a paid-up, nonexclusive, irrevocable worldwide license in the copyrighted data to reproduce, prepare derivative works, distribute copies to the public, and perform and display publicly.

FAR 52.227-15: Representation of Limited Rights Data and Restricted Computer Software

Statutory Reference	41 U.S.C. 418a (d) (5)
Regulatory Reference	FAR 27.409(g)
Principal Objective	When limited-rights data or restricted computer software are likely to be used, the insertion of this clause into the solicitation will generate a response from the contractor that will help the contracting officer use an appropriate data rights clause in the award.
Applicability	Applies to civilian agency solicitations that include the clause FAR 52.227-14, Rights in Data. Not applicable to DoD. (See FAR 27.400).

Requirements	Establishes the requirement for contractors to assert limited- or restricted-rights data that may be included in the contract data to be delivered.

FAR 52.227-16: Additional Data Requirements

Statutory Reference	None
Regulatory Reference	FAR 27.409(h)
Principal Objective	Enable the Government access to data generated under the contract but not established at the outset of the contract.
Applicability	Applies to civilian agency contracts involving experimental, developmental, research, or demonstration work. Not applicable to DoD. (See FAR 27.400).
Requirements	The contracting officer may, at any time during contract performance or within a period of three years after acceptance of all items to be delivered under the contract, order any data first produced or specifically used in the performance of the contract.

FAR 52.227-17: Rights in Data—Special Works

Statutory Reference	None
Regulatory Reference	FAR 27.409(i)
Principal Objective	Establish unlimited Government rights to copyrighted material and indemnification under the contract.
Applicability	Applies to civilian agency contracts and solicitations primarily for the production or compilation of data for the Government's internal use. Not applicable to DoD. (See FAR 27.400).
Requirements	The Government shall have unlimited rights in the data delivered under the contract and in all data first produced in the performance of the contract, and the contractor will indemnify the Government against liabilities for infringement of trade secrets and copyrights.

FAR 52.227-18: Rights in Data—Existing Works

Statutory Reference	None
Regulatory Reference	FAR 27.409(j)
Principal Objective	Acquire worldwide nonexclusive license to reproduce subject matter being acquired.
Applicability	Applies to civilian agency solicitations and contracts exclusively for the acquisition of existing audiovisual and similar works. Not applicable to DoD. (See FAR 27.400).
Requirements	The contractor grants to the Government a paid-up, nonexclusive, irrevocable, worldwide license to reproduce the works, prepare derivative works, and perform and display them publicly.

FAR 52.227-19: Commercial Computer Software—Restricted Rights

Statutory Reference	None
Regulatory Reference	FAR 27. 409(k)
Principal Objective	To ensure that the contract contains terms to obtain sufficient rights for the Government to fulfill the need for which the software is being acquired.
Applicability	Applies to civilian agency acquisitions of existing computer software. Not applicable to DoD. (See FAR 27.400).
Requirements	The Government shall have the right to use, duplicate, or disclose any restricted computer software delivered under the contract.

FAR 52.227- 20: Rights in Data—SBIR Program

Statutory Reference	15 U.S.C. 638, SBIR Reg. at 37 C.F.R. 401
Regulatory Reference	FAR 27.409(l)
Principal Objective	Establishes Government and contractor rights under Small Business Innovative Research (SBIR) program contracts.
Applicability	Applies to civilian agency contracts awarded under the SBIR program. Not applicable to DoD. (See FAR 27.400).
Requirements	♦ The Government shall have unlimited rights in the data except where the small business has retained the rights and given a notice accordingly. ♦ The contractor shall have the right to protect data delivered and establish claims to copyrighted material in accordance with the clause procedures.

FAR 52.227-21: Technical Data Declaration, Revision, and Withholding of Payment—Major Systems

Statutory Reference	41 U.S.C. 418 (a)(d) 7,8, 9 and 41 U.S.C. 403 (a) (9) (10)
Regulatory Reference	FAR 27.409(q)
Principal Objective	To ensure quality of delivered technical data under a contract.
Applicability	Applies to civilian agency contracts for major system acquisitions. The technical data to which the clause applies must be specified in the contract. Not applicable to DoD. (See FAR 27.400).
Requirements	♦ The contractor must make a declaration that the technical data delivered under the contract is complete and accurate and complies with the requirements of the contract. ♦ The Government has the right to withhold payment until data requirements are properly satisfied.

FAR 52.227-22: Major System—Minimum Rights

Statutory Reference	None
Regulatory Reference	FAR 27.409(r)
Principal Objective	Establishes unlimited rights to all data under the contract.
Applicability	Applies to civilian agency contracts for major systems for civilian agencies except NASA and U.S. Coast Guard. Not applicable to DoD. (See FAR 27.400).
Requirements	The Government shall have unlimited rights in any technical data, other than computer software, developed in the performance of this contract.

FAR 52.227-23: Rights to Proposal Data (Technical)

Statutory Reference	None
Regulatory Reference	FAR 27.409(s)
Principal Objective	Establishes unlimited rights to proposal data.
Applicability	Applies to civilian agency acquisitions in which the contracting officer desires to acquire unlimited rights in technical data contained in a successful proposal upon which a contract award is based. Not applicable to DoD. (See FAR 27.400).
Requirements	As a condition to the award of the contract, the Government shall have unlimited rights in and to the technical data contained in the proposal upon which the contract is based, except for those pages marked by the offeror as proprietary.

APPENDIX B. DFARS CLAUSE MATRIX

DFARS 252.227 provides defense-specific contract clauses applicable to intellectual property in government contracts. The DFARS clauses provided in this appendix include relevant background information, the intent and application of the clause, and clause requirements (USD[AT&L], 2001).

DFARS CLAUSE MATRIX

DFARS 252.227-7000: Non-Estoppel

Statutory Reference	None
Regulatory Reference	DFARS 227.7009-1
Principal Objective	Provides the right to challenge the validity of patents and patent applications licensed under a contract.
Applicability	Patent release and settlement agreements, license agreements, and assignments executed by the Government, when it acquires rights.
Requirements	The Government reserves the right to contest, at any time, the enforceability, validity, scope of, or title to any patent or patent application without waiving or forfeiting any rights under the contract.

DFARS 252.227-7001: Release of Past Infringement

Statutory Reference	None
Regulatory Reference	DFARS 227.7009-2(a)
Principal Objective	Releases Government from any patent infringement liability of inventions identified in a contract.
Applicability	Patent release and settlement agreements, license agreements, and assignments, executed by the Government, under which the Government acquires rights.
Requirements	The contractor releases the Government from any claims for the manufacture or use by the Government, prior to the contract's effective date, of any inventions covered by a patent and identified in a contract.

DFARS 252.227-7025: Limitation on the Use or Disclosure of Government-Furnished Information Marked with Restrictive Legends

Statutory Reference	None
Regulatory Reference	DFARS 227.7103-6(c), 227.7104(f)(1), or 227.7203-6(d)
Principal Objective	To limit the contractor's use of Government-furnished information.
Applicability	Solicitations where the Government furnishes information to the contractor.
Requirements	Where Government-furnished information marked with legends is misused or misappropriated, the contractor will indemnify the Government, as the information may be proprietary to another contractor.

DFARS 252.227-7026: Deferred Delivery of Technical Data or Computer Software

Statutory Reference	10 U.S.C. 2320 (b) (2)
Regulatory Reference	DFARS 227.7103-8(a)
Principal Objective	To protect the Government's interest in deferring the delivery of technical data or computer software.
Applicability	Contracts where necessary or applicable.
Requirements	The Government has the right to defer the delivery of technical data or computer software for up to two years after the acceptance of all other items.

DFARS 252.227-7027: Deferred Ordering of Technical Data or Computer Software

Statutory Reference	10 U.S.C. 2320 (b) (2)
Regulatory Reference	DFARS 227.7103-8(b)
Principal Objective	To give the Government time to determine whether it needs technical data or computer software under a contract.
Applicability	Solicitations when various technical data and computer software requirements cannot be specifically identified, but there is a potential need for technical data and computer software generated under the contract.
Requirements	The Government may order any technical data or computer software generated under the performance of a contract. Such order may be made within three years after the acceptance of all items.

DFARS 252.227-7002: Readjustment of Payments

Statutory Reference	None
Regulatory Reference	DFARS 227.7009-2(b)
Principal Objective	To ensure that the Government does not overpay royalties.
Applicability	Contracts providing for a payment of running royalty.
Requirements	The contractor will give the Government the same royalty rates given to other licensees of the patent.

DFARS 252.227-7003: Termination

Statutory Reference	None
Regulatory Reference	DFARS 227.7009-2(c)
Principal Objective	To preserve the Government's right to terminate a license agreement.
Applicability	Contracts providing for the payment of running royalty.
Requirements	The Government reserves the right to terminate a license by giving the contractor 30 days' notice in writing.

DFARS 252.227-7004: License Grant

Statutory Reference	None
Regulatory Reference	DFARS 227.7009-3(a)
Principal Objective	To ensure the acquisition of a patent license agreement.
Applicability	Patent release and settlement agreements, as well as license agreements that do not provide for royalty payment.
Requirements	The contractor grants the Government an irrevocable, nonexclusive, nontransferable, paid-up, Government-purpose license under the designated patents.

DFARS 252.227-7005: License Term

Statutory Reference	None
Regulatory Reference	DFARS 227.7009-3(b)
Principal Objective	To ensure the Government's right to terminate a license agreement.
Applicability	Patent release and settlement agreements, and license agreements not providing for royalty payment by the Govern-ment.
Requirements	Depending on which Alternate is used (I or II), the Govern-ment defines the term of the license.

DFARS 252.227-7006: License Grant Running Royalty

Statutory Reference	None
Regulatory Reference	DFARS 227.7009-4(a)
Principal Objective	To define the patent license grant.
Applicability	Patent release and settlement agreements, and license agreements, when the clause is desired to cover the subject matter thereof and the contract provides for royalty payment.
Requirements	The contractor grants the Government an irrevocable, nonexclusive, nontransferable license under the designated patents.

DFARS 252.227-7007: License Term—Running Royalty

Statutory Reference	None
Regulatory Reference	DFARS 227.7009-4(b)
Principal Objective	To define the term of the patent license.
Applicability	Patent release and settlement agreements, and license agreements, when the clause is desired to cover the subject matter thereof and the contract provides for royalty payment.
Requirements	The license granted shall remain in full force and effect for the full term of the patent unless terminated sooner.

DFARS 252.227-7008: Computation of Royalties

Statutory Reference	None
Regulatory Reference	DFARS 227.7009-4(c)
Principal Objective	To specify the royalty rate of a license.
Applicability	Patent release and settlement agreements, and license agreements, when the clause is desired to cover the subject matter thereof and the contract provides for royalty payment.
Requirements	Establishes the royalty rate.

DFARS 252.227-7009: Reporting and Payment of Royalties

Statutory Reference	None
Regulatory Reference	DFARS 227.7009-4(d)
Principal Objective	To report the royalty amount owed by the Government.
Applicability	Patent release and settlement agreements, and license agreements when the clause is desired to cover the subject matter and the contract provides for royalty payment.
Requirements	The procuring office shall report to the contractor the amount of royalties accrued and arrange for payment to the contractor.

DFARS 252.227-7010: License to Other Government Agencies

Statutory Reference	None
Regulatory Reference	DFARS 227.7009-4(e)
Principal Objective	To provide similar license terms to other Government agencies.
Applicability	When it is intended that a license be made available to other Government agencies on the same terms and conditions that appear in the contract license agreement.
Requirements	The contractor agrees to grant, to other Government agencies, license under the same terms and conditions that appear in the contract license agreement.

DFARS 252.227-7011: Assignments

Statutory Reference	None
Regulatory Reference	DFARS 227.7010
Principal Objective	To provide for patent assignments.
Applicability	Contracts assigning patent rights to the Government.
Requirements	The Government identifies the detailed information of the patent to be conveyed.

DFARS 252.227-7012: Patent License and Release Contract

Statutory Reference	None
Regulatory Reference	DFARS 227-7012
Principal Objective	To provide a format for inserting various patent license and release clauses as prescribed in the FAR and DFARS.
Applicability	For contracts of release, license, or assignment.
Requirements	The clause details the language to be used in a contract.

DFARS 252.227-7013: Rights in Technical Data—Non-commercial Items

Statutory Reference	10 U.S.C. 2320, EO 12591, 15 U.S.C. 638 for Alt II
Regulatory Reference	DFARS 227.7103-6(a)
Principal Objective	To set forth respective rights to technical data delivered under a contract.
Applicability	All contracts for noncommercial items under which technical data are to be delivered, except when the only deliverable items are computer software or computer software documentation.
Requirements	♦ Defines unlimited rights, limited rights, Government-purpose rights, specifically negotiated license rights, and prior Government rights. ♦ The contractor is required to provide a certified list of all asserted rights and restrictions in the furnished technical data. ♦ (b) (6) The contractor agrees to release the Government from liability for release or disclosure of technical data. ♦ (k)(4) The contractor and higher-tier subcontractors or suppliers shall not use their power to award subcontracts as economic leverage to obtain rights in technical data from their subcontractors or suppliers.

DFARS 252.227-7014: Rights in Noncommercial Computer Software and Noncommercial Computer Software Documentation

Statutory Reference	None
Regulatory Reference	DFARS 227.7203-6(a)(1)
Principal Objective	To set forth respective rights to computer software and computer software documentation delivered under the contract.
Applicability	Contracts for noncommercial computer software or computer documentation, except technical data.
Requirements	Defines unlimited rights, restricted rights, Government-purpose rights, specifically negotiated license rights, and prior Government rights. Contractor is required to provide a certified list of all asserted rights and restrictions in the furnished software.

DFARS 252.227-7015: Technical Data—Commercial Items

Statutory Reference	10 U.S.C. 2320, EO 12591
Regulatory Reference	DFARS 227.7102-3 Contract Clause
Principal Objective	To define the Government's rights in technical data related to commercial items.
Applicability	All solicitations and contracts involving commercial items where technical data is being acquired and for prime contracts where the subcontracts may require this clause in lieu of DFARS 252.227-7013.
Requirements	Defines the terms of the license for technical data, as well as restrictions placed on the Government.

DFARS 252.227-7016: Rights in Bid or Proposal Information

Statutory Reference	None
Regulatory Reference	DFARS 227.7103-6(e)(1), 227.7104(e)(1), or 227.7203-6(b)
Principal Objective	To allow the Government to use the information submitted in bids or proposals.
Applicability	Solicitations and contracts under which the successful offeror will be required to deliver technical data to the Government.
Requirements	Defines the Government's rights prior to, and subsequent to, contract award.

DFARS 252.227-7017: Identification and Assertion of Use, Release, or Disclosure Restriction

Statutory Reference	10 U.S.C. 2320
Regulatory Reference	DFARS 227.227.7103-3(b), 227.7104(e)(2), or 227.7203-3(a)
Principal Objective	To identify the nature of data to be delivered with other than "unlimited rights."
Applicability	All solicitations that include the clause DFARS 252.227-7013 or 7014.
Requirements	The contractor must identify all data (technical and computer software) that will be delivered with less than unlimited rights.

DFARS 252.227-7018: Rights in Noncommercial Technical Data and Computer Software—SBIR Program

Statutory Reference	15 U.S.C. 638
Regulatory Reference	DFARS 227.227.7104(a) License Rights
Principal Objective	To identify the scope of data rights to be delivered under the Small Business Innovative Research (SBIR) program.
Applicability	Research contracts under the SBIR Program.
Requirements	Identifies the Government's rights in the data developed under all phases of SBIR programs.

DFARS 227.7019: Validation of Asserted Restrictions—Computer Software

Statutory Reference	None
Regulatory Reference	DFARS 227.227.7104(e)(3) or 227.7203-6(c)
Principal Objective	To evaluate the contractor's asserted restrictions.
Applicability	Small Business Innovative Research solicitations and contracts.
Requirements	The clause identifies requirements for the Government's need to have information and the Government's right to challenge asserted restrictions.

DFARS 252.227-7020: Rights in Special Works

Statutory Reference	None
Regulatory Reference	DFARS 227.7105-3, 227.7106(a), or 227.72005(a)
Principal Objective	To ensure that the Government has an assignment or at least license rights to copyrighted works commissioned by the Government.
Applicability	Solicitations and contracts under which the Government has specific need to control the distribution of works first produced, created, or generated during contract performance.
Requirements	The clause spells out the Government's rights.

DFARS 252.227-7021: Rights in Data—Existing Works

Statutory Reference	None
Regulatory Reference	DFARS 227.7105-2(a), Acquisition of existing works without modification
Principal Objective	To provide necessary license rights to the Government for existing copyrighted works.
Applicability	Existing works.
Requirements	The clause defines "works" and the Government's rights to a nonexclusive license.

DFARS 252.227-7022: Government Rights (Unlimited)

Statutory Reference	None
Regulatory Reference	DFARS 227.7107-1(a)
Principal Objective	To define the scope of the Government's unlimited rights.
Applicability	Architectural designs and construction contracts.
Requirements	The Government shall have unlimited rights in all drawings, designs, and specifications, and retains a paid-up license.

DFARS 252.227-7023: Drawings and Other Data to Become Property of the Government

Statutory Reference	None
Regulatory Reference	DFARS 227.7107-1(b)
Principal Objective	To define the Government's rights in drawings and other data.
Applicability	Contracts involving architect-engineer services.
Requirements	All designs, drawings, and specifications developed under the contract become the sole property of the Government.

DFARS 252.227-7024: Notice and Approval of Restricted Design

Statutory Reference	None
Regulatory Reference	DFARS 227.7107-3
Principal Objective	To preserve the Government's rights in restricted designs.
Applicability	Architectural and construction contracts.
Requirements	Where the contractor's designs require products and materials that can be obtained only from a sole source, the contracting officer's approval is required.

DFARS 252.227-7025: Limitation on the Use or Disclosure of Government-Furnished Information Marked with Restrictive Legends

Statutory Reference	None
Regulatory Reference	DFARS 227.7103-6(c), 227.7104(f)(1), or 227.7203-6(d)
Principal Objective	To limit the contractor's use of Government-furnished information.
Applicability	Solicitations where the Government furnishes information to the contractor.
Requirements	Where Government-furnished information marked with legends is misused or misappropriated, the contractor will indemnify the Government, as the information may be proprietary to another contractor.

DFARS 252.227-7026: Deferred Delivery of Technical Data or Computer Software

Statutory Reference	10 U.S.C. 2320 (b) (2)
Regulatory Reference	DFARS 227.7103-8(a)
Principal Objective	To protect the Government's interest in deferring the delivery of technical data or computer software.
Applicability	Contracts where necessary or applicable.
Requirements	The Government has the right to defer the delivery of technical data or computer software for up to two years after the acceptance of all other items.

DFARS 252.227-7027: Deferred Ordering of Technical Data or Computer Software

Statutory Reference	10 U.S.C. 2320 (b) (2)
Regulatory Reference	DFARS 227.7103-8(b)
Principal Objective	To give the Government time to determine whether it needs technical data or computer software under a contract.
Applicability	Solicitations when various technical data and computer software requirements cannot be specifically identified, but there is a potential need for technical data and computer software generated under the contract.
Requirements	The Government may order any technical data or computer software generated under the performance of a contract. Such order may be made within three years after the acceptance of all items.

DFARS 252.227-7028: Technical Data or Computer Software Previously Delivered to the Government

Statutory Reference	10 U.S.C. 2320(b)(1)
Regulatory Reference	DFARS 227.7103-6(d), 227.7104(f)(2) or 227.7203-6(e)
Principal Objective	To identify all technical data and computer software that previously have been delivered to the Government, but that the contractor intends to deliver with less than unlimited rights.
Applicability	Solicitations for which the resulting contract will require the contractor to deliver technical data and computer software that were or are deliverable under another Government contract.
Requirements	Offerors must identify any technical data and computer software specified in the solicitation as deliverable technical data and computer software items that are the same or substantially the same as technical data and computer software items the offeror has delivered or is obligated to deliver, either as a contractor or subcontractor, under any other Federal agency contract.

DFARS 252.227-7030: Technical Data—Withholding of Payment

Statutory Reference	10 U.S.C. 2320(b)(9), 41 U.S.C. 418a(d)(9)
Regulatory Reference	DFARS 227.7103-6(e)(2) or 227.7104(e)(4)
Principal Objective	To have leverage in enforcing the contract.
Applicability	Solicitations and contracts that include the clause DFARS 252.227-7013, Right in Technical Data—Noncommercial Items.
Requirements	If technical data delivered under the contract is not delivered on time or is deficient, the contracting officer may withhold 10 percent of the contract price until the Government accepts such data.

DFARS 252.227-7032: Rights in Technical Data and Computer Software (Foreign)

Statutory Reference	10 U.S.C. 2320 (b) (1)
Regulatory Reference	DFARS 227.7103-17
Principal Objective	For the furtherance of mutual defense of the U.S. Government and the other governments.
Applicability	Contracts with foreign contractors to be performed overseas (except Canadian purchases).
Requirements	The U.S. Government may duplicate, use, or disclose all technical data and computer software, under the contract, to other governments.

DFARS 252.227-7033: Rights in Shop Drawings

Statutory Reference	None
Regulatory Reference	DFARS 227.7107-1(c)
Principal Objective	The Government may acquire exclusive control of the data pertaining to the design if the Government does not want the construction to be duplicated for any special reasons.
Applicability	Solicitations and contracts calling for the delivery of shop drawings. The clause is to be included in all subcontracts at any tier.
Requirements	The Government shall obtain unlimited rights in shop drawings for construction.

DFARS 252.227-7034: Patents—Subcontracts

Statutory Reference	None
Regulatory Reference	DFARS 227.304-4
Principal Objective	To have all parties involved in developing research, comply with the requirements of FAR 52.227-12.
Applicability	Solicitations and contracts pertaining to experimental, developmental, or research work by small business or domestic nonprofit organizations whose contract contains FAR 52.227.11.
Requirements	The contractor shall include FAR 52.227-12 in subcontracts to be performed by other than a small business or nonprofit organization.

DFARS 252.227-7036: Declaration of Technical Data Conformity

Statutory Reference	10 U.S.C. 2321 (b) (7)
Regulatory Reference	DFARS 227.7103-6(e)(3) or 227.7104(e)(5)
Principal Objective	Ensure the contractor’s accountability for data delivered.
Applicability	All solicitations and contracts (for noncommercial items), and when the successful offeror will be required to deliver technical data.
Requirements	The contractor provides a declaration that the technical data delivered is accurate and complies with the requirements of the contract.

DFARS 2252.227-7037: Validation of Restrictive Markings on Technical Data

Statutory Reference	10 U.S.C. 2321, 10 U.S.C. 2320 (b) (1)
Regulatory Reference	DFARS 227.7102-3(c), 227.7103-6(e)(4), 227.7104(e)(6) or 227.7203-6(f)
Principal Objective	To protect the Government's right to challenge the validity of restrictions marked on technical data packages.
Applicability	All solicitation and contracts.
Requirements	The contractor and subcontractor are responsible for maintaining records to justify the validity of markings that impose restrictions on the Government and others to use, duplicate, or disclose delivered technical data.

DFARS 252.227-7039: Patents—Reporting of Subject Inventions

Statutory Reference	None
Regulatory Reference	FAR 27.304-1(e), DFARS 227.303(a)
Principal Objective	To keep track of, and preserve the Government's rights in, inventions developed under the contract.
Applicability	Solicitations and contracts containing the clause FAR 52.227-11.
Requirements	The contractor shall furnish interim reports every 12 months, as well as a final report within 3 months after completion of the contract, as to whether any inventions were developed under the contract. The reports must provide all information regarding the contractor's patent application.

DFARS 252.204-7000: Disclosure of Information

Statutory Reference	None
Regulatory Reference	DFARS 204.404-70(a)
Principal Objective	To prevent the release of unclassified, but sensitive, information to the public.
Applicability	Solicitations and contracts when the contractor will have access to or generate unclassified information that may be sensitive and inappropriate for release to the public.
Requirements	The contractor and subcontractor shall not release, to anyone outside their organization, any unclassified information pertaining to any part of the contract, unless the contracting officer has given prior approval.

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