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MBA PROFESSIONAL PROJECT

**ESTABLISHING AN ADDITIVE MANUFACTURING (AM)
NAVY ENLISTED CLASSIFICATION FOR THE
MACHINERY REPAIRMAN TO ENABLE EFFICIENT USE
OF AM AND MASS ADOPTION OF THE TECHNOLOGY**

June 2019

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ABSTRACT

Additive Manufacturing (AM) technology has been making significant advances in recent years. While industry has already started exploiting it in its daily operations, the adoption and implementation of AM technology across the Department of Defense (DoD) and Department of the Navy (DoN) are still in very early stages. The major value that DoD and DoN plan to achieve are improvements in operational readiness, cost-savings, and increases in warfighting capability. The DoN has yet to identify the elements of a comprehensive training program across the fleet, including the training of operational level users. Should a Navy Enlisted Classification (NEC) be created for the Machinery Repairman (MR) rating to ensure safe and competent use of AM technology? Does creating an NEC support DoD and DoN policies and guidelines for AM implementation? This report examines those questions and provides a rationale and recommendations for the creation of an AM NEC, including a set of critical skills that should be a part of that training. Methodology developed and used in this report could be applied to examine the needs of other rates beyond MR. Recommended future work emphasizes the need to continue updating the training program recommended in this report, keeping it relevant with advances made in AM technology and our growing understanding about DoN applications of this technology.

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LIST OF ACRONYMS AND ABBREVIATIONS

3D	Three-Dimensional
AM	Additive Manufacturing
ASTM	American Society of Testing and Materials
BIFMA	Battle Force Intermediate Maintenance Activity
Cal Poly	California Polytechnic State University
CEU	Continuing Education Units
CNC	Computerized Numerical Code
CPLM	Collaborative Product Life Cycle Management
DoD	Department of Defense
DoN	Department of the Navy
EMR	Enlisted Master Record
GAO	United States Government Accountability Office
GMA	Gas Metal Arc
GTA	Gas Tungsten Arc
HR	Human Resource
IA	Individual Accounts
IMA	Intermediate Maintenance Activity
LEF	Leading Edge Forum
MIC	Mobile Innovation Center
MIT	Massachusetts Institute of Technology
MM	Machinist's Mate
MR	Machinery Repairman
NAF	Navy Availability Factor
NDI	Non-Destructive Inspection
NEC	Navy Enlisted Classification
NEOCS	Navy Enlisted Occupational Classification System
NPS	Naval Postgraduate School
OJT	On the Job Training
OPNAV	The Office of the Chief of Naval Operations
SM	Subtractive Manufacturing

UAS	Unmanned Aerial Systems
UAV	Unmanned Aerial Vehicle

EXECUTIVE SUMMARY

The purpose of this research is to determine options available to the Department of the Navy to successfully implement Additive Manufacturing (AM) within standard operating procedures. Use of AM technology (also commonly referred to as 3-Dimensional (3D) printing) is growing daily, particularly by industry. By contrast, the military is in the process of testing the technology and seeking various ways to find innovative solutions through implementation of AM technology to current processes. This research is focused on identifying appropriate categories of users of AM technology, and the level of training they will need to successfully utilize AM at their respective units. As of 2019 the need to develop a training and certification process has been identified by a set of documents that include the *DoD AM Roadmap* (DoD, 2016), the *DoN AM Implementation Plan V2.0* (DoN, 2017), and *A Design for Maintaining Maritime Superiority V2.0* (Richardson, 2018). Specific objectives and goals identified in these documents are discussed in the literature review.

In order to determine the level of training required to use AM proficiently in support of projected position and work assignments, the authors researched the complexity of the critical skills required for those assignments. The authors then provide an analysis of current naval rates with related occupational standards. The analysis of the critical skills corresponding to AM compared to the occupational standards of a Machinery Repairman (MR) led to the authors identifying the MR as a likely candidate to use AM at the operational level. To ensure MRs have received the appropriate training, the research focused on the creation of a Navy Enlisted Classification (NEC) code that applies to operational users of AM. The authors also looked into the current training processes conducted by industry and private educational institutions and observed the Mobile Innovation Center (MIC) San Diego, CA, and Naval Surface Warfare Center Corona, CA, to gain an understanding of the current AM processes used to manufacture components.

The results of the research provided the authors with an understanding of how industry and educational institutes apply training topics, course delivery, and the amount

of time necessary to receive various levels of certification commensurate with organizational roles. Using the results from this research, the authors made recommendations on the complexity and duration of the training required to develop an NEC for an MR. Creating an AM NEC would provide a skill set and skill proficiency needed to operate effectively with AM technology.

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I. INTRODUCTION

This chapter introduces the guiding research questions and provides a brief background of Additive Manufacturing (AM) and its use in the Department of the Navy (DoN). The chapter also describes the methodology used to conduct our research, and the scope of our research effort.

A. PURPOSE OF RESEARCH

Adoption of AM technology (also commonly referred to as Three-Dimensional (3D) printing) continues to expand daily, particularly by industry where it is already widely in use. By contrast, the military is still in the process of testing the technology at levels that vary from branch to branch. The DoN is seeking solutions to further implement AM within its current processes while simultaneously accelerating mass adoption of this technology. The DoN and its Systems Commands are committed to the use of AM; this technology holds a promise of cost-savings, increased readiness, sustainment, and enhanced warfighting capabilities. The DoN has already adopted some non-critical parts manufacturing via AM, such as polymer parts in aviators' helmets, knobs for calibration equipment and radios, to more advanced components; an example includes a sand mold used to cast metal parts such as a slide valve grid used on a submarine. These simple examples of the aviator's helmets, calibration equipment plastic knobs, and metal casting molds demonstrate how the usage of AM within the supply chain can provide innovative solutions to maintain units' readiness goals at their highest levels. In addition, the DoN (Department of the Navy [DoN], 2017, December) specifically solicits innovative solutions from all its members, uniformed and civilian, to use AM and meet current and future readiness challenges. This solicitation is further indication of the hope that AM technology could be used to a greater extent across the spectrum of DoN units and at all levels such as Organizational Units, Intermediate Maintenance Activities (IMA), Battle Force Intermediate Maintenance Activities (BIFMA), and Depot Repair and Overhaul Activities. Nonetheless, the U.S. Navy has yet to identify who (which rate, if any) is considered most qualified to use AM and what

training is required to use AM effectively at various operational levels. Due to the operating nature at sea and the occupational skills needed to execute these operations, the DoN established ratings to identify personnel who possess a broad category of skill sets in accordance with occupational standards. Furthermore, when a specified skill or skill set is required to perform specific tasks, the DoN creates a Navy Enlisted Classification (NEC) to identify the training and educational requirement necessary to perform the particular function. These skill sets are often acquired through formalized training or On-the-Job training (OJT), or a combination of both.

B. METHODOLOGY

The goals of the Department of Defense (DoD) outlined in the *DoD AM Roadmap* (DoD, 2016), the *DoN AM Implementation Plan V2.0* (DoN, 2017), and *A Design for Maintaining Maritime Superiority V2.0* (Richardson, 2018) are to establish AM processes at various levels of operations. The focus of activities outlined in the documents include the multiple roles of the personnel at every level that will support the adoption of AM technology and its application across the DoN. The methodology used in this report is focused on key enablers of these DoD objectives identified in the cited documents (DoD, 2016): (1) capability development, and (2) formalized access to training, education, and certification of users. Users in the context of our methodology are defined as those performing the processes of AM to create either a prototype or end item. This study includes a literature review, a background of AM technology, AM training, and establishing an NEC for the MR rating. The following sections contain brief descriptions of each chapter.

1. Literature Review

Chapter II includes research on the advantages of using AM compared to conventional manufacturing with Computerized Numerical Code (CNC) machines from the perspective of the complexity of the design and the manufacturing process differences.

It includes previous research and data that support the use of AM, instead of the conventional manufacturing method, for a significant reduction in production lead time to manufacture three metal components.

Chapter II describes the necessity of AM implementation within current processes of the DoD. This study includes the training requirements for personnel who must possess the knowledge to ensure the practical application of this technology at the operational level.

We present previous research that identifies limited design tools and the lack of a skilled workforce as significant challenges to wider usage of AM technology in the DoN and for AM to reach its full innovative potential.

2. Background and Overarching DoN Initiatives for AM

This step of our methodology, which is detailed in Chapter III, reviews AM technology and its implementation across the industrial domain. The *DoD AM Roadmap* (DoD, 2016), the *DoN AM Implementation Plan V2.0* (DoN, 2017) and *A Design for Maintaining Maritime Superiority V2.0* (Richardson, 2018) provide the goals and objectives to achieve AM technology adoption across the DoD and the DoN.

3. Current AM Training

We review existing solutions for multiple roles of AM enablers and users. The contents of the courses are described in Chapter IV.

4. Machinery Repairman NEC

We examined the core competencies required to perform AM and compared them with current occupational standards of an MR in the DoN. This analysis was conducted to determine the applicability of creating an NEC for the MR rating.

C. RESEARCH QUESTIONS

The questions we are researching are:

1. Should an NEC be created for the MR rating to ensure safe and competent use of AM technology?
2. Does creating an NEC support the *DoD AM Roadmap* (Department of Defense [DoD], 2016), *DoN AM Implementation Plan V2.0* (DoN, 2017), and *A Design for Maintaining Maritime Superiority V2.0* (Richardson, 2018)?

D. SCOPE

The scope of this research is limited to considerations of AM training and education to establish an NEC for the MR rate. Follow-on research could be conducted on other Naval Ratings such as Aviation Structural Mechanics or Machinist's Mates.

E. SUMMARY OF CHAPTER

This chapter described the purpose of our research and guiding research questions. It elaborates the methodology used to conduct our research, and the scope of our research efforts.

II. LITERATURE REVIEW

This chapter includes a brief overview of previous AM research. The research consists of a comparison of AM and conventional manufacturing with CNC machines, the reduction of production lead time when using AM to manufacture parts, and other benefits of AM. It also provides research on the necessity of AM implementation into current DoD processes and the Government Accountability Office (GAO) report 15-505SP (GAO, 2015) that identifies the significance of an unskilled AM workforce and its impact to improve the underlying AM innovative culture.

A. PREVIOUS RESEARCH

The largest difference between CNC and AM are that CNC will remove material to manufacture a component, while AM will add thin layers upon layers to create the same component. The amount of time to create a part or item varies with AM and CNC machines. Gibson et al. (2015) point out that when using AM technology, such as a 3D printer to manufacture simple components, it usually takes longer for the layering process of AM compared to the subtractive process for creating the same component using CNC. The real benefit, however, is the time it takes to complete the entire manufacturing process (see Figure 1). When considering setup time and the several stages often required to manufacture a component using CNC, AM is often more efficient than CNC when producing the same component. In addition, AM can produce parts and components in a single print job, and in some cases, due to geometric complexities, these parts can only be created from AM.

The use of the CNC machining process is usually multistage, requiring replacement of the product being machined along with additional processes needed to produce a finished part. Gibson et al. (2015) point out that “CNC machines require considerable setup and process planning, especially as parts become more complicated in their geometry” (p. 11). The bits used in a CNC mill or router often become dull or broken and need replacement to ensure precise cuts are made in the material being shaped during manufacturing. This ensures that the quality is repeatable. Gibson et al. (2015)

describe that making a part via AM can include manufacturing multiple parts, printed together during a single build, which takes considerably less time than the same part created using CNC. Additionally, depending on the quality of the end item, it may only take days to perform finishing. Conversely, the research of Gibson et al. (2015) identified that even when using a complex 5-axis high-speed CNC machine, it will often take much longer to complete the same process.

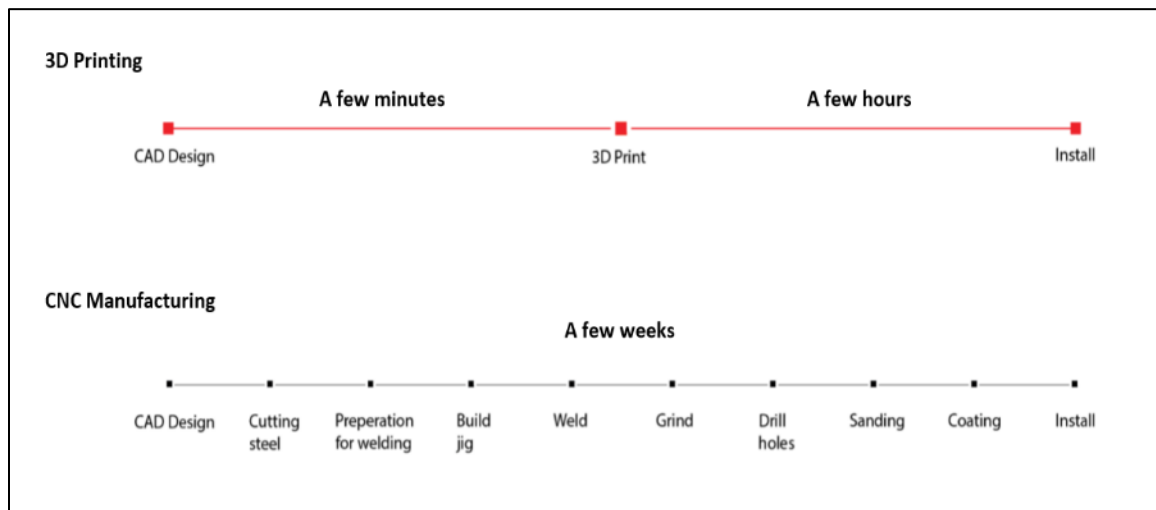


Figure 1. Timeline Comparison of 3D Printing (AM) and CNC Manufacturing. Adapted from Varotsis (n.d.).

The complexity of the shape of the manufactured component and accuracy of manufacturing are other advantages of using AM processes; sample components and their complex shapes that can be made from the AM process are shown in Figure 2 (all parts were printed in the Naval Postgraduate School (NPS) RoboDojo Laboratory). As Gibson et al. (2015) point out, AM is preferred over CNC when producing components that have or require complex shapes. Some shapes cannot be produced with CNC processes. This creates a challenge, and in some cases, it is impossible to produce single piece components by CNC. The accuracy of 3D printers is due to their performance parameters. Often, 3D printers operate with high resolution and fidelity. Gibson et al. (2015) have observed that some 3D printers “operate at a resolution of a few tens of microns” (p. 11).



The 3D printed objects pictured here were created at the Naval Postgraduate School in Monterey, CA.

Figure 2. 3D Printed Polymer Objects

Just like other machinery, test devices, and manufacturing equipment, 3D printers require periodic maintenance to ensure they meet performance standards of quality. As such, a qualified workforce capable of performing maintenance tasks on AM machines will be required to meet quality and repeatability goals. According to Gibson et al. (2015), many AM machines contain fragile components such as lasers or printer technology that must be checked and monitored to ensure proper operation within tolerances, specifically to ensure quality and repeatability. In addition, Gibson et al. (2015) describe how environment, such as one that is unclean or has high noise levels, can negatively affect the performance of AM machines and the process those machines use to create components. The authors also remark that 3D printers operate independently once a print job has been created, but it is crucial to ensure that a maintenance schedule is established and that it includes periodic checks to ensure proper operation and function. The authors emphasize that, based on the AM printing technology and raw materials used, maintenance level requirements and frequency will vary. Raw material storage and shelf life also need to be understood by an AM user. Some raw materials used in AM can

become damaged or otherwise unusable and can cause damage to the 3D printer or create performance deficiencies.

Sidoryk and Tirougnanassambandamourty (2018) provide data from their research in support AM adoption. Three metal parts that have low demand and consumption both via traditional manufacturing and AM were used in their research. They suggest that the power bed fusion method is the most favorable AM method to use to fabricate the parts. This method of AM includes using a material powder that is spread across a build platform, much as other materials are layered in other forms of AM. The metal powder is then heated using a laser or thermal print head that melts each layer to the preceding layer. This is done numerous times, layer by layer, until the object is fully printed based on the computer-aided design (CAD). Sidoryk et al. (2018) identify the main benefit of this method as a significant reduction in the lead time to manufacture the item while the conventional manufacturing method dominates in manufacturing cost. Their study also suggests a possible existence of hidden cost advantages of AM, such as lower inventory holding cost due to only using the powder material required to print the object while the remainder of the raw material can be reclaimed and stored for future use. Parts used in the research are shown in Figure 3. Cost and lead time comparisons are presented in Figures 4 and 5.

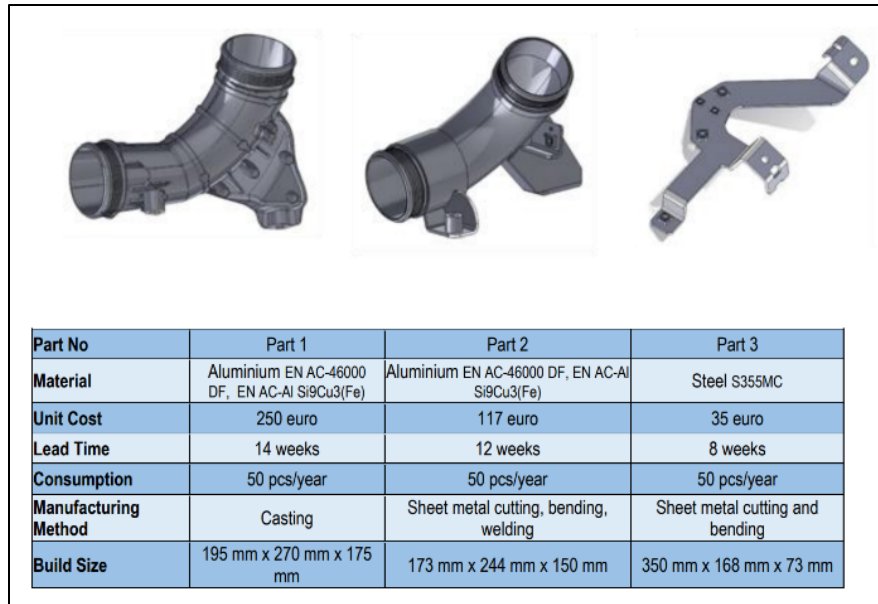


Figure 3. Parts Used in the Research. Source: Sidoryk et al. (2018).

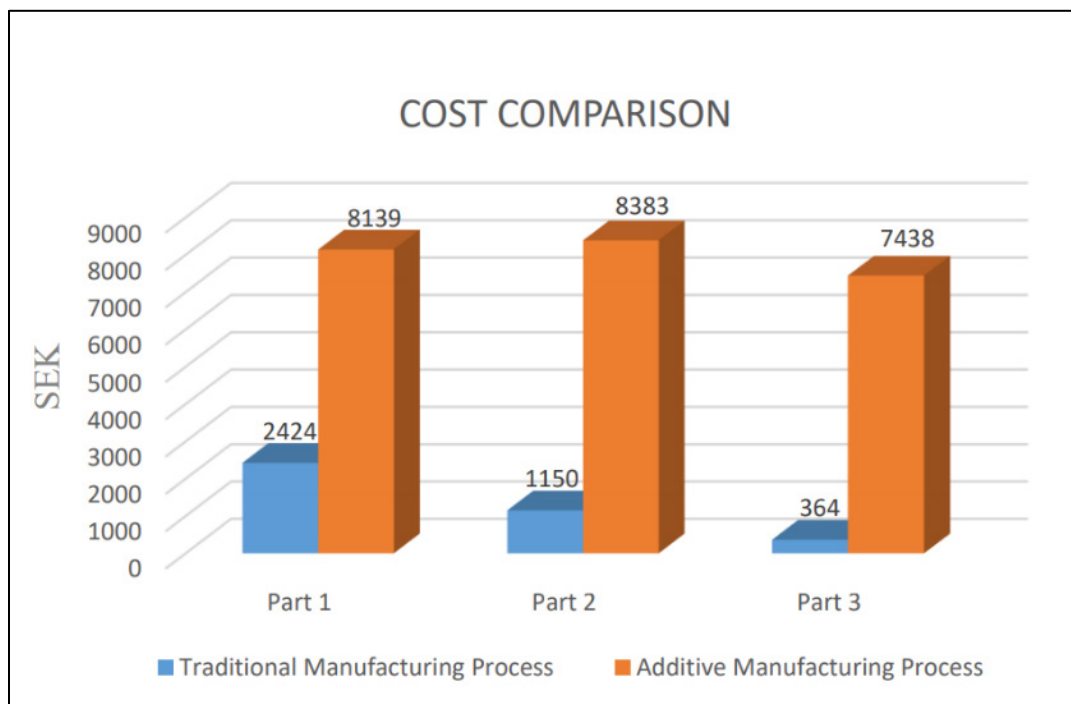


Figure 4. Comparison in Cost Source: Sidoryk et al. (2018).

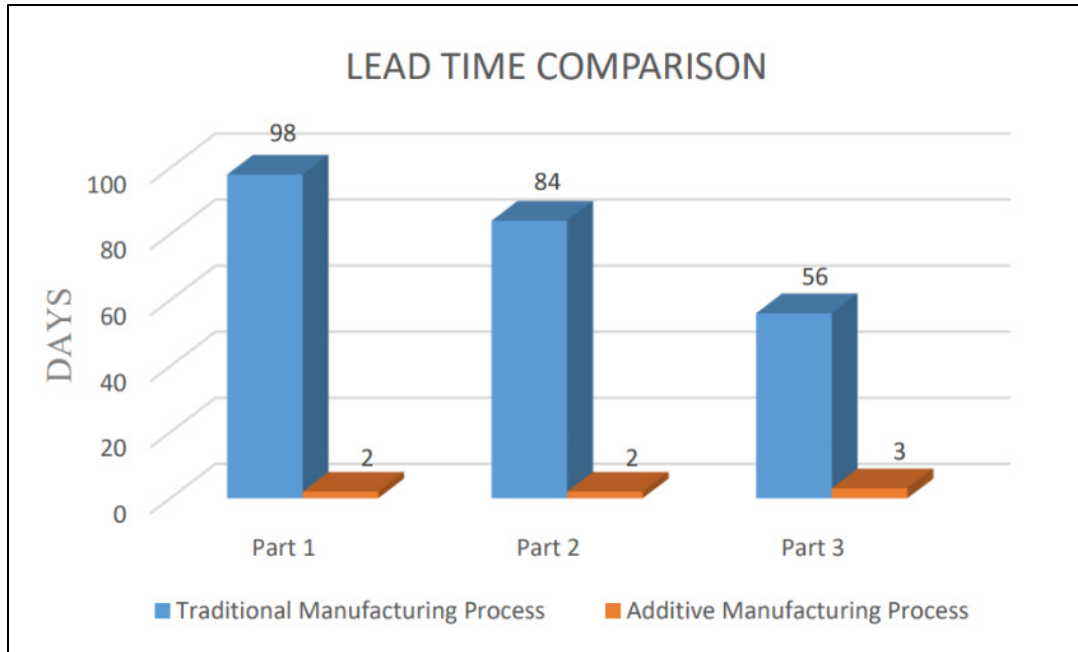


Figure 5. Comparison in Lead Time Source: Sidoryk et al. (2018).

The Leading Edge Forum (LEF) (2012) also refers to AM's superiority, describing that "a single machine can create vastly different products" (p. 3). The future application of AM can change the industrial structure by manufacturing various products with a 3D printer that can manufacture specific components in specific facilities, as shown in Figure 6. As the LEF (2012) predicts, the future of manufacturing may be a "factory that can manufacture tea cups, automotive components and bespoke medical products all in the same facility via rows of 3D printers" (p. 3). The only requirement for entry would be for new entrants to acquire 3D printers and raw materials instead of investing in many machines to competitively perform in the manufacturing industry. Those companies with AM require smaller amounts of capital to generate the same number of sales. Therefore, by reducing overhead cost AM can compete with traditional manufacturing despite smaller scales of its production. From the DoN perspective, the 3D printer's ability to manufacture various products with the same machine will reduce or minimize a need to carry additional stock or even contract for obsolete or long lead time parts still required and in use across the fleet. The greatest potential for innovating the future of AM is a competent workforce that effectively performs the processes, including designing and building.



Figure 6. 3D Printers. Source: Peels (2018).

The Rand Corporation recently published a research report regarding the potential changes of AM technology and its impact on supply chains (Véronneau et al., 2017). The report provides a lengthy background on the history and evolution of the AM process. The authors assume that in the future the DoD will be using AM, and the DoD will require follow-on research to evaluate how AM can be implemented into current processes. This includes the personnel training requirements and the skills personnel must possess to ensure the safe and effective application of this technology at the operational level. The report also provides descriptions of four different 3D printers that can be utilized based on the demand requirements and offers a discussion on patents. The entire AM concept is relatively new; it is highly likely every time it evolves to the next level the issue of intellectual property protection and trade strategies will need to be reevaluated. The report (Véronneau et al., 2017) claims that “the level of capability, stability, and maturity of these technologies is ready for the development of cost-efficient military and civilian applications” (p. 15). The authors also discuss the advantages of using AM, the issue of intellectual property ownership, the competition field and status of other countries using AM, and the revision of the existing acquisition policy. They recommend a “certification and testing approach” (p. 18) be evaluated for AM. According to

Véronneau et al. (2017), further research will be necessary to integrate AM into current naval processes successfully. As they point out, “within the next few years, it is reasonable to expect to see weapons systems that include parts designed for AM, which will require AM capability to replace” (p. 18).

B. AM BENEFITS FOR THE DON

AM brings significant benefits in cost and time reduction across many industries. For the DoN that translates to readiness and sustainment. Coyle (2017) suggests that AM is worthwhile when the Navy manufactures “a high cost item with long lead time” (p. 49). Even though the cost of the raw materials is as high as half of the total cost because of the emerging technology, Coyle (2017) suggests that AM will contribute to the reduction of procurement cost by 55%, and a significant amount of procurement lead time.

Very similar findings were reported by Kenney (2013) who discusses the significance of AM and the collaborative product life cycle management (CPLM) as the introduction of AM and CPLM contributes to considerable reductions in cost. He states that these reductions could be as much as \$1.49M per year, including the reductions in lead time.

The GAO (2015) findings focused on the AM domain include information about the largest challenges to using AM in the production of functional parts. The study participants included government officials, business, academia, and nongovernmental agencies. According to the GAO report (2015), these challenges included: “(1) ensuring product quality, (2) limited design tools and workforce skills, and (3) supporting increased production of functional parts” (p. 3). Highly relevant to our central thesis research topic, the GAO (2015) report suggests the largest contributor to the constrained ability of AM to reach its full innovative potential is the combination of an inadequately skilled workforce and inadequate access to analytical design tools. To realize the full advantage of AM over traditional manufacturing, the report identifies the value of developing a skilled workforce that can be innovative in the design and manufacturing of single piece products. Furthermore, the GAO (2015) explains that AM curricula should

be implemented into education and workforce training. The implementation of education would help prepare a future workforce capable of understanding and using AM at all levels, from managers and decision makers to the users of AM, and across multiple disciplines and industries. This implementation would include various levels of education and training, from a fundamental understanding of AM at early stages of education up to university level education and AM training as part of a two-year technical degree.

Several researchers support the capability or possibility of AM creating cost reductions and reducing lead times in acquiring or repairing parts. Yet, our observation is that very few researchers described how to implement AM into the U.S. Navy. In other words, there is still uncertainty about who should be AM users and how to train or educate the workforce to achieve favorable results. Even though we understand that AM has great potential to improve the readiness and sustainability of operations of the DoN, it is unclear how to best support mass adoption of the technology.

C. SUMMARY OF CHAPTER

This chapter highlighted the advantages of AM usage compared to conventional manufacturing with CNC machines from the perspective of the complexity of the design and the manufacturing process differences. It also presented previous research that supports using AM rather than conventional manufacturing methods to realize a significant reduction in production lead time. The identification of limited availability of design tools and limited skilled workforce were presented as a significant challenge that leads to limited uses of AM technology and restricts AM from reaching its full innovative potential.

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III. BACKGROUND OF DON AM INITIATIVES

This chapter introduces basic elements of AM, its application across industry, and the *DoD AM Roadmap* (DoD, 2016), the *DoN AM Implementation Plan V2.0* (DoN, 2017), and *A Design for Maintaining Maritime Superiority V2.0* (Richardson, 2018).

A. BASIC DESCRIPTION OF AM

AM is a unique concept and technology that is already employed across various industries such as aerospace, shipbuilding, medical prosthetics, and used to produce many products we use daily. A simple description of AM is that it is akin to printing an image or a document as an ink printer does on paper, but instead of one layer of material, it adds layer upon layer to build 3D objects from raw material such as polymers, metal alloys, or even composites. (An example of 3D printers that use polymers are shown in Figure 7.) According to Gibson et al. (2015), AM is a method of manufacturing that encompasses a specified range of manufacturing technologies, such as 3D printing, that translate virtual data from CAD software and then produce a physical model by a relatively rapid but very specific process of printing in 3D space.

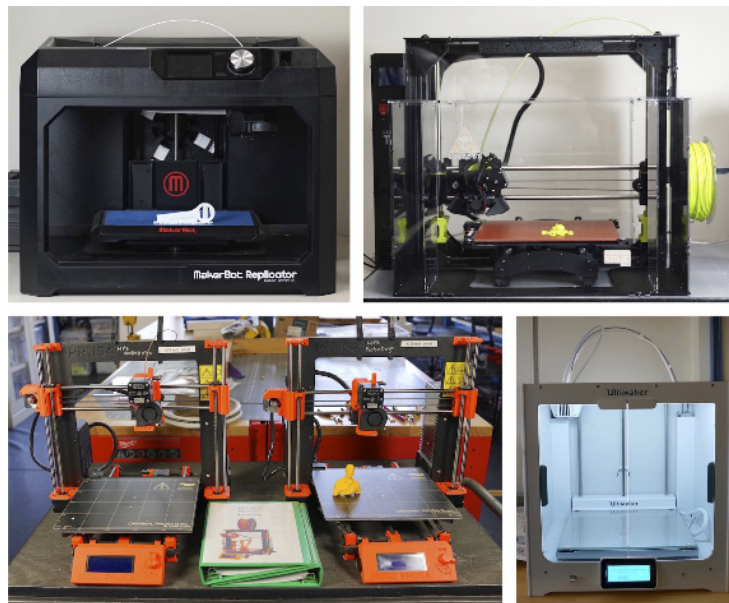


Figure 7. Various Types of Polymer 3D Printers at NPS

Past references to AM were associated with rapid prototyping. Even today AM is frequently applied across various industries for rapid prototyping, a technique that is used to create a model or proof of concept prior to going into full production or creating a final end-item. Gibson et al. (2015) suggest that rapid prototyping is beneficial when “the emphasis is on creating something quickly and that the output is a prototype or base model from which further models and eventually the final product will be derived” (p. 1). From our experience and research, rapid prototyping has been the primary use of AM and polymer 3D printing done by uniformed service members in the DoN. To understand AM, its complexity as well as its benefits, one must understand the basic process of AM. At the most basic level, AM consists of an eight-step process as shown in Appendix A according to Gibson et al. (2015, pp. 44–49).

Gibson et al. (2015) describe that AM creates items “by adding material in layers; each layer is a thin cross-section of the part derived from the original CAD data” (p. 2). Their study refers to an example of object creation by using the 3D printing process where “each layer must have a finite thickness to it, and so the resulting part will be an approximation of the original data; the thinner each layer is, the closer the final part will be to the original” (p. 2). Gibson et al. (2015) describe “all commercialized AM machines to date use a layer-based approach, and the major ways that they differ are in the materials that can be used, how the layers are created, and how the layers are bonded to each other” (p. 2). Those same characteristics are very important for the use of end items in the DoN or across any industry employing the technology. The research of Gibson et al. (2015) also emphasizes that these differences will influence the correct form and fit of the final part and the material and mechanical strength of the component that is manufactured. They predict that these differences will also affect how and when 3D printing is used to meet the logistic challenges across the DoN as these factors determine the time required to produce and manufacture the part, any post-processing that may be needed, the size and type of the 3D printer, such as its resolution capability, and the total cost incurred in the process.

AM differs from traditional manufacturing, such as the use of a CNC machine, currently used by skilled Machinist’s Mates (MM) or Machinery Repairmen (MR) ashore

and afloat. If an MM or MR were to produce a prototype from CAD drawings, it would require multiple stages to complete the manufacturing process. The MR must employ a variety of methods such as lathes and CNC milling machines to manufacture parts and components that require very close tolerances. This often includes the use of other tools such as punches, arbors, scribes, edge finders, drill chucks, grinding wheels, and files. When performing traditional manufacturing one often needs to create a mold or model first in order to create a final product. According to Gibson et al. (2015), “molding technology can be messy and frequently will require the building of one or more molds and CNC machining requires planning due to the sequential approach required that may also require the construction of fixtures prior to the part itself being manufactured” (p. 10). This latter process commonly takes place across the fleet. Due to the complexity of the process and the machinery used, only those who are formally trained and possess the applicable NEC have the necessary competence and qualifications to perform the AM process.

According to Gibson et al. (2015):

AM can be used to remove or at least simplify many of these multistage processes. With the addition of some supporting technologies like silicone-rubber molding, drills, polishers, grinders, etc. It can be possible to manufacture a vast range of different parts with different characteristics. Workshops which adopt AM technology can be much cleaner and more streamline. (p. 10)

To ensure the context of comparing AM to traditional manufacturing or subtractive manufacturing (SM) one needs to understand that a CNC machine, like AM, uses a computer and input parameters so that the computer operates the milling machine somewhat independently to manufacture the component.

Gibson et al. (2015) describe that when manufacturing components that have stringent tolerances and consist of metals it is more desirable to use CNC machining to produce the component. They identify “one of the complexities in using AM is that they may have voids or anisotropy that are a function of part orientation, process parameters or how the design was input to the machine, whereas CNC parts will normally be more homogeneous and predictable in quality” (p. 10). As AM technology matures, however, it

will require a trained workforce that will then enable the desired repeatability and quality of producing components beyond the polymers, as shown in Figure 8; examples of such materials include metal alloys, composites, ceramic, and even glass.



Figure 8. Filament in Different Colors for 3D Polymer Printing

B. AM IN INDUSTRY

Although we cannot divide every manufacturing process into two parts, such as AM and the rest, AM has several advantages over what is considered a form of traditional manufacturing. Traditional manufacturing often includes drilling, milling, or refining, which is specific to subtractive manufacturing (SM). Bouchaib and El Hami (2016) identify some of the distinct advantages of AM, specifically the advantages of 3D printing, in comparison to SM:

- (1) a lower consumption of raw materials;
- (2) the reduction of energy needs;
- (3) the limited use of hazardous chemicals;
- (4) the reduction of transport requirements (relocation, production close to the consumer);
- (5) the possible maintenance of the objects to avoid the accumulation of waste. (p. 106).

These advantages reflect cost savings and risk reduction inherent in AM technology.

The assembly of the final products or modular products does not conform to the working definition of AM that we adopted for this research. Fabrication in AM means to produce final products or modular products additively from raw materials. For example, assembling car components, such as the body, an engine, tires, and interior cloth is not AM. In contrast, manufacturing the turbine blades of the engine with 3D printers is considered a type of AM.

Cunningham et al. (2015) also identify the benefits of AM as a reduction in lead time and greater flexibility of design than those of SM. Similarly, Coykendall, Cotteleer, Holdowsky, and Mahto (2014) identify a benefit in the reduction of lead time by using AM. They state that “when A&D companies switch from traditional manufacturing to AM, they could benefit from time savings in prototyping ranging from 43 percent to 75 percent” (p. 8). Véronneau et al. (2017) support the benefit of AM design in comparison to SM suggesting that:

AM is uniquely suited to employ generative design—an optimization process in which computers are used to explore a large number of variations in forms that meet user-defined criteria in different ways. Because SM constraints do not bind generative designs in AM, results often take ‘biologically-inspired’ forms. (pp. 6–7)

Given our experience in the military domain, this is significant to the nature and the environment in which the military domain operates and meets its readiness challenges and goals.

Enabling an enlisted workforce and making sure it is capable of realizing this benefit can only be accomplished by trained personnel knowledgeable of how to utilize AM technology. An example of a complex-designed product manufactured by the AM process is shown in Figure 9. The ability of the designer to use the AM process enables that individual to leverage superior solutions resulting in the design and production of parts that could not be technically nor economically done by grinding and cutting. Another example is the case of small components that essentially improve user-friendliness or durability of a larger system. The example illustrated in Figure 10 is a fuse box cover designed by the DoN and produced at the Mobile Innovation Center (MIC) in San Diego, CA. The cover shown in Figure 10 prevents significant damage to the component that, if there was no cover, would likely result in early replacement and repair of the component.

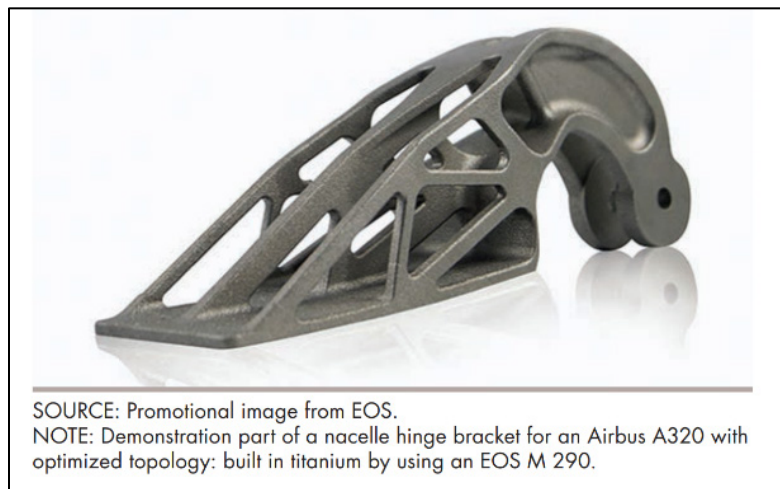


Figure 9. Complex-Designed Product. Source: Véronneau et al. (2017).



Figure 10. UHF Radio Fuse Cover Created by AT2 List & AT2 Trout

AM was developed in the 1980s, when the objective of the technology was still limited. Linke (2017) describes AM in the early 1980s as initially used solely to develop prototypes and the products created were barely functional. AM was referred to as rapid prototyping as it was used for scale models to rapidly prove a concept not requiring the standard costs or processes. Bouchaib & El Hami (2016) support this idea noting that “these prototypes were non-functional and were only intended to illustrate or validate a concept” (p. 110).

The improvement of technology is shifting the role of AM in the industry, however, and it is now used to fabricate more end-products and not only those used to validate a concept or for prototyping. According to Waller et al. (2014), AM “has taken a substantial shift to the possibility of manufacturing high-quality complex metallic parts for infusion into primary structural hardware” (p. 1). For example, Lufthansa, a German airline company, established an AM center in its maintenance department in October 2018. According to Boissonneault (2018), the purpose of the center is focused “on ensuring that its adoption and use of 3D printing complies with the strict regulations of the commercial aircraft industry.” GE Additive (2016) released that “GE’s Auburn plant is running 28 additive printing machines around the clock, producing fuel nozzle injectors (also called ‘nozzle tips’) for the best-selling LEAP jet engine.” The nozzle tip that GE manufactures is shown in Figure 11, and Boeing’s 737 MAX and the Airbus

A320 NEO, the airplanes with LEAP jet engines, are shown in Figures 12 and 13, respectively. The ability of AM to make critical components that can be used on aircraft illustrates the potential for military application of the technology. The information collected for this research suggests that today's industry is far more developed and mature in using AM technology than the military.

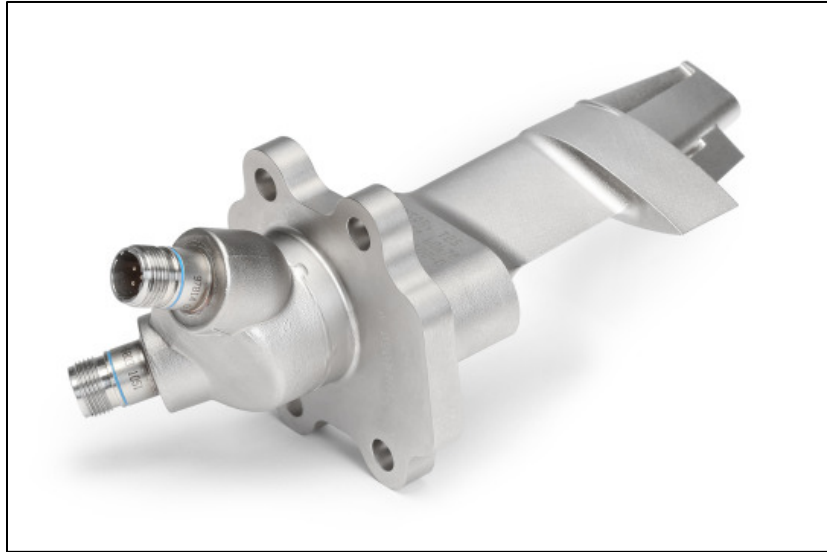


Figure 11. Nozzle Injector Manufactured with AM. Source: Kellner (2015).



Figure 12. Boeing 737 MAX. Source: Boeing (n.d.).



Figure 13. Airbus A-320 NEO. Source: Airbus (n.d.).

In the automotive industry, the body of a car, the Urbee, is fabricated by AM, as shown in Figure 14. According to Bargmann (2013), the cost of building and running the production facility of Urbee is less expensive than conventional car factories thanks to the 3D printer, which can make 50 different components. However, mass production by automated factories located around the world is still more advantageous in production cost and time. As AM technology becomes more advanced that situation could change in the future.



Figure 14. Urbee. Source: Kor Electric (2013).

AM also helps healthcare dramatically. As we know, the human body is different from one person to another. For example, the size of bones or organs can vary by gender, age, and lifestyle. The LEF (2012) reports, “3D printing is ideal for these highly customized, small production requirements” (p. 13). Manufacturing body parts that perfectly match patients’ bodies reduces the discomfort that patients may feel, and it reduces the probability of secondary damage or infections. Manufacturing artificial organs by AM techniques helps physicians to plan their surgeries and minimize the risk of operations. According to GE Additive (2018), researchers have used bioprinting, which uses living cell structures to promote regeneration of blood vessels and heart valves, as shown in Figure 15.



Figure 15. 3D Printed Blood Vessel. Source: Hebden (2018).

C. DOD AND DON AM CODIFYING DOCUMENTS

The *DoD AM Roadmap* (DoD, 2016), the *DoN AM Implementation Plan V2.0* (DoN, 2017), and *A Design for Maintaining Maritime Superiority V2.0* (Richardson, 2018) are the documents that focus on the goals and objectives for implementing AM into the DoD and the DoN.

The *DoD AM Roadmap* (DoD, 2016) identifies multiple goals and objectives necessary to implement AM technology into the DoD. According to the *DoD AM*

Roadmap (DoD, 2016) there are four non-technical key enablers, which include: 1. cultural change, 2. workforce development, 3. data management, and 4. policy change. The first of the four key enablers in this report include a cultural change to enable a general knowledge and acceptance of AM, with a broad acceptance of its application across the DoD. Workforce development is identified as the second of the four key enablers—its unique role is in ensuring that the workforce operating in multiple areas such as acquisition and manufacturing are competent with the AM process. The third key enabler is that of data management, which includes “data policy, specs/standards, accessible and secure data repositories, and active database upkeep” (DoD, 2016, p. 19). The last, fourth key enabler, is policy change. This includes a change in policy or procedures to realize the benefits of AM technology. The largest goal of the *DoD AM Roadmap* (DoD, 2016) is to use and apply the technology most effectively to meet the DoD goals of readiness and lethality. In addition, the DoD (DoD, 2016) identifies AM as specific to the “Third Offset” (p. 4) strategy and an additional enabler of convergent technologies such as Unmanned Aerial Vehicles (UAV) / Unmanned Aerial Systems (UAS), rapid prototyping, etc. while also being significant to the sustainment of current and future platforms and weapon systems. Cultural change is identified by the *DoD AM Roadmap* (DoD, 2016) as the adaptation of an organization to facilitate increased understanding and comfort with AM. In the authors’ opinions, part of enabling this objective is to ensure skills and knowledge in AM are commensurate with their roles. Developing the workforce includes increasing their mastery of AM. Specifically, to identify and support intended users who possess the skills and expertise to effectively apply AM at the appropriate levels at the appropriate time.

The *DoN AM Implementation Plan V2.0* (2017) outlines goals and corresponding objectives to enable increased readiness, sustainment, and enhancement of warfighting capabilities through the adoption of AM. The *DoN AM Implementation Plan V2.0* (2017) strategy seeks to accelerate the adoption of AM technology and its application at all levels of the DoN. The five objectives in the *DoN AM Implementation Plan V2.0* (2017) identify key enablers to the implementation strategy. See Appendix B for the *DoN AM Implementation Plan V2.0* (2017) objectives relevant to this study.

1. DoN AM Implementation Plan V2.0 Objective One

The first objective of the *DoN AM Implementation Plan V2.0* (2017) is to “develop the capability to rapidly qualify and certify AM components” (p. 9) to meet the readiness challenges and requirements of naval systems. The end-state of meeting this objective is described as a developed framework that will enable accelerated qualification and certification of components at a lower cost than can currently be achieved. The end-state also includes assurances that components produced via AM will achieve their expected performance. In addition, this first objective includes development of feedstock materials such as polymers, elastomers, ceramics, and metals, and the development of new materials to be used in AM. This objective includes finding solutions to other challenges of AM implementation such as establishing standards for operators/users, machines and calibration, and procedures and process qualifications.

2. DoN AM Implementation Plan V2.0 Objective Two

The second objective of the *DoN AM Implementation Plan V2.0* (2017) is to enable the “end to end process integration of secure on-demand manufacturing with integrated digital AM data, infrastructure and tools” (p. 10). This objective encompasses the entire digital framework required to manage the significant amount of digital data that is required for implementation. According to the DoN (2017), finding solutions to satisfy this objective will provide a “standardized and secure AM data and infrastructure that will enable accelerated DoN lifecycle processes” (p. 10).

3. DoN AM Implementation Plan V2.0 Objective Three

The third objective of the *DoN AM Implementation Plan V2.0* (DoN, 2017) identifies “formalized access to training, education, and certifications for the workforce of the DoN” (p. 10). The end-state is described as a workforce that can exploit and take advantage of the benefits of AM and other related emerging technologies in the context of increased readiness and sustainment while enhancing warfighting capabilities. In addition, the DoN (2017) describes the development of a training program for the current DoN workforce as a sub-objective enabler. As of the date of this report, this goal has not been formally accomplished for uniformed service members in the DoN.

4. DoN AM Implementation Plan V2.0 Objective Four

The fourth objective of the *DoN AM Implementation Plan V2.0* (DoN, 2017) is to develop “AM related business practices that address contracting, intellectual property, and legal and liability guidance” (p. 11). This objective is designed to find solutions to enabling a clear understanding of business models that support the growth and evolution of AM across the DoN to ensure adoption of the technology is achieved. The end state of this objective is described as the achievement of agile business models that enable a responsiveness of incorporation of AM into the DoN.

5. DoN AM Implementation Plan V2.0 Objective Five

The fifth objective of the *DoN AM Implementation Plan V2.0* (DoN, 2017) is identified as “enabling manufacturing agility through low volume production in maintenance and operational environments” (p. 12). This objective seeks to find solutions that shorten the logistics chain and realize the full potential of AM implemented beyond laboratories and shore facilities, and engage expeditionary, surface, subsurface, and forward deployed units. Additionally, this objective includes the environmental factors that must be addressed to ensure quality and repeatability of AM. The end goal is to have the ability to use AM at any location to manufacture the components that are needed.

Based on our research as of 2019, the focus of AM technology has been on the 3D printing type, and as such, it has already been implemented at various levels across the DoN. Currently, civilian artisans use the 3D printing process at depot and shipbuilding facilities. It is also being used by sailors ashore and afloat. Part of their duties include the concerns with complexity and requirements to meet quality goals; this, of course, should be highly considered when determining who, what, where, and when AM processes will be used in the DoN. As of the date of this report, no NEC is established nor process formalized to select, train, or identify uniformed service members of the DoN by means of being qualified, certified, or otherwise competent in the performance of AM processes at the user level.

Most of the current uses of AM technology in the DoN are focused on the types of technology, developed around polymer materials. Yet, there are many other materials in

use by the DoN that can now be used in AM, such as composites, metals, and ceramics. Many items in the DoN that require maintenance and repair, across all platforms, consist of these very same materials in addition to polymers. Many of the newer platforms and weapon systems across the DoN contain more composite materials than those of previous generations. This trend is important to understand for the workforce that uses and enables AM to meet the logistics and readiness challenges of the DoN. This workforce will need the skills to repeatedly produce quality components consisting of these materials.

The Chief of Naval Operations Admiral Richardson has included AM in his *Design for Maintaining Maritime Superiority V2.0* (2018). As a part of the DoN strategy for increased readiness and sustainment and enhanced warfighting capability this operational guidance is designed to link strategy with execution (Richardson, 2018). The *Design for Maintaining Maritime Superiority V2.0* (2018) provides four color coded lines of effort with the green line of effort as “Achieving High Velocity Outcomes” (Richardson, 2018, p. 10). The essential focus of this line of effort is to provide AM solutions for fabrication of obsolete or difficult to produce components and do so at the level at which the component is needed (Richardson, 2018). Additionally, Admiral Richardson (2018) provides guidance for using AM to the maximum extent to create reductions in costs and reliance across logistics chains, and to field more effective weapon systems.

D. SUMMARY OF CHAPTER

This chapter provided a description of AM and its implementation across industry. The elements of the *DoD AM Roadmap* (DoD, 2016), the *DoN AM Implementation Plan V2.0* (DoN, 2017) and *A Design for Maintaining Maritime Superiority V2.0* (Richardson, 2018) are highlighted and discussed in the context of goals and objectives to innovate and adopt AM technology across the DoD and the DoN.

IV. CURRENT AM TRAINING

This chapter describes existing training solutions for multiple roles of AM enablers and users. The specific solutions we cover are ASTM International and MIT webinars in AM, which enable students to understand the general principles and limitations of AM. In addition, San José State University and California Polytechnic State University (Cal Poly) provide more in-depth academic courses designed for engineering students. These four AM courses of different institutes are selected randomly without a systematic search. We compare the level and duration of AM training provided by these institutes to evaluate the applicable education and training required of a user to perform AM at the operational level.

A. EDUCATION AND TRAINING

Identified course delivery methods, students for whom the courses are designed, duration, and certificates earned upon completion of the courses are shown in Table 1. Identified course topics and learning outcomes of each course are shown in Tables 2 and 3, respectively. Detailed course designs at the four institutes are shown in Table 4, 5, 6, and 7, respectively.

Table 1. AM Courses at Various Educational Institutes

Institute	Delivery	Expected Students	Duration of Course	Certificate
ASTM International	Webinar	All	15 hours	
MIT	Online Course	Engineers and Executives	12 weeks 5–7 hours/week	AM Professional. 4.5 CEUs from MIT.
San José State University	Resident Course	Mechanical Engineering Graduate Students	1 semester (3 credit hours) 2 lectures/week	
Cal Poly	Resident Course	Engineering Students	1 quarter (4-unit hours) 3 lectures and 1 lab/week	

Adapted from ASTM International (n.d.); MIT (2018); San José State University (2019); California Polytechnic State University (n.d.).

Table 2. Topics of AM Courses across Institutes

Institute	Principles	Design	Process	Application	Polymer	Metal	NDI	Business Case Study
ASTM International	•	•	•	•	•	•	•	
MIT	•	•	•	•				•
San José State University	•	•	•	•				
Cal Poly	•	•	•	•	•			

Adapted from ASTM International (n.d.); MIT (2018); San José State University (2019); California Polytechnic State University (n.d.).

Table 3. Learning Outcomes across Institutes

Institute	Learning Outcomes
ASTM International ^a	Improving the design, test, and manufacturing of new products by utilizing the standards developed, thereby creating a reduction of lead time and cost of the components manufactured within industry.
MIT ^b	Understanding the terminologies, principles, and processes and performance, and limitations of AM. Identification of AM's value across the product lifecycle and how to decide the best AM process and the raw materials for a specific application. Obtaining the skills for parts design combining engineering intuition with computationally driven design and constraints of the process. Quantitative assessment of the value of a part manufactured via AM based on its production cost and performance. Evaluation of the business case in support or non-support of using AM.
San José State University ^c	Understanding various processes, workflow, and manufacturing principles of AM. Application of AM for a specific component. Designing principle of AM. Prototyping and product realization via AM.
Cal Poly ^d	STL file generation from diverse sources. Description of the basic process workflow of AM. Explanation of various AM systems, materials, principles, features, input, and output. Selection of the suitable AM method for a given design. Understanding of the construction, components and feature of different types of AM systems. Analysis or assessment of the design and modification of the design for better manufacturability. Topological optimization to achieve light weight and high performance.

Adapted from ASTM International (n.d.); MIT (2018); San José State University (2019); California Polytechnic State University (n.d.).

Table 4. AM Course Design of ASTM International Webinar.
Adapted from ASTM International (n.d.).

Topics (example)	Duration
Principles (AM processes, ASTM standards)	2 ^a sessions
Design	1 session
Metal AM processing (Power bed fusion, directed energy deposition)	2 sessions
Polymer AM processing	1 session
Nondestructive testing of AM metal parts	2 sessions
Characterization and analysis of powder (Size and shape characterization)	1 session

^aOne session consists of 1.5 hours of lecture.

Table 5. AM Course Design of MIT Online Course.
Adapted from Hart (2019).

Topics (example)	Duration
Status and implication of AM (Vocabulary, AM workflow and digital thread, and industry leaders and academic experts' view).	1 week
AM processes (Different AM processes and comparison of their performance, fundamentals, materials, and design guidelines for each process).	1 week
Application (AM across the product life cycle, application examples, and selecting and classifying method of potential applications of AM).	2 weeks
Design (Scanning process, design methods, and process and material selection).	3 weeks
Cost and value analysis (quantitative AM value capture versus conventional manufacturing, AM cost modeling, and implications of AM on supply chain operations).	2 weeks
Case studies (Solving real-world problems with the knowledge of AM obtained).	2 weeks
Future of production (AM challenges and opportunities)	1 week

Table 6. AM Course Design at San José State University. Adapted from San José State University (2019).

Topics (example)	Duration	Other
AM fundamentals (Introduction, technological development)	2 weeks	1 week of lab training. Final two weeks are for final project.
AM processes and systems	2 weeks	
Vat Polymerization	1 weeks	
Power Bed Fusion	1 weeks	
Binder Jetting	1 week	
Directed Energy Deposition	1 week	
AM process selection	1 week	
AM Design	2 weeks	
Post Process	1 week	

Table 7. AM Course Design at Cal Poly

Topics (example)	Duration	Other
AM fundamentals (STL generation and repair, generic AM process, and 3D scanning).	2 weeks	3 hours of lab every week.
Design (Lattice structure and shape optimization).	2 weeks	
Powder Bed Fusion (Principles, defects and prevention, powder characteristics, design rules, and post processing and qualification).	3 weeks	
Binder Jetting, Direct Energy Deposition, and stereolithography.	2 weeks	
Final week is for project presentation and exam.	1 week	

Adapted from X. Wang, personal communication (February 21, 2019).

ASTM International (n.d.) offers a webinar on AM. The subjects of the courses offered cover various levels of AM topics. These fundamental topics range from the principles and the process of AM to more advanced fundamental topics, such as the application of different AM processes to produce a component, and familiarization with the testing methods of AM manufactured products. The course consists of approximately 15 hours of sessions and costs approximately \$450. According to ASTM International (n.d.), the course is designed to provide knowledge rather than practical training. One significant difference between a course at universities and a web-based course is whether the students use 3D printers, which we believe essential experience for training of AM users at the operational level.

MIT also has a 12-week webinar, which provides instruction from between five to seven hours a week and costs \$1,950. This course enables students to learn general principles and limitations, terminologies, core competency in engineering and business, and CAD. Furthermore, the course takers can earn an AM Professional Certificate and 4.5 Continuing Education Units (CEU) from MIT (Massachusetts Institute of Technology [MIT], 2018). As depicted in Table 2, this general familiarization is for those who will oversee the workforce employing this technology and will aid in accelerating adoption of AM but is not best suited as training for the users themselves.

San José State University has a one-semester AM course consisting of 2.5 class hours per week for mechanical engineering students. According to San José State University (2019), the course covers the following topics: introduction and basic principles of AM, AM processes, selection of AM method for a specific component, design for AM, and post process.

Cal Poly has a ten-week AM course designed for that institution's engineering students. According to Professor Xuan Wang (X. Wang, personal communication, February 21, 2019) of Cal Poly, the course covers "engineering principles, materials, equipment, design for manufacturing, process flow, post processing, and applications of AM processes, including photopolymerization, powder bed fusion, extrusion, direct energy deposition, printing, binder jetting, and sheet lamination. Process selection, environment considerations, safety, and cost analysis for manufacturing."

B. TRENDS OF EDUCATION AND TRAINING

The educational trends in the current training domain are to impart the knowledge of the principles of AM, the skills for designing the products, an understanding of various processes of AM, and the capability to determine the best process to manufacture specific components.

1. Topics and Learning Outcomes

According to Gao, Zhang, Ramanujan, Ramani, Chen, Williams, Wang, Shin, Zhang, and Zavattieri (2015), the future AM workforce will need to have knowledge in five fields:

- (1) AM processes and process/material relationships, (2) engineering fundamentals with an emphasis on materials science and manufacturing, (3) professional skills for problem solving and critical thinking, (4) design practices and tools that leverage the design freedom enabled by AM, and (5) cross-functional teaming and ideation techniques to nature creativity. (p. 82)

Considering our research is on AM implementation at the operational level rather than that of the executive level, the understanding of teaming in this context refers to the executive level and is out of our scope of research. On the other hand, cross-functional understanding of innovative material solutions that can be created by an AM user is applicable.

The education and training offered by the four institutes, including ASTM International, MIT, San José State University, and Cal Poly, described in the previous section, and the study of Gao et al. (2015) suggest the trends in education and training in the current AM domain. Learning principles, design, application, and different processes of AM are common among the institutes regardless of the delivery of the course material or the category of students expected to take the course, as shown in Table 1. These four areas of knowledge meet the requirements of an AM user, as described in the study by Gao et al. (2015). In addition, at three of the four institutes the learning outcomes cover the selection of AM processes applied to produce specific components, which support the validity of the study by Gao et al. (2015).

2. Duration of Education and Training

The webinar of ASTM International, as shown in Table 1, offers the shortest training course. The webinar is specifically designed to provide the participant a basic understanding of each topic and does not grant any professional certificates. The other three courses offer more in-depth knowledge of AM. Therefore, we evaluated the contents of the three courses offered at MIT, San José State University, and Cal Poly to analyze the duration of education and training that will provide AM users the knowledge and skills required to perform AM processes at the operational level.

Our research indicates that the duration of AM education and training required for an entry level AM user is about 50-55 hours for lectures and practical lab application. An equivalent amount of time for self-study should also be included.

a. Online Course

MIT offers a 12-week online course that contains from five to seven hours of online lectures per week, as shown in Table 1. During the roughly 70 hours of the course, as shown in Table 5, at least two weeks of lectures are related to executive level business decisions. We believe this portion of lectures is not required for AM users at the operational level. Therefore, MIT spends about 55 hours to provide AM users with the skills necessary to perform AM processes that would be used at the operational level. In addition to the lecture, course takers are expected to perform self-study to ensure comprehension of lecture material. Course takers will spend the first two weeks learning the general principles of AM and another five weeks on design and application, which is approximately 40 hours of lectures, as shown in Table 5.

b. Universities

Universities offer engineering students one-quarter or one-semester courses consisting of three lectures and one lab-hour per week. For example, San José State University offers a three-credit-hour AM course. According to San José State University (2019), the students in the course receive at least 45 hours of in-class instruction and require an equal amount of self-study during a semester. Students at Cal Poly also receive

48 hours of in-class instruction and also require an equal amount of self-study, but during a quarter. The students at Cal Poly spend four weeks on the principles, design, and application of AM, which consists of approximately 12 lectures and 12 lab hours.

C. SUMMARY OF CHAPTER

This chapter described existing solutions for multiple roles of AM enablers and users. ASTM International and MIT provide online courses that enable students to understand the general principles and limitations of AM. In addition, San José State University and Cal Poly provide more in-depth academic courses designed for engineering students and are suitable for AM users in the DoN.

Evaluation of each education and training course enabled us to analyze that AM users at the operational level require approximately 55 hours of instruction to obtain the fundamental skills required to perform AM processes. This includes 30 to 40 hours of instruction on the principles, design, and application of AM.

V. MACHINERY REPAIRMAN NEC

We evaluated the core competencies required to perform AM in comparison to the current critical skills of an MR in the DoN. This analysis was conducted to determine the applicability of creating an NEC for the MR rating.

A. SUITABLE AM USERS IN THE DON

The DoN core competencies for any enlisted rate are classified by an occupational standard and in some cases also by an NEC. The purpose of the NEC is to classify personnel on active or inactive duty by the training and education one has received to perform specialized skills. According to the Navy Enlisted Manpower and Personnel Classifications and Occupational Standards (Navy Personnel Command, 2019), “NEC codes identify a non-rating wide skill, knowledge, aptitude, or qualification that must be documented to identify both people and billets for management purposes. Additionally, an NEC code can be used to identify special circumstances or situations with approval via the NEOCS process” (p. 7). The Navy Enlisted Occupational Classification System (NEOCS) process is discussed later.

An assigned NEC helps to facilitate the billeting process by identifying personnel that possess the special skills required to be fully qualified to perform the functions relevant to that assignment. It assists in the detailing process to ensure the right people are placed in the right job. For example, according to Navy Personnel Command (2019), a 3001 NEC is classified as an Independent Duty Postal Clerk. Personnel with a coded 3001 NEC are expected to perform all postal duties in accordance with DoN procedures with minimum oversight. Whenever new technology or requirements arise that the DoN considers relevant to implement into standard practice, the assignment of an NEC to a particular rate is the tool to ensure personnel are qualified to execute those duties.

According to Navy Personnel Command (2019), NEC codes may be assigned through multiple avenues: commands conducting formal training and submit required completion reports, recommendation from Enlisted Classification Units, and recommendation that NEC be received through OJT, web-based, or residence training.

For the DoN to take advantage of the benefits provided by AM, an NEC code could be established to assign a specific rate and a rank competent to use this technology. Based on the inherent core competencies and the functions of rating groups, the MR for surface and Aviation Structural Mechanic for aviation are good options to implement AM NECs.

1. Machinery Repairman

The role of an MR on surface ships is to serve as a skilled mechanic supporting the surface fleet. They are responsible for the manufacturing of replacement parts that are not a simple pull from the supply stockroom. An MR uses raw materials and tools such as hacksaws, CNC machines, boring mills, and other machine tools to fabricate the new part as necessary. If there is a leaking pipe that requires a 10-inch pipe to be cut from raw material to fix the leak, the MR is expected to have the skills and tools necessary to do so.

According to Navy Personnel Command (2019), common abilities associated with the occupational standards of an MR and applicable NECs include finger dexterity, manual dexterity, control precision, mathematical reasoning, and flexibility of closure (the ability to identify a known pattern that is hidden in other material).

An MR is basically a “jack of all trades” on the ship who can fabricate from raw materials a part necessary to fill a requirement. If AM were to be implemented in the surface Navy, then a 3D printer could be assigned to an MR work center.

According to Navy Personnel Command (2016, January), an MR at the paygrade of an E-4, is included in the apprentice pay band. This person possesses core competencies to perform tasks such as balancing grinding wheels, and fabricating machine couplings from castings, machine valve disks, deck bolts, deck plugs, and sockets. E-5 core competencies fall under the journeyman pay band and include the tasks such as machining impellers from castings, manufacturing equipment wearing rings, and repairing end bell housings. Which pay band an AM NEC should be applied to is beyond the scope of this research, though either pay band could be appropriate. Nonetheless, the establishment of an NEC to implement AM into the surface naval forces, in our opinion, will likely fall under the journeyman pay band of the MR rating. Descriptions of the

existing occupational standards and related NECs for the MR apprentice and MR journeyman are provided in Appendix D and E, respectively.

As an example of the sort of NEC we recommend should be established for the MR rating, here is a current and applicable NEC with a source rating of MR, U31A, an Advanced Machinery Repairman. According to Navy Personnel Command (2019), Advanced Machinery Repairman:

Performs calculations using basic algebra and trigonometry to manufacture spur, helical, bevel gears, and worm/worm wheels. Manufacture and repair precision parts from blueprints utilizing tool and cutter grinders, surface grinders, cylinder grinders, universal milling machines, optical comparators, surface finish analyzer, disintegrators, vertical turret lathes, and horizontal boring mills. Understanding the nature and physical properties of metal and alloys with demonstration and practice in metal testing, identification and heat treating. (p. 127)

For an MR to obtain this NEC, the required school must be attended. This would provide the MR with the required skill set to perform the functions listed in the description of the NEC. A similar NEC for AM could similarly ensure the required schooling and skill sets are acquired by MR ratings before they are assigned significant responsibility for AM.

2. Aviation Structural Mechanics

The scope of this research focuses on the MR rating. The following is a brief explanation of potential aviation ratings suitable for using AM. Like an MR, Aviation Structural Mechanics are considered the skilled mechanics able to fabricate raw materials into finished products that support naval aviation. According to Navy Personnel Command (2016, October), one of the many core competencies expected of an Aviation Structural Mechanic is to “fabricate and assemble metal components and make minor repairs to aircraft skin, weld, fabricate repairs for composite components, and perform Non-Destructive Inspections (NDI)” (p. 3).

The 827A Rubber and Plastics Worker NEC described below is available to all ratings to include the Aviation Structural Mechanic. This NEC is closely aligned to meet

the requirements for AM implementation. According to Navy Personnel Command (2019), Rubber and Plastic Worker:

Fabricates and repairs rubber and plastic parts of equipment. Formulates, compounds, and processes rubber and plastic to obtain required characteristics. Operates various types of mixing, heating, molding, pressing, shaping, and related machinery to repair, replace, or modify rubber or plastic items. Performs routine maintenance on ship machinery. (p. 257)

The key word in the description of NEC 827A is fabricate. Like an MR rating in the surface navy, perhaps the AM aviation rating would need to adopt the competency to take raw materials and turn them into finished products that meet safety standards through AM. The degree of training required, and which rank an AM NEC should be applied to, is beyond the scope of this research.

B. NEOCS PROCESS

Establishment of a new NEC must go through the Navy Enlisted Occupational Classification System (NEOCS) process, depicted in Appendix C. All proposals must come from an Echelon 3 or higher command, except for proposals concerning student individual accounts (IA). IA proposals have different criteria. The Navy Manpower Analysis Center (NAVMAC) is the administrator for NEC change proposals. The proposal goes to an NEOCS board first. If all members concur, it is forwarded to the NAVMAC executive secretary for approval, after which the change is made to the NEC manual. If all members do not concur on the proposed change, the originator needs to work with the board to gain consensus.

According to Navy Personnel Command (2019), an NEC change proposal (see template provided in Appendix F) must meet the following criteria:

- (1) The NEC code must not duplicate Occupational Standards.
- (2) Skill identification needs must be long term.
- (3) The proposed NEC code must not reflect routine fleet training.
- (4) There must be a need to document the skill in the Enlisted Master Record (EMR).
- (5) The skill identification must be necessary throughout the DoN.
- (6) The proposed NEC code must reflect workload required to support new equipment. (p. 278).

Based on the research we present, we believe that the criteria listed for AM is not a duplicate of occupational standards. Its implementation will be long term, current fleet training does not include AM, the skill is necessary throughout the DoN (AM will affect all elements of Naval domain), and AM will require new equipment and analysis of the workload to operate. Once a clear way forward is established on the scale and levels the DoN will utilize AM, the next step is to utilize the NEOCS process and establish an applicable NEC. This NEC will reflect the training and skills required for the rate/rank of the AM user.

C. SKILLS TO BE OBTAINED

Our research indicates that AM users need to learn and have a good command of AM principles, design, and various processes of AM, only then will they be able to fully apply AM to a specific component and issues they need to address with AM means. During our observation of sailors performing under the instruction of civilian subject matter experts (SME) at the MIC San Diego, CA, we identified that AM operations consists of three phases. These phases include pre-manufacturing, manufacturing, and post-manufacturing.

The pre-manufacturing phase includes the identification of demand for a component and whether the component is a good candidate to be manufactured via AM. The decision to manufacture via AM is rather knowledge-centric and when applied correctly ensures the success of the other phases. Designing/scanning, compounding the raw materials, and manufacturing are classified in the manufacturing phase. Any post

processing occurs in the post-manufacturing phase shown in Figure 17. Analysis of the critical skills of the processes in each phase enabled us to understand the knowledge the AM user requires to apply AM processes. Detailed analyses of each process are as follows:

1. Demand for the Component

Every manufactured part first must be identified as a need or requirement. Thus, the need generation is achieved by the consumer, or as our research indicates, end users of components, regardless of the method of manufacturing employed. Therefore, the needs generation of the parts manufacturing is not a critical skill for the AM user at the operational level. Yet, it is essential that one can competently evaluate the preferred or best method of manufacture should a component not be readily available through the logistics chain. This includes the ability to identify solutions to non-existent components.

2. Decision for Manufacturing via AM

Once demand to manufacture a part exists, the ability to identify which components can and should be manufactured must be exercised prior to parts fabrication. The decision of whether AM or the traditional manufacturing method should be used as the means of manufacturing requires users to possess expertise in AM, traditional manufacturing, or both. As the authors have observed, understanding when the application of AM is a solution based on its capabilities and limitations is a critical skill for effective employment.

3. Design

Compared to traditional manufacturing, engineers use 3D models or CAD to design and virtually create parts demanded. This is significant to the success of the AM process and, as the researchers have observed, requires expertise. This can be learned through formal education or training. Furthermore, this can include previous experiences that required the use of CAD and manipulation of raw materials via other processes. Design is a critical skill for a user to apply AM. From our research, we observed that there are two critical skills to designing parts, that of correct 3D scanning and

manipulation of images via computer software, and effective application and manipulation of CAD by the users. 3D scanning would be most applicable to components that can be reverse engineered such as obsolete components or where sub-assemblies or structures themselves are still required to perform further maintenance or for component performance. Example candidates for 3D scanning would be knobs, replacement tools, or tube shaped components.

To fabricate the parts of the right size and function, 3D scanning is quite significant (see Figure 16). For example, the authors observed at the San Diego MIC that two types of 3D scanners, the Artec EVA 3D scanner and Artec Space Spider 3D scanner, can be used depending on a component's shape, size, or contrast. From the authors' observations, without the knowledge of these functions and understanding their limitations, the designer cannot use AM effectively to create non-existent solutions nor reengineer needed components. In addition, some 3D scanners utilize blue or white lights to scan objects. Users need to know that scanning glossy parts, such as shiny metal handles, requires reflection mitigation procedures to reduce the excessive reflection that can cause a malfunction of the 3D scanner in addition to an ineffective image for processing. An ineffective image scan is one that cannot be used for printing to meet the user's requirements.

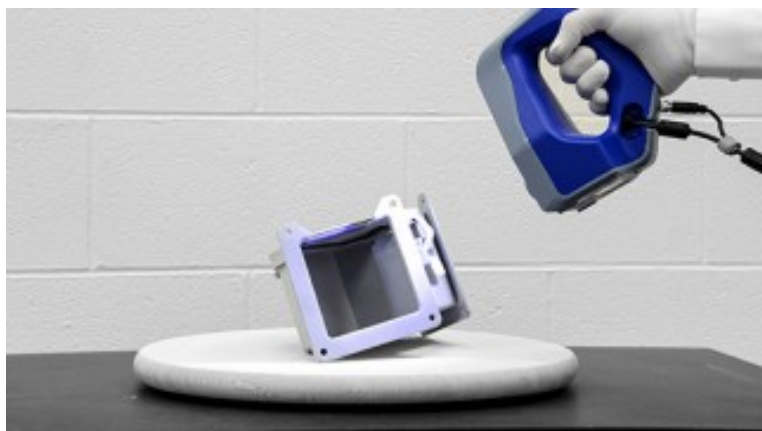


Figure 16. 3D Scanning. Source: JG and A Metrology (n.d.).

After the 3D scanning, the data of scanned parts are visualized on the computers. During this process, AM users finalize the design of the parts to be printed, by manipulation of the image using CAD. Knowledge of the capabilities and restrictions of CAD is critical for printing desired parts. For example, when users attempt to 3D scan a tube-shaped object, they still need to use CAD to manipulate the design inside the tube to meet the specifications of the item to be 3D printed.

4. Compounding Raw Materials

AM includes the capability to fabricate parts of various raw materials, such as plastic, aluminum, titanium, and other alloys. The knowledge of the materials that will be used in the manufacturing of a component is essential to the effective use of AM. The authors observed that the raw materials of the manufacturing parts are determined by the conditions or environment in which the parts are used. We should note that the environment where parts are manufactured by 3D printing is also significant to achieving the desired end-product. Humidity, temperature, inclination, and vibration, and the raw materials used to produce the component a consumer desires are factors that need to be evaluated by an AM user. This evaluation will ensure conditions are satisfactory to produce the correct and desired product prior to printing and that the product will perform in the expected operational environment.

5. Manufacturing

The use of the 3D printer itself is also critical to AM. One must possess the knowledge of the functions of the printers, the structure of the printers, and how they operate. This knowledge is required for troubleshooting or repair if there are errors during the 3D printing process. In addition, there is limited durability of 3D printers and a user must understand the effect on performance and reliability in terms of inclination and vibration when used onboard DoN vessels, industrial facilities, or deployment locations.

6. Post Process

After the parts are printed, most parts must be refined to use as the final product or end-item. For example, as we observed, when manufacturing tube-shaped components,

3D scanners cannot scan inside. As a result, post processing such as drilling holes after the components are printed may be required for the end-item to meet the form, fit, and function desired. This process, although not specific to AM, as the authors observed, needs to be understood by the user. An overview of the AM process we observed, including the post process, is depicted in Figure 17.

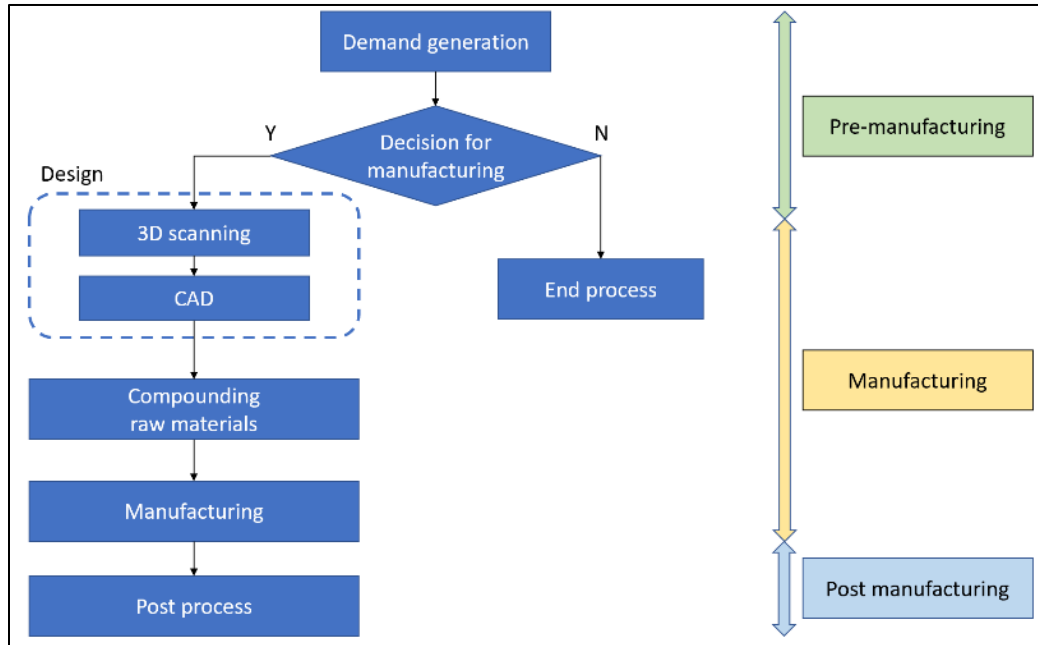


Figure 17. Observed AM Process

D. DURATION OF INSTRUCTION

According to our research of AM courses at various institutes identified in Chapter IV, we observed that the duration of AM training and education is approximately 50–55 hours with the same hours of self-study. The Navy Total Force Manpower Policies and Procedures (DoN, 2019) indicate the Naval Availability Factor (NAF) for the Continental United States (CONUS) and Outside the Continental United States (OCONUS) during peacetime is 40 hours per five-day workweek. According to the Navy Total Force Manpower Policies and Procedures (DoN, 2019) the productive availability factor is 33.38 hours per five-day workweek. This results in approximately seven hours of productive time per day, given a five-day workweek. Considering the time for self-

study and other factors identified in the Navy Total Force Manpower Policies and Procedures (DoN, 2019) such as service diversion, other training, and holidays, those under instruction would attend five hours of lecture and one or two hours of laboratory application. Therefore, the duration of total instruction and laboratory application required is approximately no less than 14 days.

Considering the course design at educational institutes and our research in Chapter IV, we recommend allocating a minimum 30 hours of instruction for AM fundamentals, application, and design. Manufacturing and post processes are designed to be accomplished during the laboratory instruction. Understanding raw materials and various AM processes is a continuous learning process and will require a workforce that remains active in the application of the knowledge beyond the initial training, as shown in Table 8.

Table 8. Proposed 3D Printing Course Design

Topics	Duration
AM fundamentals	10 hours
Application	10 hours
Design (3D scanning, CAD)	10 hours
Raw material	5 hours
Different AM processes	5 hours
Manufacturing and Post process	15 lab hours

E. TRAINING DELIVERY METHOD

From our research and observations, we conclude that AM training and education should be delivered at the DoN “C” school and an NEC should be awarded upon successful completion. According to Navy Education and Training Command (1990),

there are two training and education methods for sailors to obtain the occupational skills adopted by the DoN. This includes “A” schools and “C” schools. In addition, OJT is often used to acquire skills both in the U.S. Navy and industry.

According to the Navy Education and Training Command (1990), “A” school “provides the basic technical knowledge and skills required to prepare for job entry level performance and further specialized training. [It also] includes apprenticeship training” (p. 6). A more specialized skillset would be provided by instruction at a “C” school as it “provides the advanced knowledge, skills and techniques to perform a particular job in a billet and/or any course which awards or is a prerequisite to a skill awarding course” (p. 6). From our research, the skills required of an AM user are not equivalent to the occupational standards of a particular rating. Those skills would be broad and the instruction to receive those skills is classified as the type of instruction (and resulting skills) received at an “A” school. In addition, we believe that effective AM implementation and accelerated adoption requires many sailors who possess sufficient skills and knowledge at the unit level to perform AM. From this standpoint, OJT alone is not sufficient as a sole delivery method of AM technology instruction or training. As we have observed, however, regular practical application is required to maintain the skills an AM user will need to possess. As such, the addition of OJT at the unit level does suffice to prevent the deterioration of AM skills.

F. SUMMARY OF CHAPTER

This chapter evaluated suitable users of AM in the DoN. While all personnel should have a basic knowledge and appreciation of the capability of AM, the user of the technology is likely to be assigned to a particular rate. The chapter discussed the core competencies inherent in the occupational standards of Machinery Repairman and Aviation Structural Mechanics. We evaluated these core competencies against occupational standards. In our opinion, the MR is identified to be the suitable workforce in AM operations because of the favorable comparison between MR’s current skill set and expected skill set required of AM users. This chapter also discussed the reason and

need for the DoN to establish NECs. A brief description of the NEOCS process was presented as applicable to the process for the establishment of a new NEC.

VI. SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

This chapter presents the results of the analysis focused on the essential training factors for the MR, the subsequent implementation of AM into the DoN, and the AM user role. In addition, this chapter reviews the way in which the DoN can establish an NEC for relevant billets to facilitate the identification of a certified AM workforce.

A. SUMMARY

A qualitative examination of additive manufacturing was conducted in industry and the DoN. The DoN does not have an institutional AM training program in the fleet or ashore. According to OPNAV N4 (2019) the DoN has recently put AM machines on the USS John C Stennis (CVN 74), USS Makin Island (LHD 8), and the USS Boxer (LHD 4) with additional plans to place AM capabilities on a total of eight more surface combatant ships by the end of 2019. Furthermore, their intent is to place AM capabilities on all DoN surface platforms. In addition, institutionalized Knowledge, Skills and Abilities (KSA) could not be found in any enlisted occupational rating manual or NEC. This research was conducted with an MR in mind. The results of the analysis identified the need for essential MR training factors and the subsequent implementation of AM into the user role for adoption of AM. The research further identifies what skills an MR should possess and apply and shows how the establishment of an NEC for relevant billets facilitates the identification of a certified AM workforce. Our research questions are restated here, and the result of our research is presented in the following sections.

B. CONCLUSIONS AND RECOMMENDATIONS

For each research question, we provide the conclusions and recommendations based on our research.

1. Should an NEC be created for the MR rating to ensure safe and competent use of AM technology?

- Conclusion

We conclude that the DoN needs to establish a new NEC for AM users. Previous research, presented in Chapter II, identified the benefit of AM implementation into the DoN and the potential to enhance material readiness. In addition, the significance of establishing the standard of AM was articulated in Chapter III. Considering that the DoN does not have a standard instruction method for AM, the DoN needs to create an NEC for AM users, and ensure the safe and effective application of AM throughout the fleet.

- Recommendation

Navy Personnel Command (2019) defines the purpose of an NEC as to:

identify a non-rating wide skill, knowledge, aptitude, or qualification that must be documented to identify both people and billets for management purposes. Additionally, an NEC code can be used to identify special circumstances or situations with approval via the NEOCS process. (p. 6)

For the DoN to take advantage of the benefits inherent in AM technology, the DoN needs to establish an NEC that identifies the billets and the workforce trained to safely and competently perform the critical skills required of the AM processes. This research focused on the MR rate, but the NEC could be assigned to other rates. As discussed in Chapter V, the Aviation Structural Mechanic may be a suitable option for the aviation community. Units that have 3D printers would need to have billets that are coded for the not-yet established AM NEC. MRs and other ratings with similar occupational standards would obtain the NEC associated with AM.

2. Does creating an NEC support the *DoD AM Roadmap* (Department of Defense [DoD], 2016), *DoN AM Implementation Plan V2.0* (DoN, 2017), and *A Design for Maintaining Maritime Superiority V2.0* (Richardson, 2018)?

- Conclusion

We conclude that the establishment of the new NEC of AM users for the MR rating meets the strategy of both the DoD and the DoN. Chapter II elaborated on the growing demand for AM in the DoN. To meet the strategy of maintaining increased material readiness and warfighting capability, effective use of AM is one of the largest factors toward these goals. This cannot be achieved without establishing an AM workforce; the way we do it is to include a standardized method of providing instruction to personnel. Our research indicates that an AM NEC will particularly enable the goals of AM implementation for maintenance and sustainment in addition to deployment and expeditionary readiness goals.

- Recommendation

Our recommendation for training outlines the critical skills required to perform AM processes, the duration of instruction, and the most suitable training delivery method. Critical skills were identified in Chapter V, along with their practical application in the AM process that we observed at the MIC San Diego, CA. Duration of the proposed training and education is identified from the evaluation of the length required of the courses in the training domain described in Chapter IV and the typical daily routine of a U.S. Navy Education and Training Command. The scale of the training needed to meet the NEC requirements of the fleet is dependent on the culture, policies, and funding associated with the implementation of AM technology, as well as the required number of users for each printer.

C. FUTURE RESEARCH

AM technology touches many functional processes within industry and the DoD and DoN. We could not focus on every aspect of AM technology implementation but did

focus on what we believe to be critical to the success of AM technology implementation. We provide the following recommendations for future research.

1. Rating Restriction

In this research, we considered the MR as the most suitable AM users and limited the scope of our research to AM implementation establishing a new NEC within the MR rating. Furthermore, we also believe that the capability of AM will grow significantly in the future and the established NEC will be given to sailors who are in other ratings. We believe the MR and Aviation Structural Mechanics are the most suitable candidates to be AM users in this research. We believe that the growth in demand for AM fabrication will increase the number of 3D printers in the DoN and various components will be manufactured at the operational level. Shorter duration of AM instruction and the need to supply a database of components that can be printed via AM and have fleetwide application will likely eliminate any potential rating barriers of an AM NEC.

2. Innovation in AM Technology

AM technology is still growing. For example, according to Cebul (2018), some aircraft makers such as Bombardier and Airbus are researching 3D printing production of final components consisting of metal alloy materials. Although the DoN primarily applies AM to polymer or non-critical components and is experimenting with other materials and AM methods used, the future of AM will see the full potential of increased capacity of the innovative application of AM technology across the fleet. In addition, the establishment of quality assurance methods of critical components can further accelerate the adoption of AM across the DoN. The DoN will need to take the most effective instruction method to ensure competent AM users and a suitable number of required sailors are capable of further technological advances and innovations of AM.

D. SUMMARY OF CHAPTER

This chapter summarizes the results of the evaluation of the critical skills and method of delivering essential training for the MR. The implementation of AM into the DoN is reviewed in the context of the AM user role and adoption of AM. We also

provided the results of the critical AM skills that an MR should possess for the tasks an MR must perform and described the way in which the DoN can establish an NEC for billet and certified AM workforce identification.

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APPENDIX A. GENERIC EIGHT-STEP AM PROCESS

A description of the AM process borrowed from Gibson et al. (2015, pp. 44–49).

(1) Computer Aided Design

All AM parts must start from a software model that fully describes the external geometry. This can involve the use of almost any professional CAD solid modeling software, but the output must be a 3D solid or surface representation. Reverse engineering equipment (e.g., laser and optical scanning) can also be used to create this representation.

(2) Conversion to STL

Nearly every AM machine accepts the STL file format, which has become a de facto standard, and nowadays nearly every CAD system can output such a file format. This file describes the external closed surfaces of the original CAD model and forms the basis for calculation of the slices.

(3) Transfer to AM Machine and STL File Manipulation

The STL file describing the part must be transferred to the AM machine. Here, there may be some general manipulation of the file so that it is the correct size, position, and orientation for building.

(4) Machine Setup

The AM machine must be properly set up prior to the build process. Such settings would relate to the build parameters like the material constraints, energy source, layer thickness, timings, etc.

(5) Build

Building the part is mainly an automated process and the machine can largely carry on without supervision. Only superficial monitoring of the machine needs to take place at this time to ensure no errors have taken place like running out of material, power or software glitches, etc.

(6) Removal

Once the AM machine has completed the build, the parts must be removed. This may require interaction with the machine, which may have safety interlocks to ensure for example that the operating temperatures are sufficiently low or that there are no actively moving parts.

(7) Post-processing

Once removed from the machine, parts may require an amount of additional cleaning up before they are ready for use. Parts may be weak at this stage or they may have supporting features that must be removed. This therefore often requires time and careful, experienced manual manipulation.

(8) Application

Parts may now be ready to be used. However, they may also require additional treatment before they are acceptable for use. For example, they may require priming and painting to give an acceptable surface texture and finish. Treatments may be laborious and lengthy if the finishing requirements are very demanding. They may also be required to be assembled together with other mechanical or electronic components to form a final model or product.

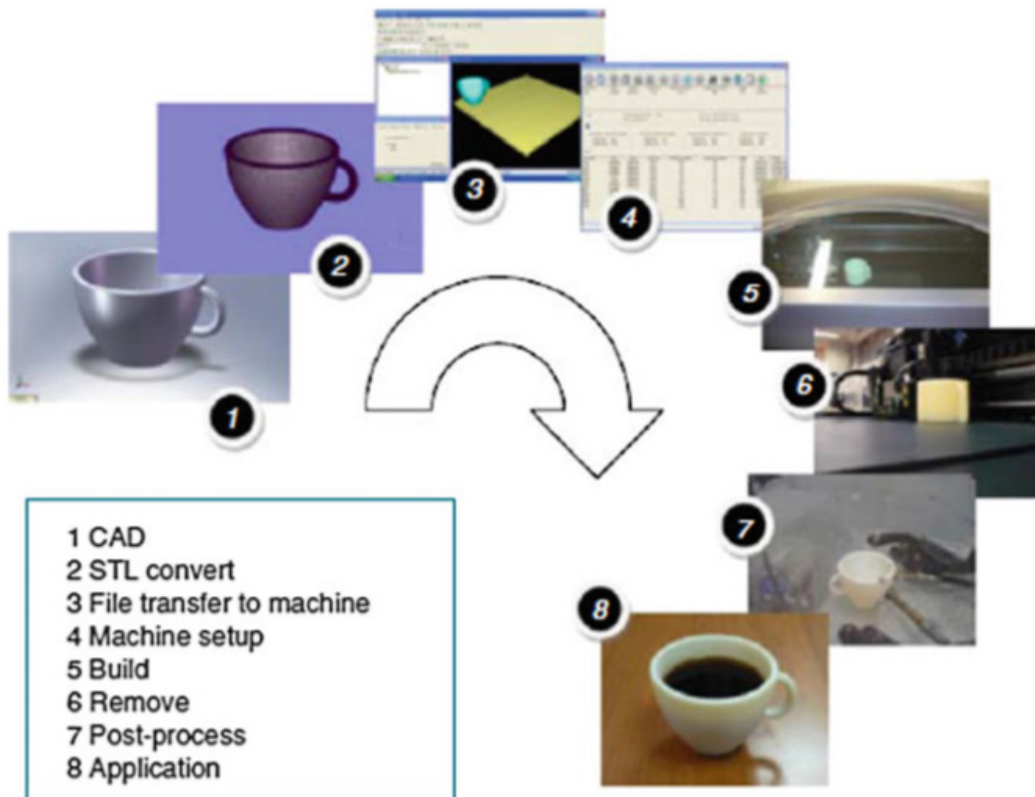


Figure 18. Generic Eight-step Process of AM.
Source: Gibson et al. (2015, p. 45).

APPENDIX B. DON AM IMPLEMENTATION PLAN V2.0

Table 1. Objective 1: Develop the capability to rapidly qualify and certify AM components

Implementation Challenges to be Overcome	
Focus Area	Project Description
1.1 Broader Library of Materials for Naval AM Use	1.1.1 Develop criteria for AM metals feedstock material
	1.1.2 Develop and optimize new materials for AM
	1.1.3 Develop criteria for AM polymers feedstock material
	1.1.4 Develop criteria for AM elastomers feedstock material
	1.1.5 Develop criteria for AM ceramic feedstock material
1.2 Pre and Post Processing	1.2.1 Develop criteria for AM specific pre and post-processing for property modification
	1.2.2 Develop AM specific finishing processes
	1.2.3 Develop criteria for assessing AM processes
1.3 Material Properties	1.3.1 Establish link between as fabricated AM process, environment, microstructure, and resulting properties
	1.3.2 Establish a link between post-processing, microstructure, and resultant properties
	1.3.3 Develop computational modeling to reduce amount of required testing for qualification and certification
	1.3.4 Develop modeling and simulation to open up design space
1.4 Quality Assurance	1.4.1 Identify AM specific defects and establish link between defects and properties
	1.4.2 Develop criteria for inspection techniques that can be used on AM parts
1.5 Standards and Specifications Development	1.5.1 Establish operator standards
	1.5.2 Establish procedure and process qualification standards
	1.5.3 Establish machine and calibration qualification standards
	1.5.4 Establish essential variables/parameters for AM processes
	1.5.5 Establish material standards
	1.5.6 Establish Quality Assurance standards
	1.5.7 Establish AM joining and repair standards
1.6 Manufacturing Process Control	1.6.1 Develop criteria for in-situ control
	1.6.2 Develop criteria for material re-use (for all materials and forms)
	1.6.3 Develop criteria for AM modeling and simulation tools to inform manufacturing
<i>End-State: A framework developed to enable accelerated Q/C of components at a lower cost than is currently possible, thereby providing reasonable assurance those components will perform to meet their performance requirements.</i>	

A-2

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Figure 19. DoN AM Implementation Plan V2.0. Source: DoN (2017, p. 15).

Table 3. Objective 3: Plan to formalize access to AM education, training, and certification for the DON workforce

Implementation Challenges to be Overcome	
Focus Area	Project Description
3.1 Current Workforce Training	3.1.1 Develop broad AM familiarization training
	3.1.2 Identify means to increase workforce access to Maker Spaces and Fabrication Laboratories (FABLAB)
	3.1.3 Develop designer training
	3.1.4 Develop Accelerated Learning Centers
	3.1.5 Develop training and certification process for users/operators
	3.1.6 Identify Navy rating, USMC military occupational specialty, and associated learning centers
	3.1.7 Develop maintenance activity support training
	3.1.8 Develop warfighter training
	3.1.9 Develop training for expeditionary spaces
3.2 Future Workforce Training	3.2.1 Engage Science, Technology, Engineering, and Math (STEM) programs
3.3 Workforce Metrics	3.3.1 Measure impact of AM training for the warfighter, designers, and maintenance support
<i>End-State: A 21st century workforce capable of capitalizing on AM benefits, capabilities, and emerging technologies.</i>	

Figure 20. DoN AM Implementation Plan V2.0. Source: DoN (2017, p. 15).

APPENDIX C. NEOCS PROCESS

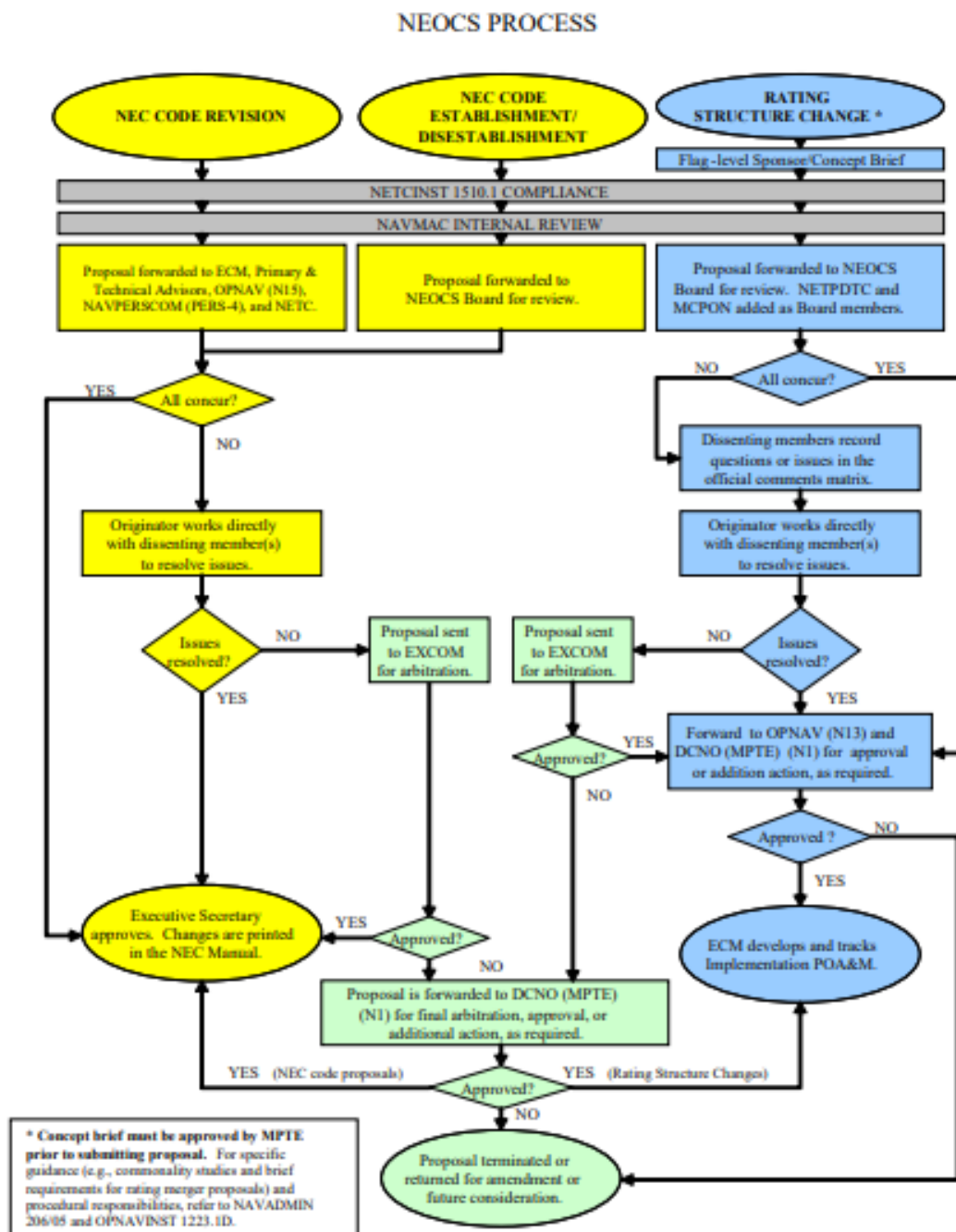


Figure 21. NEOCS Process. Source: Navy Personnel Command (2019).

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APPENDIX D. OCCUPATIONAL STANDARDS OF AN MR APPRENTICE

<u>Job Title</u>		<u>Job Code</u>		
Machinery Repairman Apprentice		003156		
<u>Job Family</u>		<u>NOC</u>	<u>Short Title (30 Characters)</u>	<u>Short Title (14 Characters)</u>
Production		TBD	MACHINERY REPAIRMAN APPRENTICE	MR APPRENTICE
<u>Pay Plan</u>	<u>Career Field</u>	<u>Other Relationships and Rules</u>		
Enlisted	MR	Not applicable, based upon the NEC assigned to the job (if any).		
<u>Job Description</u>				
Machinery Repairmen Apprentices manufacture replacement parts and repair or overhaul ship's engines and auxiliary systems; work on deck equipment, including winches and hoists, condensers, and heat exchange devices; occasionally operate main propulsion and auxiliary machinery; perform machine shop and repair duties; repair and operate auxiliary machinery, including calculating time and material needed for machine shop work and repair of auxiliary machinery; draw sketches and prepare specifications for replacement parts; produce replacement parts from sketches and specifications; operate machine shop equipment, such as lathes, drill presses, shapers, bench grinders, milling machines, boring mills, and power hacksaws; work with precision measuring instruments such as micrometers, depth gauges, vernier calipers, gauge blocks, protractors, and dial indicators; operate engravers; and work under the supervision of a mentor while learning the trade				
<u>DoD Relationship</u>		<u>O*NET Relationship</u>		
<u>Group Title</u>	<u>DoD Code</u>	<u>Occupation Title</u>	<u>SOC Code</u>	<u>Job Family</u>
Machinists	170200	Machinists	51-4041.00	Production
<u>Skills</u>		<u>Abilities</u>		
<i>Equipment Selection</i>		<i>Finger Dexterity</i>		
<i>Management of Material Resources</i>		<i>Manual Dexterity</i>		
<i>Technology Design</i>		<i>Control Precision</i>		
<i>Operation and Control</i>		<i>Written Comprehension</i>		
<i>Repairing</i>		<i>Arm-Hand Steadiness</i>		
<i>Operation Monitoring</i>		<i>Wrist-Finger Speed</i>		
<i>Coordination</i>		<i>Written Expression</i>		
<i>Quality Control Analysis</i>		<i>Mathematical Reasoning</i>		
<i>Reading Comprehension</i>		<i>Category Flexibility</i>		
<i>Writing</i>		<i>Flexibility of Closure</i>		

Figure 22. Occupational Standards of MR Apprentice. Source: Navy Personnel Command (2016, January, p. 5).

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APPENDIX E. OCCUPATIONAL STANDARDS FOR MR JOURNEYMAN

<u>Job Title</u>				<u>Job Code</u>
Machinery Repairman Journeyman				003381
<u>Job Family</u>		<u>NOC</u>	<u>Short Title (30 Characters)</u>	<u>Short Title (14 Characters)</u>
Production		TBD	MACHINERY REPAIR JOURNEYMAN	MR JOURNEYMAN
<u>Pay Plan</u>	<u>Career Field</u>	<u>Other Relationships and Rules</u>		
Enlisted	MR	May include NEC's 4402, 4404		
<u>Job Description</u>				
Machinery Repairmen Journeymen are skilled machinists; manufacture replacement parts and repair or overhaul ship's engines and auxiliary systems; work on deck equipment, including winches and hoists, condensers, and heat exchange devices; occasionally operate main propulsion and auxiliary machinery; perform machine shop and repair duties; repair and operate auxiliary machinery, including calculating time and material needed for machine shop work and repair of auxiliary machinery; draw sketches; perform Computer Aided Drafting (CAD); prepare specifications for replacement parts; produce replacement parts from sketches and specifications; operate machine shop equipment, such as lathes, drill presses, shapers, bench grinders, milling machines, boring mills, and power hacksaws; operate Computer Numerically Controlled (CNC) machinery; work with precision measuring instruments such as micrometers, depth gauges, vernier calipers, gauge blocks, protractors, and dial indicators; operate engravers; and are expected to perform work independently and mentor Machinery Repair Apprentices.				
<u>DoD Relationship</u>		<u>O*NET Relationship</u>		
<u>Group Title</u>	<u>DoD Code</u>	<u>Occupation Title</u>	<u>SOC Code</u>	<u>Job Family</u>
Machinists	170200	Machinists	51-4041.00	Production
<u>Skills</u>		<u>Abilities</u>		
Equipment Selection		Finger Dexterity		
Operation and Control		Manual Dexterity		
Management of Material Resources		Control Precision		
Repairing		Written Comprehension		
Operation Monitoring		Written Expression		
Technology Design		Arm-Hand Steadiness		
Reading Comprehension		Information Ordering		
Writing		Wrist-Finger Speed		
Coordination		Flexibility of Closure		
Quality Control Analysis		Oral Comprehension		

Figure 23. Occupational Standards of MR Journeyman. Source: Navy Personnel Command (2016, January, p. 8).

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APPENDIX F. NEC CODE ESTABLISHMENT PROPOSAL

NEC CODE PROPOSAL TEMPLATES

A. INTRODUCTION

This Appendix provides guidance on how to prepare and submit recommendations for *establishing, disestablishing, or revising* Navy Enlisted Classification (NEC) codes. The Navy Manpower Analysis Center (NAVMAC) is the administrator for all proposals submitted to the Navy Enlisted Occupational Classification System (NEOCS) process for approval. **ALL** proposals **shall** be submitted by an Echelon 3 or higher activity, and those having an impact on the student Individuals Account (IA) **shall** be submitted via their enterprise Primary Advisor (i.e., OPNAV (N2/N6, N95, N96, N97, N98) (endorsement letter, Figure A-3, **MUST** accompany proposal) to: Commanding Officer, Navy Manpower Analysis Center (Code 10), 5722 Integrity Drive, Millington, TN 38054-5011 or navmac_neocs@navy.mil. Proposals which do not have an impact on the student IA (e.g. Planning/Tracking NEC code establishments, PQS/JQR/OJT awardable NEC code establishments) **DO NOT** require a preliminary endorsement letter. However, **IF** the proposal identifies additional coordination Via activities who have equity in the requirement other than a funding impact, the originator **shall** obtain a signed endorsement prior to submission from those activities as well, which **MUST** also accompany the formal proposal for processing. **ALL** Acquisition related proposals for NEC codes **shall** be approved and endorsed by the Assistant Secretary of the Navy (ASN) for Research, Development and Acquisition (RDA) - Director, Acquisition Career Management (DACM) office. Please note that although technical merit is a primary consideration in a NEC code proposal, NEC code actions will always be finalized in light of resources, programming, and personnel management implications.

B. METHODOLOGY FOR ESTABLISHING NEC CODES

1. The NEOCS Board will review and decide upon all new NEC code proposals. NAVMAC is responsible for Board administration and technical assistance in developing and implementing changes to the enlisted classification system. OPNAVINST 1223.1 series details NEOCS Board composition and responsibilities.

2. **Criteria for Establishing NEC codes.** The NEOCS Board reviews all requests for new NEC codes considering following technical criteria:

- a. The NEC code must not duplicate Occupational Standards.
- b. Skill identification needs must be long term.
- c. The proposed NEC code must not reflect routine fleet training.
- d. There must be a need to document the skill in the Enlisted Master Record (EMR).
- e. The skill identification must be necessary throughout the Navy.
- f. The proposed NEC code must reflect workload required to support new equipment.

NOTE: A good rule when drafting or reviewing new NEC code requests is to justify the Navy's need to **identify a skill over five to ten years**.

3. NEC Code Establishment.

a. **Rating Career Field, and Special Career Field NEC Codes.** Figures A-1 and A-2 identify the information and format required to establish a Rating Career Field or Special Career Field NEC codes. Submit recommendations to establish a NEC code 180 days before the date the NEC code is to be awarded, i.e., 180 days before completion of initial course/factory training.

b. **Planning NEC Codes.** Figure A-2, paragraphs 1.a., d., h. (2), i., k., p., q., r., v, and w. identify the information required to establish a Planning NEC code. Submit recommendations to convert Planning NEC codes to Rating Career Field or Special Career Field NEC codes 180 days before the date the NEC code is to be awarded, (i.e., 180 days before completion of initial course/factory training) using all components of Figure A-2.

c. **Tracking NEC Codes.** Figure A-2 identifies the information and format required to establish a Tracking NEC code, all information which makes reference to billets (paragraphs 1.i., and k.) is not required.

NOTE: To revise an existing Tracking NEC code (personnel only) for assignment to billets and personnel, proposal **MUST** be submitted utilizing Figure A-2 to include billet information. **ALL funding implications MUST be clearly stated as having an offset, planned/programmed (POM) for or APPROVED; and endorsed utilizing Figure A-3.**

4. **NEC Code Revision.** All recommendations to revise an NEC code must identify the proposed change and state the justification/rationale for the revision. Revisions which involve a change from OJT to course mandatory training also should address resource implications. Use standard Navy letter format as identified in Figure A-4 when submitting requests for NEC code revisions.

EXCEPTION: When revising an existing Tracking NEC code to include assignment to billets, Figure A-2 **MUST** be utilized as stated above for new establishments; however, the proposal will be processed as a revision and the Subj: line **shall** be annotated as such.

Figure 24. NEC Code Establishment Proposal Template, First Page. Source: Navy Personnel Command (2019).

5. **NEC Code Disestablishment.** All recommendations to disestablish a NEC code must state the reason or rationale for disestablishment and any required billet and/or personnel recoding action. Use standard Navy letter format as identified in Figure A-5 when submitting requests for NEC code disestablishments.

C. NEC CODE CONSTRUCT

1. The first character is alphanumeric indicating the specific Enlisted Career Field (AXXX-WXXX); or that the NEC code is open to multiple Enlisted Career Fields (7XXX/8XXX). All language NEC codes begin with 9 and the DoD mandated three character language tri-graph is added, e.g. 9KUR (Kurdish). All Career Fields are identified in Figure A-1 below.

- a. NEC codes with associated training that is not blocked ends with a letter (XXXA-XXXZ); prerequisite C/F schools, OJT/JQR/PQS, and Factor/Cadre training.
- b. NEC codes with associated training that is blocked ends with a number (XXX2, XXX1, XXX0); prerequisite A school training that identifies the number of blocks remaining, e.g. Block 0, Block 1, and Block 2 which means there are 3 NEC codes established (0 = fully trained).

Figure 25. NEC Code Establishment Proposal Template, Second Page. Source: Navy Personnel Command (2019).

OCCUPATIONAL COMMUNITIES (12), CAREER FIELDS (23) & ASSOCIATED RATINGS

	NEC CODE CAREER FIELDS
<u>AVIATION COMMUNITY</u>	
- Deck (AB, ABE, ABF, ABH, AO).....	DXXX
- Squadron (AD, AE, AF**, AM, AME, AO, AT, AV**)	EXXX
- Support (AC, AN*, AS, AZ, PR).....	FXXX
- Air Crew (AWF, AWO, AWR, AWS, AWV).....	GXXX
- Intermediate Level/Fleet Readiness Center (FRC) (AD, AE, AM, AT).....	IXXX
<u>EXECUTIVE SUPPORT COMMUNITY</u>	
- LN, MC, MU, NC, PS, RP, YN.....	AXXX
<u>INFORMATION WARFARE COMMUNITY</u>	
- Cryptology (CTI, CTM, CTR, CTT).....	CXXX
- Cyber (CTN, IT).....	HXXX
- Meteorology/Oceanography (AG).....	JXXX
- Intelligence (IS).....	KXXX
<u>MEDICAL COMMUNITY</u>	
- HM.....	LXXX
<u>NUCLEAR COMMUNITY</u>	
- EMN, ETN, MMN.....	NXXX
<u>SEABEES COMMUNITY</u>	
- BU, CE, CM, CU**, EA, EO, EQ**, SW, UC**, UT.....	BXXX
<u>SECURITY COMMUNITY</u>	
- MA.....	PXXX
<u>SPECIAL OPERATIONS COMMUNITY</u>	
- EOD, ND.....	MXXX
<u>SPECIAL WARFARE COMMUNITY</u>	
- SB, SO.....	OXXX
<u>SUBMARINE COMMUNITY</u>	
- Mechanical (MMA, MMW).....	QXXX
- Service (CSS, LSS, YNS).....	RXXX
- Technical (ETR, ETV, FT, ITS, MT, STS).....	TXXX
<u>SUPPLY COMMUNITY</u>	
- CS, LS, SH.....	SXXX
<u>SURFACE COMMUNITY</u>	
- Engineering (DC, EM, EN, FN*, GS, GSE, GSM, HT, MM, MR).....	UXXX
- Technical (ET, FC, FCA, GM, IC, STG).....	VXXX
- Operations (BM, MN, OS, QM, SN*).....	WXXX
* Indicates Apprenticeship (General Rates)	
** Indicates Compression Ratings	
<u>UNIQUE CAREER FIELDS</u>	
- Open to multiple Career Fields (Ratings).....	7XXX
- Open to all Career Fields (Ratings).....	8XXX
- Language Career Field.....	9XXX

FIGURE A-1. OCCUPATIONAL COMMUNITIES, CAREER FIELDS & ASSOCIATED RATINGS

Figure 26. NEC Code Establishment Proposal Template, Third Page. Source: Navy Personnel Command (2019).

Letterhead

1221
Ser

From: **Title of activity submitting proposal (SNDL Listing) (Echelon 3 or higher activity)**
To: Commanding Officer, Navy Manpower Analysis Center (Code 10)
Via: **Endorsement (s) (REQUIRED for all new establishments; accompanying endorsement letter(s) shall CLEARLY communicate acceptance of responsibility for any funding (i.e. training or systems) implications, and said funding has been APPROVED in support of subject NEC code establishment (s) (Figure A-3). IF the proposal identifies additional coordination Via activities who have equity in the requirement other than a funding impact, the originator shall obtain a signed endorsement prior to submission from those activities as well, which MUST also accompany the formal proposal for processing)**
Subj: PROPOSAL TO ESTABLISH/REVISE (Tracking NEC code) NAVY ENLISTED CLASSIFICATION (NEC) CODE (annotate the first character Career Field (Figure A-1) and three Xs (e.g. AXXX) and the proposed title here)
Ref: (a) NAVPERS 18068F, Volume II (NECs)
(b) OPNAVINST 1223.1D
(c) List additional references that relate to this proposal

1. Request establishment of a new NEC code per references (a) and (b).
 - a. NEC Code and title. Recommend a NEC code number and a title. Use the **first character Career Field and three Xs** (e.g., AXXX).
 - b. Sequence Code. Recommend a sequence code for prioritizing the NEC code on the Enlisted Master Record. See Chapter I paragraph C., 4. for sequence code discussion.
 - c. Description. Describe the proposed NEC code by identifying the job tasks to be performed; particularly what skill-sets the NEC code provides that is not associated with a rating.
 - d. Source Rating(s). List the rating(s) associated with the NEC code (e.g., BM only, BM and QM, or BM, QM, GM).
 - e. Component NEC. Identify any prerequisite skill(s) (Component NEC) that a member must have earned before being awarded the principle NEC code, if any. Under normal circumstances the Component NEC is removed once the principal NEC code is awarded. However, with sufficient justification for unique situations such as community management initiatives or legacy retainment purposes, the Component NEC may be retained in the members EMR; the stipulation for retainment will be annotated in the NOTE section of the principal NEC code. If multiple Component NECs, identify and/or requirement (AXXX and 7XXX) (AXXX or 7XXX).
 - f. Related NEC. Identify existing NEC(s) similar in scope to the proposed NEC (Related NEC), if any.
 - g. Cost Analysis. What will be the **net effect** on students IA in terms of man-years/Manpower Personnel Navy (MPN)?

NOTE: MPN man-years in the student IA are calculated by multiplying course length in days (include weekends) by number of students and dividing that by 365 for initial training in man-years. This figure is divided by 3 for approximate follow-on, per-year cost for out years.

$$\text{MPN} = \frac{\text{Course length in days (including weekends)} * \text{number of billets}}{365} \qquad \text{Approx. follow-on} = \frac{\text{MPN}}{3}$$

h. Training/Offsets. List the training needed to earn the proposed NEC code, the implications it may have on TAD training, and the impact it may have on increasing overall cost to the Navy in the out-years. Offsets must be identified with submission of your proposal. Offsets are required to cover the expected follow-on training costs. Acceptable offsets for student IA may be reduced time-to-train or reduced annual throughput in related NEC codes; elimination of related NEC codes; transfer of end strength from the force structure to the student account; or successful POM actions. NEC code requests which will cause an increase in the number of instructors or increase in TDI expenses also require offsets in MPN and/or OMN funding. Requests which do not have identified offsets will not receive concurrence when routed for approval. POC for questions regarding offsets is OPNAV (N122D).

- (1) Identify whether the NEC code will be awarded through formal training or through OJT.
- (2) State whether the course is new or on-going. If new, state the ready-for-training date.
- (3) List CIN/CDP when a formal training course is required. If CIN/CDP is unknown, list training as "under development."
- (4) List the length of training (actual classroom days).
- (5) Any establishments, revisions etc., to CIN/CDP should be addressed to NETC.

FIGURE A-2. NEC CODE ESTABLISHMENT PROPOSAL - FIRST PAGE
(TEMPLATE)

Figure 27. NEC Code Establishment Proposal Template, Fourth Page. Source:
Navy Personnel Command (2019).

Subj: PROPOSAL TO ESTABLISH/REVISE (Tracking NEC code) NAVY ENLISTED CLASSIFICATION (NEC) CODE (*annotate the first character Career Field (Figure A-1) and three Xs (e.g. AXXX) and the proposed title here*)

- (6) Increase/savings to course length.
- (7) Will difference course be required?
- (8) Can this be done through non-traditional training sites, or by internet-based course?
- (9) How does this fit into Navy Training System Plan (NTSP)? (Contact appropriate SYSCOM for info)
- (10) If this is replacing another NEC or school, to what percent? How many personnel went through previous NEC, and how long was the course (man-years)?
- (11) How many personnel are intended to go through per year? (Contact OPNAV (N00T)

NOTE: Unless otherwise directed, the originator of a request for an NEC code establishment is responsible for ensuring entry of proper course data into the corporate enterprise Training Activity Resource System (CeTARS) as an integral part of the process.

- i. Number of Billets. Identify the approximate number of billets requiring the NEC.
- j. Personnel Paygrade. Identify the paygrade range for personnel who will hold the NEC (e.g., E4 - E5, E6 - E9).
- k. Billet Paygrade. Identify the paygrade range for billet identified with this NEC (e.g., E4 - E5, E6 - E9).
- l. Special Qualifications/Stipulations. Identify special qualifications associated with the NEC code (i.e. a security clearance, 20/20 vision, certifications); specific criteria for recertification and any related timelines shall also be addressed; any other special stipulations required for awarding and/or assignment. It is also very prudent for accurate NEC code management that the Primary and Technical Advisors conduct, **at a minimum**, an annual review of **ALL** NEC codes under their purview for validity. The Catalog of Navy Training Courses (CANTRAC) is the authoritative source for specific training, certification/recertification, and other requisite requirements such as physical stature attributes that **MUST** be maintained by an individual.
- m. Skill Identification. Indicate whether the proposed skill (NEC) currently exists as part of a rating or another NEC code.
- n. Legacy NEC Code. Identifies the NEOCS approved Legacy NEC code established prior to the 1 October 2017 implementation start date for the current RRL/BL NEC code construct attached to the title. Will be left blank for new establishments approved after 1 October 2017.
- o. Inactive Duty Select Reservists. Identify the applicable inactive duty Selected Reserve (SELRES) category for the NEC from the following listing and provide supporting rationale. Coordinate your recommendation with OPNAV (N951G).

Category "A": The NEC code is attainable by SELRES, and is therefore assignable to SELRES personnel and manpower requirements with no restrictions. SELRES are able to complete training for the NEC code within three years of normal inactive duty training cycles of 48 regular drills and two weeks Annual Training (AT) per year (Training Category (TRC) A). The NEC code can be earned by the following means:

- Active Duty formal training courses that have not been modified or segmented into modules for SELRES applications,
- Segmented or modularized formal training courses that may be completed within three years of normal TRC A training cycles (Note 1),
- Specific civilian training/certification (Note 2), or
- OJT that can be completed with three years of normal TRC A training cycles (Note 2).

Additionally, NEC codes are assignable to SELRES manpower requirements if the formal courses of instruction that award the NEC code will be modified to facilitate SELRES completion of all requirements for the NEC code within three years of normal TRC A training cycles. The requirements for periodic recertification/requalification for the NEC code cannot exceed a normal, annual TRC A training cycle (Note 1).

Category "R": The NEC code cannot normally be attained by SELRES within three years or normal TRC A training cycles; however, is assignable with restrictions to SELRES manpower requirements if SELRES already holding a NEC code in this category can maintain periodic recertification/requalification required for the NEC code within a normal, annual TRC A training cycle.

Category "N": The NEC code is not assignable to SELRES personnel or manpower requirements because periodic recertification/requalification for the NEC code cannot be maintained by a SELRES during a normal, annual TRC A training cycle. Programming of SELRES manpower requirements with these NEC codes is not authorized.

NOTE 1: A formal training course that awards the NEC code or maintains recertification/requalification may be segmented into modules if recommended by COMNAVRESFOR, approved by OPNAV (N12)/NETC and certified to be funded for segmentation by the appropriate OPNAV resource sponsor. If the Training Agent certifies that the training course will be on line within one year, assignment of the NR IND of A is allowed.

FIGURE A-2. NEC CODE ESTABLISHMENT PROPOSAL - SECOND PAGE (TEMPLATE)

Figure 28. NEC Code Establishment Proposal Template, Fifth Page. Source:
Navy Personnel Command (2019).

Subj: PROPOSAL TO ESTABLISH/REVISE (Tracking NEC code) NAVY ENLISTED CLASSIFICATION (NEC) CODE (*annotate the first character Career Field (Figure A-1) and three Xs (e.g. AXXX) and the proposed title here*)

NOTE 2: NEC codes will be awarded to SELRES personnel upon completion of civilian training courses leading to the awarding of a certificate, diploma or license, and for the completion of OJT when a waiver of formal training requirements has been requested and obtained from the appropriate Training Agent.

NOTE 3: COMNAVRESFOR will annually review and coordinate the update of all SELRES NEC code categories with the appropriate NEC Advisors.

p. Coordination. The primary advisor should **look** at all cost associated with the establishment and **provide** a cost estimate for the establishment and **agree** to assume all associated cost. If TAD cost are associated with the establishment TYCOMS should be **notified and agree** to assume any associated TAD cost.

NOTE: Originator shall obtain a signed endorsement from activity identified in their proposal on the VIA: line, signed endorsement shall accompany proposal. Originator is responsible for contacting appropriate commands for this info prior to submission. The accompanying endorsement letter(s) shall CLEARLY communicate acceptance of responsibility for any funding (i.e. training and/or systems) implications, and said funding has been APPROVED in support of subject NEC code establishment(s) (Figure A-3).

q. Directives. Identify special directives associated with the proposed NEC code, such as instructions or manuals.

r. Justification. Explain the purpose of the proposed NEC code and how it will impact manpower increases/decreases. Be as specific as possible.

s. Platform/Equipment. Identify the new platform(s) and/or equipment the proposed NEC code will support.

1. Identify the "phase in" period for new platform(s), equipment, and training.

2. Is the proposed NEC code replacing an existing NEC code? If yes:

a) When is the old platform(s) or equipment no longer in service; and

b) Identify the date the NEC code being replaced may be deleted.

t. Occupation Standards. When requesting establishment of a Rating Series NEC code, indicate whether the proposed NEC code does or does not duplicate existing Occupational Standards for the rating(s) involved, NAVPERS 18068F, Volume I identifies rating specific occupational standards.

u. Workload Measurements. When requesting the establishment of a NEC code, identify workload levels for each new equipment. The work may be generated either by watch station requirements, Planned Maintenance (PM), Corrective Maintenance (CM), or by other specific mission essential elements. The work could be supported by any combination of the preceding types of workload.

v. Primary Advisor/Technical Advisor/Enlisted Community Manager. Provide the abbreviated activity name, along with the specific internal code responsible for subject NEC code, which identifies the respective Primary Advisor/Technical Advisor/Enlisted Community Manager.

w. Point of Contact. Identify the name, telephone number (commercial and DSN), and E-Mail address of a person knowledgeable about the proposed NEC code.

Notes:

1. Paragraph s. is applicable for NEC codes proposed to support new equipment.

2. Each new skill code shall be evaluated by OPNAV (N122) when the equipment or system is fully developed.

K. LEADERSHIP
Authorized Signature

Copy to:
Commands that have an interest in this proposal

FIGURE A-2. NEC CODE ESTABLISHMENT PROPOSAL - THIRD PAGE
(TEMPLATE)

Figure 29. NEC Code Establishment Proposal Template, Sixth Page. Source:
Navy Personnel Command (2019).

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