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THESIS

OPERATIONAL CYBERSECURITY RISKS AND THEIR EFFECT ON ADOPTION OF ADDITIVE MANUFACTURING IN THE NAVAL DOMAIN

by

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December 2017

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13. ABSTRACT (maximum 200 words)

   Additive manufacturing (AM) has been proven to provide multiple benefits over traditional manufacturing methods including cost-savings, mission adaptability, and increased unit capabilities. Multiple DOD organizations are exploring and utilizing AM technology, and efforts are ongoing to determine how best to achieve large-scale adoption of AM in the United States Navy (USN). The primary concern that must be addressed is the trustworthiness of AM objects to ensure they will not increase risks to personnel, equipment, and systems. Including cybersecurity throughout the AM life cycle is a necessary component of protecting AM data and ensuring trust in AM objects to support adoption. This thesis reviews aspects of cybersecurity domain as it is applied to AM, and discusses the insights of a survey conducted with USN, United States Army (USA), and United States Air Force (USAF) resident NPS students. The goal of the survey was to contrast current understanding of adoption of technology and cybersecurity threats in AM, with the knowledge, attitudes, and opinions that prospective users have. The thesis identifies barriers to achieve large-scale adoption of AM in the naval domain with special emphasis on cybersecurity, and proposes approaches to address those barriers and support accelerated adoption of AM.

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**OPERATIONAL CYBERSECURITY RISKS AND THEIR EFFECT ON
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ABSTRACT

Additive manufacturing (AM) has been proven to provide multiple benefits over traditional manufacturing methods including cost-savings, mission adaptability, and increased unit capabilities. Multiple Department of Defense (DOD) organizations are exploring and utilizing AM technology, and efforts are ongoing to determine how best to achieve large-scale adoption of AM in the U.S. Navy (USN). The primary concern that must be addressed is the trustworthiness of AM objects to ensure they will not increase risks to personnel, equipment, and systems. Including cybersecurity throughout the AM life cycle is a necessary component of protecting AM data and ensuring trust in AM objects to support adoption. This thesis reviews aspects of cybersecurity domain as it is applied to AM, and discusses the insights of a survey conducted with USN, U.S. Army (USA), and U.S. Air Force (USAF) resident NPS students. The goal of the survey was to contrast current understanding of adoption of technology and cybersecurity threats in AM, with the knowledge, attitudes, and opinions that prospective users have. The thesis identifies barriers to achieve large-scale adoption of AM in the naval domain with special emphasis on cybersecurity, and proposes approaches to address those barriers and support accelerated adoption of AM.

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LIST OF ACRONYMS AND ABBREVIATIONS

3D	three-dimensional
AFSC	Air Force Specialty Code
AM	additive manufacturing
Avg	average
CAC	common access card
CAD	computer aided design
CIA	confidentiality, integrity, & availability
CNO	Chief of Naval Operations
COTS	commercial off the shelf
DARPA	Defense Advanced Research Projects Agency
DIUX	Defense innovation unit experimental
DOD	Department of Defense
Fab Lab	Naval fabrication laboratories
FSA	Force Structure Assessment
HADR	humanitarian assistance disaster relief
HIDS	host intrusion detection systems
HIPS	host intrusion prevention systems
I&A	identification and authentication
IoT	Internet of things
IP	intellectual property
IRB	institutional review board
IT	information technology
JITC	Joint Interoperability Test Command
JPME	Joint Professional Military Education
Max	maximum
Min	minimum
MOS	military occupational specialty
NAMTI	Naval additive manufacturing technology interchange
NCMS	National Center for Manufacturing Sciences
NPS	Naval Postgraduate School

ONR	Office of Naval Research
PII	personally identifiable information
PKI	public key infrastructure
PoLP	principle of least privilege
QA	quality assurance
ROI	return on investment
ROTC	reserve officers training corps
SD	secure digital
SEAL	Sea Air and Land
SNTWI	Secretary of the Navy tours with industry
STL	standard tessellation language
Stdev	standard deviation
TTP	tactics, techniques, and procedures
USA	United States Army
USB	universal serial bus
USAF	United States Air Force
USN	United States Navy
USNS	United States Naval Ship
VR	virtual reality
Wi-Fi	wireless fidelity

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I.   INTRODUCTION

A.   RESEARCH DOMAIN

The growth and development of technologies such as virtual reality (VR), Internet of things (IOT), and additive manufacturing (AM), commonly referred to as three-dimensional (3D) printing, has blurred the lines between the cyber and physical worlds to the point that they are now inseparable. This codependent cyber-physical relationship creates endless possibilities for advances throughout the world, but it also results in an increased need to protect people from additional threats that can use the bridge from cyber to physical to cause harm to people and property at potentially life-threatening levels.

On the surface, cybersecurity measures are implemented to protect the confidentiality, integrity, and availability (CIA) of physical IT resources, such as computers and network devices, and digital data, such as files and software. However, files, software, networks, computers, and all IT exists because of the tremendous capabilities those things provide to people. Even the Internet, which is one of the best examples of large-scale adoption of technology, exists because its founders wanted to develop a way of social interaction enabled by networking (Leiner et al., 2009). They wanted to provide people with a global interconnection that facilitated quick access to data and programs by getting computers to talk to each other (Leiner et al., 2009).

Today, computers allow us to communicate across great distances extremely quickly, store and manage incredible amounts of data, and control resources and processes that we depend on in our daily lives. However, pulling the string on any cybersecurity measure will result in the realization that cybersecurity is fundamentally about protecting people. Whether cybersecurity measures are implemented to protect critical infrastructure, financial transactions, databases containing personally identifiable information (PII) or any other cyber-enabled capability, the root goal of cybersecurity measures are to protect people from harm.

Cyber presents a constantly evolving threat that allows small adversaries to pose a threat with targeted attacks that could not be achieved in other warfare domains. A recent example that shows the extremely quick and far reaching damage of a cyber-physical threat is the WannaCry ransomware attack that started in May 2017. The malware infected more than 300,000 computers in over 150 countries in approximately 72 hours (Chappell, 2017). The cyber impact came in the form of affected users being unable to access computers and files, but the impact was also felt in the users' physical lives as they were financially extorted for a payment of $300 to restore their files. Additionally, the malware impacted a wide range of businesses and public services including hospitals, police stations, and educational institutions (Chappell, 2017).

The cyber-physical threat is also a reality when applied to the field of AM. The AM process that creates a physical object relies on a wide variety of cyber capabilities and structures. For example, if the digital model that the printer relies on has not been properly protected from creation through final printing, then multiple opportunities exist for modification of the model. Minor modifications, which may go undetected, can cause major failures in the final 3D printed object. If that object is being relied upon for a mission-critical purpose, its failure could cripple the units' war-fighting capabilities. In order to take full advantage of the benefits of AM technology, the U.S. Navy (USN) must prioritize cybersecurity in all phases of development, adoption, and implementation of the Naval AM capability.

As AM technology continues to rapidly advance, the areas for application of that technology within the DOD continue to grow as well, as shown in Figure 1, and government organizations such as the Office of Naval Research (ONR) and Defense Advanced Research Projects Agency (DARPA) have taken a vested interest in this domain (McNulty, Arnas, & Campbell, 2012).

Revolutionary Production	
Efficient use of resources	Fewer processing steps, net-shape, less assembly, post-processing, less waste material, less energy
Small lot productions	Production in lot size of 1, mass customization
Rapid manufacturing	Tool-less, extreme cycle time reductions
Agile manufacturing	Spare parts on demand, no stockpiles, simplified supply chain/logistics
Reverse engineering	Scan and manufacture parts for legacy systems
Cost reduction	Expendable/disposable products

Enabling New Technology	
Lightweight structures	Weight removal increases mission capabilities
Modularity	New designs to switch components in and out
Complexity	Exotic structures, functionally-graded materials, fabricated moving joints, embedded electronics

Local Production	
Factory-less production	Remote, mobile fabrication
Agility/flexibility	Rapid response to changing missions
Shortening of supply chain	Potential use of local raw materials

Source: Jennifer Fielding, National Advanced Manufacturing Innovation Institute (Additive Manufacturing Symposium, Washington, DC, August 20, 2012)

Figure 1. Potential AM Implications for DOD.
Source: McNulty et al. (2012).

AM can be a true game changing innovation but it also would not be the first technology to start with a great idea that fails to reach realization. Large-scale adoption of AM in the Naval domain depends on a well-executed plan that balances usability, capability, and security. Within the Navy, AM can provide a great deal of independence for deployed units by drastically reducing reliance on the Navy's supply chain and providing much quicker access to physical parts that are needed for normal operation.

Additionally, it is widely recognized that AM has a potential to save resources by consuming less material and limiting overproduction issues experienced in traditional manufacturing. Figure 2 shows how AM may also speed productivity by reducing time spent waiting on delivery and decrease storage requirements by limiting the amount of

specific use items that need to be kept in inventory (Thomas & Gilbert, 2014). Perhaps the most unique benefit that AM has over traditional manufacturing is that it provides its users with the capability to prototype and make physical artifacts that did not exist before.
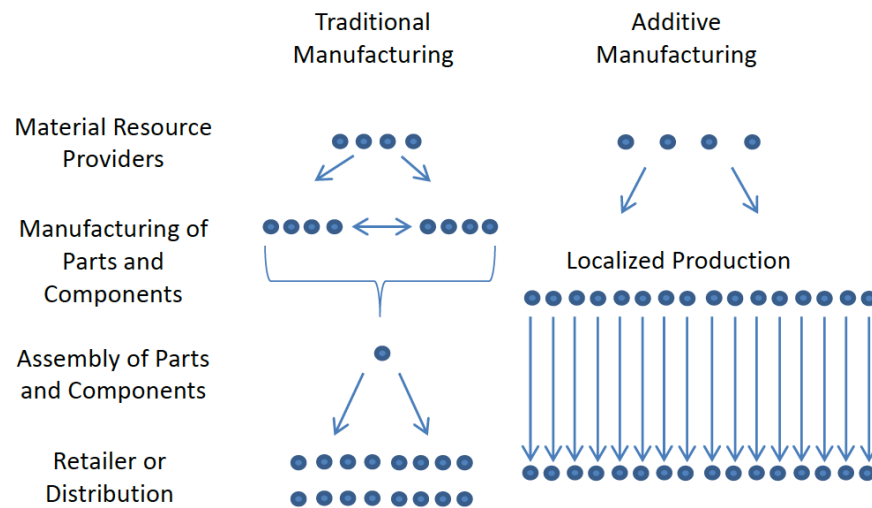
Figure 2. Example of Traditional Supply Chain Compared to the
Supply Chain for AM with Localized Production.
Source: Thomas and Gilbert (2014).

As the Navy increases its AM capabilities and expands implementation of this cost saving technology, the need to ensure that the data that the AM process creates and relies on is secure increases as well. AM presents the realistic potential for deployed Strike Groups and individual units to be able to 3D print critical parts and supplies without having to utilize the potentially time consuming and costly supply chain. However, those units need to have confidence that the part they are fabricating is going to fit and work correctly.

AM has the potential to help the Navy reach new levels of independence from current logistics restraints while saving valuable resources including time, manpower, and money, but failure to implement AM technology with effective, user-focused, cybersecurity principles could result in wasted resources and increased vulnerability to

cyber threats. Additionally, the threat of cyber attacks could be a barrier to large-scale adoption efforts if decision makers are hesitant to support the technology out of fear that it may not be safe from cyber attacks, and individual service members choose not to use AM technology because they do not trust the AM product will perform as intended due to possible cyber attacks. Much research has been done to identify barriers to the adoption of technology and the goal of this thesis is to apply those concepts to the capabilities of AM as they are applied to Naval domain to arrive at recommendations at how to achieve maximum use of the technology without sacrificing cybersecurity.

B.   MOTIVATION FOR RESEARCH

In his May 17, 2017, white paper titled *The Future Navy*, the Chief of Naval Operations (CNO) Admiral John M. Richardson states that numerous studies exploring what the future USN Fleet should look like led to two main conclusions. First, the fleet needs to increase in size to 350 ships, including manned and unmanned systems. Currently, there are approximately 275 USN vessels so that represents a 21% increase while enduring a challenging fiscal environment and budget constraints. Figure 3 illustrates "the range of proposed future battle fleet sizes in comparison to the Navy's latest budget submission, and how these recommendations compare to the evolutionary approach taken in the 2016 FSA. What the figure also make clear is that while the Navy has been on a growth path in recent years, a change will be required to reach and sustain sufficient numbers" (Richardson, 2017, p.5).
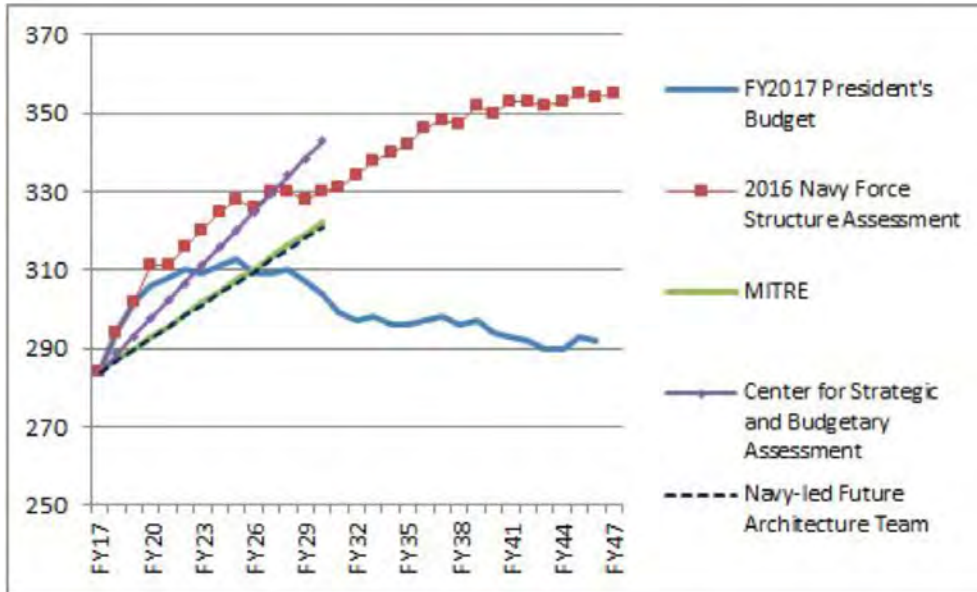
Figure 3. Proposed Navy Battle Fleet Sizes Source: Richardson (2017).

Second, Richardson contends that, "the Navy must also incorporate new technologies and new operational concepts" (Richardson, 2017, p.1). The CNO emphasizes the importance of forward thinking, fast innovation, and technological superiority in order to stay competitive on a global scale with countries like China and Russia. He also recognizes the importance of being able to quickly respond to a variety of mission sets including diplomatic collaboration, disaster relief, and terrorism. The CNO states that the solution for achieving the desired future fleet is to simultaneously build and innovate to realize a larger, more distributed, and more capable force (Richardson, 2017).

Undoubtedly, the solution to this complex situation will consist of a mix of approaches. It is also highly probable that one of those approaches will need to embrace AM as a piece of the answer to the CNO's goals. An example of AM's potential in the USN was evidenced in July 2017 when a partnership between the Naval Surface Warfare Center, Carderock Division's Disruptive Technology Laboratory, and Oak Ridge National Laboratory resulted in the development of a prototype submersible that they, and multiple other partners including DARPA, ONR and Navy Special Warfare, began working on in August 2016. The 30-foot long vehicle, which is shown in Figure 4, is based on the Mark 8 Mod 1 SEAL delivery vehicle and represents the Navy's largest 3D

printed asset (Diaz, 2017). It was produced at 90% cost savings and in less than a quarter of the time of a traditionally manufactured similar submersible. While this prototype is not functional or watertight, a second version is in development that is supposed to be a "fleet-capable prototype" and ready for use in 2019 (Liptak, 2017).

Figure 4. NPS Faculty and Students in Front of 3D Printed Navy Vessel

These experiments provide proof that AM can produce valuable assets quickly and cheaply. Fully adopting this technology in the Navy would go a long way towards answering the CNO's call for innovation that helps the Navy reach its fleet enlargement and capability goals. Figure 5 depicts "the kind of fleet we must pursue: one that is larger, yes, but more capable than any of the recent analyses have suggested, and arriving much more quickly. In short, a Navy that achieves an exponential rate of improvement" (Richardson, 2017, p. 9).
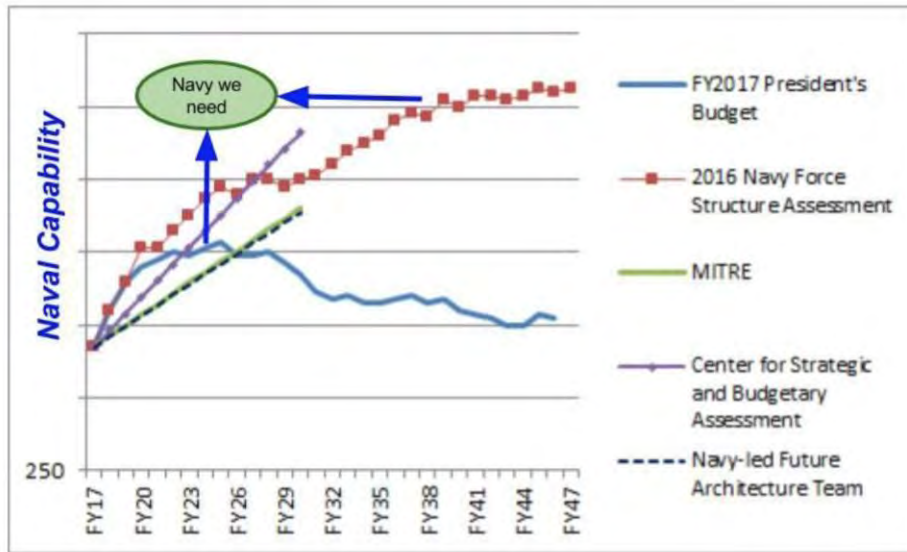
Figure 5. Resultant Capability of New Fleet Design and Architecture.
Source: Richardson (2017).

C.   RESEARCH QUESTIONS

Research questions pursued in this work include:

1.   What can be targeted in digital models used by the Navy for AM and how can the Navy best protect those models?

2.   What are the attitudes, opinions, and adoption trends identified in population of potential "change agents"?

3.   What issues relevant to cybersecurity stand in the way of successful large-scale adoption of AM?

4.   What cybersecurity measures should be implemented to properly store and communicate AM data?

D.   SCOPE

This thesis focuses on the study of cybersecurity issues and potential effects that they may have on large-scale adoption of AM in the Naval domain. The study investigates the full life cycle of data and processes used in additive manufacturing from a cybersecurity perspective. Specifically, recommendations are made for cybersecurity applied to AM and identification of potential target vectors vulnerable to attack based on the Navy's AM implementation models. Potential vulnerabilities exist based on human interaction with the

data, data creation, data storage, data sharing, and data translation into physical form. The study assesses ways to implement successful large-scale adoption of AM technology without compromising cybersecurity. The research survey population was comprised of current USA, USN, and USAF Officers that are resident students at NPS. This population represents potential future change agents and leaders within the DOD.

E.   THESIS CONTRIBUTION

This thesis will benefit the Navy by creating an understanding of what the current obstacles are for user adoption of cybersecurity in Naval Additive Manufacturing. The thesis also offers recommendations on how best to mitigate those obstacles to encourage large-scale adoption of the capabilities available through Naval Fabrication Labs and traditional USN technology implementation models. Cybersecurity must be addressed and funded during the design and acquisition of the system; failing to do that may be more costly and difficult to fix later in the process. The benefits of including cybersecurity early on in the system development and adoption process include avoiding costly future upgrades and preventing security incidents throughout the process. Although this thesis focuses on the Naval domain, many of the issues presented are applicable in the joint environment as well. If each service independently develops service specific solutions within the AM domain then issues will arise when attempting to integrate those solutions in a joint war-fighting environment. Additionally, some elements that are not specific to military domain are also highly applicable to civilian domain.

F.   THESIS STRUCTURE

Chapter I offers an introduction to the to cybersecurity for large-scale adoption of AM in the Navy research domain and the motivation for this research. Chapter II provides more in depth background information about technology adoption, cybersecurity, and AM. Chapter III examines AM cybersecurity threats in the Naval domain. Chapter IV details the results from the research survey conducted as part of this thesis. Chapter V summarizes the research conclusions and offers recommendations and areas for future research.

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II.   BACKGROUND

A.   BRIEF HISTORY AND EXPLANATION OF AM

AM was conceived of by several European, Japanese, and American inventors in the early 1970s but the capability was not fully developed until the 1980s (McNulty, Arnas, & Campbell, 2012). Chuck Hull established the first AM company, 3D Systems, in 1986 after inventing the Stereolithography Rapid Printing System (McNulty, Arnas, & Campbell, 2012). The AM process creates objects from engineering design files typically built in Computer Aided Design (CAD) software programs. Unlike other manufacturing types that remove or alter material, AM 3D printers build the object from the base up, layer by layer using a wide variety of materials including plastics, metals, sand, glass, etc. ("What Is Additive Manufacturing," 2013). The eight steps shown in Figure 6 generally define the AM process (Gibson, Rosen & Stucker, 2015, Chapter 1).

1 CAD
2 STL convert
3 File transfer to machine
4 Machine setup
5 Build
6 Remove
7 Post-process
8 Application
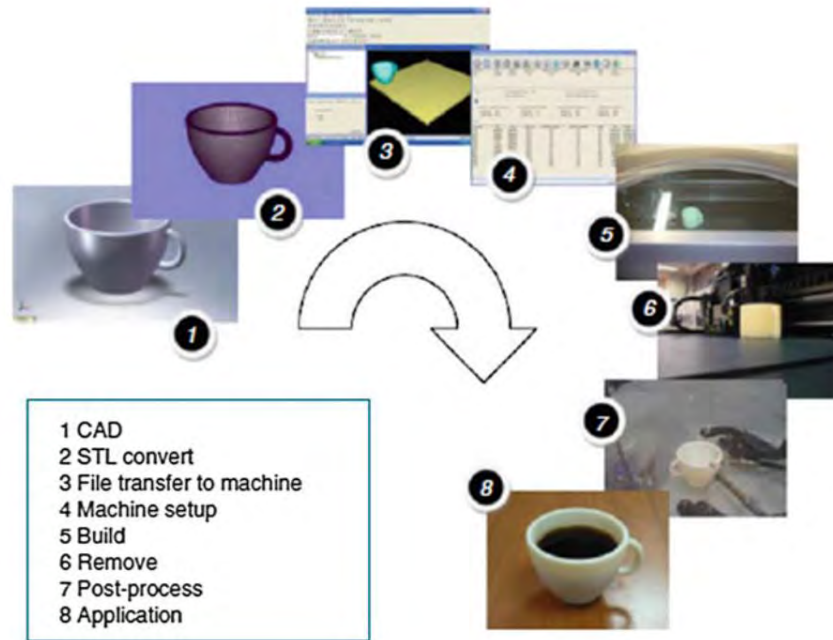
Figure 6. Generic AM Process. Source: Gibson, Rosen, and Stucker (2015).

1. Benefits of AM

The benefits of AM include the ability to reverse engineer parts by 3D scanning the original part and then printing replicas, which is very useful and often characterized as critical when dealing with dated parts that are no longer available or supported by the companies that originally developed them. This benefit also applies to situations when there is an urgent need for an unavailable part, such as in the case of deployed ships where it is often not possible to order and receive parts on extremely short notice. AM also provides the capability to produce lighter weight parts without compromising strength depending on the internal mesh of the printed object (McNulty, Arnas, & Campbell, 2012). Additionally, AM provides costs savings due to more efficient resource usage, energy savings, and greater flexibility than traditional manufacturing processes. For the Navy, these benefits translate into increased independence for deployed units with greater capabilities to create customized objects that are needed on short notice. AM makes rapid prototyping and experimentation much more accessible to Sailors, which encourages cost-saving and mission-enhancing innovations.

2. Concerns

Multiple concerns exist based on the wide range of uses that AM can be applied to. One major concern, both in DOD and in the civilian market, is the ability to create counterfeit or fraudulent items. Theft of Intellectual Property (IP) by our competitors and/ or adversaries abroad is one issue that must be addressed before AM will see the support it needs for adoption (McNulty, Arnas, & Campbell, 2012). Potential Naval AM investors also have apprehension about the return on investment (ROI) from AM. However, as AM technology becomes less expensive, more capable, and faster, ROI concerns will dissipate. Most importantly, AM objects must be proven to be safe for Sailors to use and equipment to operate with. Finally, DOD must address their industrial base's concerns that an advanced and extensive DOD AM capability could replace the manufacturing role that industry partners currently fill.

B. CURRENT STATE OF NAVAL AM DOMAIN

A variety of research teams, laboratories, and installations have already engaged in exploration of the AM landscape. There are at least 25 separate entities working in the Naval AM domain shown in Figure 7. Most of these units are focused on research, capabilities, and exploring possible applications of AM technology. However, adoption of any technology relies heavily on user trust in the highly automated processes that the technology is built on (Pak, Rovira, McLaughlin, & Baldwin, 2017).
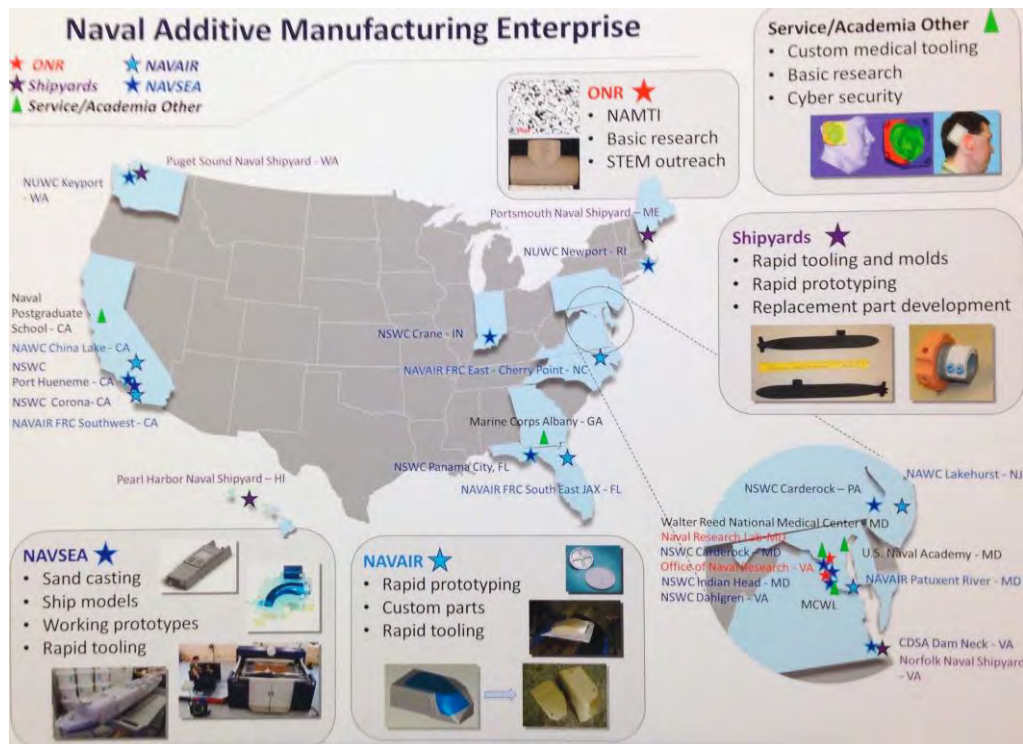
Figure 7. Current State of Naval AM. Source: "Naval Additive Manufacturing Enterprise" (2017).

AM technology adoption in the Naval domain is facing the same challenge of building trust from leadership and potential end users in the automation inherent in creating a 3D print. Generally, if users are not confident in the technology's ability to achieve their desired result, it will be abandoned in favor of established methods. However, the level of trust required for adoption can vary greatly based on multiple factors including user group, domain of intended use, and degree of automation (Pak,

Rovira, McLaughlin, & Baldwin, 2017). The user group consisting of military members typically have higher trust judgments than the civilian population due to intensive training, increased discipline, and adherence to orders which may require the use of technology (Pak, Rovira, McLaughlin, & Baldwin, 2017). These factors may lead to the assumption that AM adoption in the Naval domain would be easier than in the civilian domain but multiple additional issues continue to stand in the way of adoption.

At the 2017 Naval Additive Manufacturing Technology Interchange (NAMTI), keynote speaker Mr. Bryan Wood, Assistant Deputy Commandant, Installations and Logistics, remarked that there is an urgent need for AM in the USN and USMC and that AM is a part of "hybrid logistics" to support forward deployed forces. These logistics take a modern view with a focus on providing combat support with the goal of lightening the amount of parts, tools, equipment, and supplies that need to be carried or transported. Instead, ideally AM would enable the creation of many of these necessities at or near the destination. However, the quality of the AM created object and the data that goes into making that object is extremely important. The object must be trustworthy and the data must be protected. The potential for numerous forward deployed AM capabilities inherently brings with it the potential for numerous opportunities for malicious actors to impact those capabilities. Possible malicious actions range from intellectual property theft of patented objects or data files to hardware attacks on AM printers. The Navy and Marine Corps wants to move forward as rapidly as possible with AM capabilities but has to do so in a safe and secure manner so as to not jeopardize the mission and the Sailors and Marines who are interacting with AM technology.

One of the major outcomes from NAMTI was the need for a Naval AM digital storage and sharing solution. Representatives from the Naval Postgraduate School (NPS) are working on a digital repository also known as a "3D print exchange" with standardized file formats. Successful implementation for this solution must include availability in some form of a secure cloud environment that would be accessible by forward deployed Naval AM assets.

Another AM adoption path the Navy is pursuing is via Naval Fabrication Laboratories (Fab Labs). Most of the Fab Labs are located in fleet concentration areas

including Norfolk, San Diego, and Jacksonville. However, there is also a mobile version that travels to provide familiarization training to Sailors and demonstrate the emerging capabilities of additive manufacturing (Eichner, 2016). Fab Labs have a limited capability due to the amount of space, equipment, personnel, and funding they have. While Each Fab Lab operates independently, there is agreement that the labs are not being utilized at a rate that is going to jump-start adoption of AM technology.

C. AM DIGITAL THREAD AND CYBERSECURITY

Applying the digital thread concept to AM enables tracking of AM objects and systems through their entire life cycle and analyzing the data collected during that process to quantify risks and inform decisions (Fielding et al., 2016). In November 2016 the DOD released an AM Roadmap report that briefly addressed cybersecurity as the need to "ensure that all AM data is secure from design to production to storage." (Fielding et al., 2016). When mission related AM printed objects are being created, transferred or stored, it is essential to ensure end-to-end file security to guarantee model integrity. If AM data is compromised, specific weaknesses could be introduced that would cause the object to fail. File checksums or hashes should be used to validate AM data, but they are only part of the solution, as they do not provide any protection for the data. Also, securing AM data alone does not go far enough towards providing cybersecurity for AM. The digital thread provides the map of the AM process that can be followed to examine cybersecurity vulnerabilities throughout the AM process.

Effective cybersecurity for AM will have to address all vectors of AM subversion including hardware, where the printer itself could be compromised before or after installation, software, CAD creation, and data transmission and storage. As in most cybersecurity problem sets, the earlier that an AM cyber-attack is detected, the better. Early detection can result in cost savings due to material not being wasted on a defective product, time savings in both human and machine time, and prevention of damage to equipment and personnel. Most importantly, it is absolutely critical to ensure detection of malicious prints before the object is used.

Cybersecurity vulnerabilities exist in all stages of the AM life cycle as shown in Figure 8.
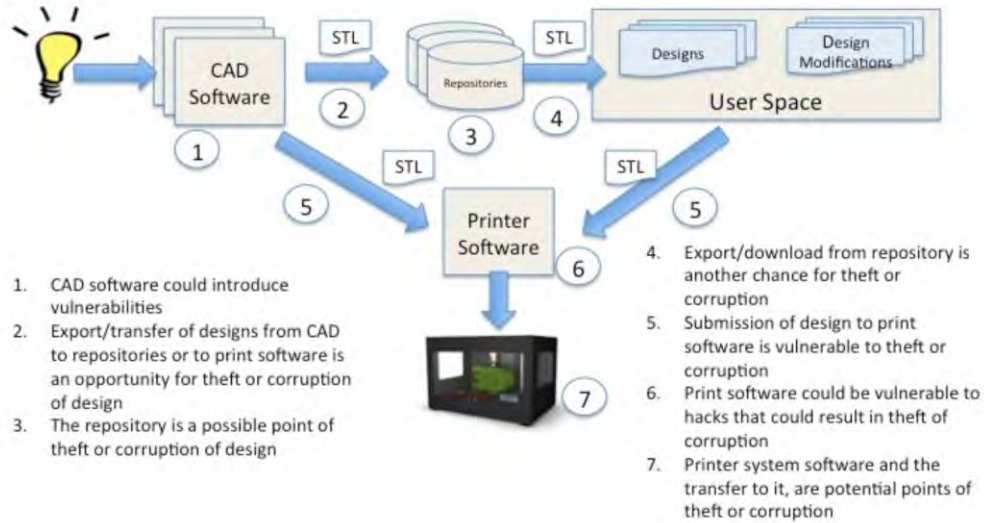
Figure 8. AM Process Vulnerabilities. Source: Bridges, Keiser, Sissom, and Graves (2015).

In the software phases of the life cycle, commercial 3D printer and CAD software are becoming more vendor specific. Companies such as Makerbot and Cubify require the user to use their software to interact with their brand of printers. However, others including Lulzbot work with open-source software solutions like Cura (Baguley, 2017). Without a standard software solution, transferring CAD objects between different locations with different printers becomes very challenging. Cyber vulnerabilities may exist in the software or could be introduced when the software updates are distributed and installed. Both the printer and the CAD software must be able to receive and install updates without jeopardizing security.

Network security introduces a wide range of cyber threats and vulnerabilities and is a crucial portion of AM cybersecurity. Networks are used to transfer AM data, monitor printer status and ongoing print progress, and send jobs to the printer (possibly wirelessly). Networks are also the main vectors for external threats to gain access to a system and steal data from organizations.

D.   DIFFUSION OF INNOVATION

The word "innovation" is over-used throughout the military and society at large to the point where it is used synonymously with invention. However, there are major differences between the two. Although innovation is typically associated with a new technology-based solution to a problem, the more appropriate term would be invention vise innovation. In the book *The Innovators Way*, innovation is defined as "the adoption of new practice in a community" (Denning and Dunham, 2010). Diffusion of innovation leading to large-scale adoption is a process that requires time, patience, resources, and trained innovation leaders who are given the opportunity to continuously improve their skillset.

1.   Conditions for Successful Adoption

Simply providing the opportunity to utilize new technology is not enough to achieve the goal of large-scale adoption. In his book, Diffusion of Innovations, Everett Rodgers identifies five categories of individuals in the adoption process. They are innovators, early adopters, early majority, late majority, and laggards (Rogers, 1995). Each of these groups represents a percentage of overall adopters as shown in Figure 9.
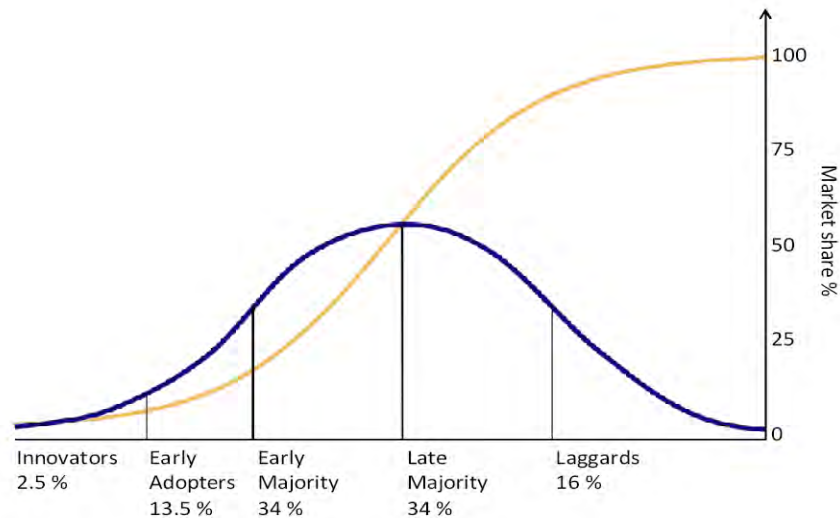
Figure 9. Diffusion of Innovations. Source: OpenABM (2009).

Innovation requires more than a great invention, in fact it may not include an invention at all. As commented by Everett Rodgers, it needs persistent leadership, proper timing, sufficient investment of time and resources, and dedicated support. One of the greatest innovators in Naval History, Admiral Hyman Rickover, claimed "Good ideas are not adopted automatically. They must be driven into practice with courageous patience." Trained innovation leaders can be make the difference as to whether or not adoption occurs, regardless of the potential of the actual innovation. Rogers refers to these individuals as "change agents" and states that "change agents aides" can assist them (Rogers, 1995).

Innovation leaders expertly navigate through obstacles, mobilize networks, and bring together numerous contributors to reach adoption. Denning and Dunham detail eight essential practices that successful innovation leaders must be proficient in. These practices are sensing, envisioning, offering, adopting, sustaining, executing, leading, and embodying (Denning & Dunham, 2010). The practices are not linear, meaning you cannot start with sensing and step through each one to arrive at your desired result. They must be expertly integrated and applied at the appropriate time by an experienced innovator for the highest probability of success. The best opportunities for realization come from situations where the innovation leader has an opportunity to spend time within the adoption community and sense where there is any area of need that they may be able to address.

For the military, innovation is not a choice—it is an imperative. The military must innovate faster than its adversaries or risk losing the ability to defend the Nation. It is also critical to realize that innovation inherently creates problems. Sometimes these problems reveal themselves early on in the innovation process and sometimes they appear well after adoption has occurred. Ideally, the goal should be to identify problems as early as possible and include solutions in the innovation plan. The ability to quickly address and correct these problems will be important to the success of Naval AM capabilities.

E. HUMAN ROLE IN CYBERSECURITY

Although cyber attacks are more advanced and complex than ever, more often than not, people remain the biggest threats, vulnerabilities, and targets in the cybersecurity realm. AM is an incredible invention but cybersecurity is a large problem set inherent with AM and it must be planned for as part of AM innovation to achieve adoption. Cybersecurity solutions are a necessary part of AM innovation because they provide protection for the individuals involved in the adoption process. For large-scale Naval domain adoption, earning the trust of users and investors/decision makers hinges on the ability to demonstrate the safety and reliability of AM products. Cybersecurity helps ensure that AM objects will perform as they were designed to and will not put critical equipment, systems, and personnel at risk.

A commonly identified issue in Cybersecurity systems is that it is difficult to separate true threats from unimportant data. Several reasons for this exist including too much data, ineffective notification systems, and under-staffed or under-trained cybersecurity teams (Dutta & Joyce, 2016, p. 13). Training users to be more conscientious about cybersecurity and more familiar with the cybersecurity features of the systems they are working with can assist cybersecurity professionals in preventing, detecting, and quickly correcting cybersecurity issues.

While AM capabilities can benefit all warfare areas, the cybersecurity maintenance responsibilities for AM systems such as patching, installing updates, and conducting vulnerability scans should be assigned to trained personnel with cybersecurity expertise. Additionally, Naval AM systems need to have the ability enforce PoLP through effective Identification and Authentication (I&A) to ensure only system administrators have access to these capabilities.

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III.   AM CYBERSECURITY THREATS IN NAVAL DOMAIN

A.   INTRODUCTION

It is impossible to protect against all cybersecurity threats, and attempting to address each individual threat on an item-by-item basis is resource intensive and ultimately ineffective. More effective cybersecurity implementations use defense in depth to layer technical solutions, non-technical solutions, and supporting infrastructures like CAC, PKI, and biometrics throughout the life cycle to create a hardened infrastructure that addresses general categories of threats. Technical solutions are those that are implemented in hardware and software including firewalls, routers, network segmentation, detection and prevention devices, and secure coding while non-technical solutions include trained personnel, physical security, and proven TTPs.

B.   DATA INPUT

Most commercial 3D printers that would be adapted for Naval use include multiple methods for connecting data files from external sources to the printer itself. Some examples of these connections are via removable devices such as SD cards or flash drives. These types of devices present a threat because they can be used to easily transfer malware from infected devices into the 3D printer. They also make it easy for insider threats with access to the printer to steal files.

In addition to removable devices, Wi-Fi connectivity is another popular feature that makes it very easy to transfer files to a 3D printer. While this method is very user friendly and convenient, it introduces another path for attackers to exploit cybersecurity vulnerabilities. The portability benefits that Wi-Fi capabilities provide should only be available for temporary situations that are approved and executed by a trusted system administrator.

The third type of connection is via USB cable tethered to a supporting computer. The computer must stay powered and connected throughout the print process unless the printer has some embedded storage that the file can be downloaded to. While this method does present some risk of malware transferring from the connected computer to the 3D

printer, it is safer than the other options and the risk can be minimized by properly securing the connected computer. Additionally, using public and private key asymmetric encryption to digitally sign files can provide authentication to make sure files have not been modified during transfer from a secure CAD development system to a secure 3D printing system. Firewalls, malware protection, antivirus protection, host intrusion detection systems (HIDS), and host intrusion prevention systems (HIPS) between CAD systems and production systems provide additional cyber security protection and should be included in the overall system design.

Ideally any USB connection would be established only when a 3D print file was being transferred to the printer, and then removed immediately following transfer. While this process results in slightly more work for the user, it also keeps the printer air gapped for the majority of its life cycle providing a much smaller target window for the 3D printer. This could also be used as an opportunity for a trusted supervisor to check the data before allowing the USB cable connection.

Finally, quality assurance (QA) is engrained in Navy processes and should be developed and implemented for AM as well. AM QA would provide standard methods to evaluate AM designs and products to ensure accuracy, security, and to systematically inspect the finished 3D printed object. These methods should be created with the end-user in mind so as not to build an overly complicated or burdensome AM QA process that would deter potential users from adopting the technology.

C.   INSIDER THREAT

While it is commonly assumed that most cybersecurity threats come from external sources, studies show that an estimated 58% of reported incidents come from insiders (Nurse et al., 2014). For Naval AM, the insider is anyone who is trusted with access to Naval AM systems or data at any point in the life cycle. The insider threat can be separated into two broad categories; malicious and accidental (Nurse et al., 2014). Malicious insiders threaten AM CIA through intentional actions while accidental insiders do damage through unintentional human error. Understanding insider attacks through characterization can help with prevention.

Characterization can be achieved through four broad categories of identifying a catalyst, actor characteristics, attack characteristics, and organization characteristics as shown in Figure 10 (Nurse et al., 2014). However, from a cybersecurity perspective many of the same measures can be used to prevent both malicious and accidental threats. Adhering to the PoLP while designing and implementing AM cybersecurity will go a long way towards preventing Insider threats.
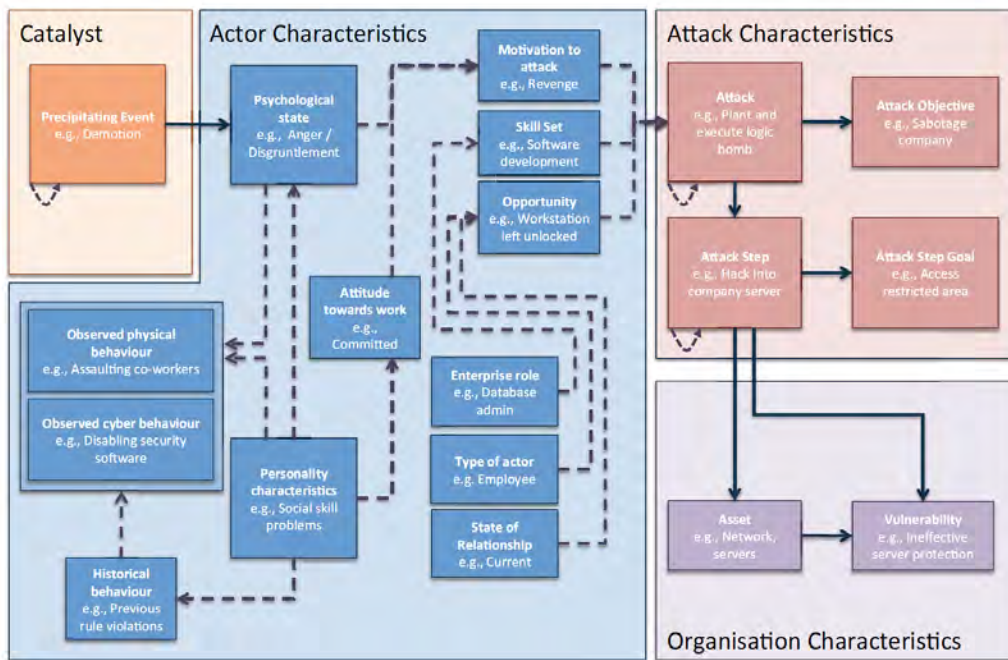
Figure 10. A Framework for Characterizing Insider Attacks.
Source: Nurse et al. (2014)

D. POWER THREATS

Loss of power, regardless of the cause, could cripple a Naval unit's AM capability and severely degrade cybersecurity measures protecting the AM system. Each of the types of power outages in the following list could also interrupt a print in progress, possibly causing the print to have to be restarted by an operator from where it left off or from the beginning of the print. Worse still, they could potentially damage AM printer or connected computers and systems. Types of power issues Naval AM systems should have protection against include:

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- Brown outs—short term drop in voltage

- Black outs—total loss of power

- Spikes—Instantaneous massive boost in voltage

- Surges—momentary rise in voltage

- Noise—electromagnetic interference

E. CHAPTER SUMMARY

Ultimately the potential adversary's decision to attack the system depends on the work factor to achieve their desired result. If the system is difficult to attack and the gain to the adversary is low, then they are more likely to spend time and effort on a higher value system. Currently, AM presents an easy target because there are no standards for verification of AM products. The Navy must establish clear cybersecurity policies and standards that provide guidance to companies and forces them to build security into their AM products. AM becomes an even greater target if it is used to make safety-critical products, such as parts found in aircraft, due to the cyber-physical nature of AM. One minor change that goes undetected on the cyber side could have devastating results on the physical form. Policy is the key to driving AM cybersecurity into system design, implementation, and ultimately large-scale adoption.

IV. USER STUDY

A. INTRODUCTION

This chapter reviews the results of the Technology Use and AM adoption survey by examining the responses of the participants; all surveyed participants were resident students at the Naval Postgraduate School. Due to a limited time frame to include additional IRB review procedure requested by USMC IRB Committee for USMC students-participants, the survey was approved and made available to USA, USN, and USAF resident NPS students. The chapter includes discussion of the design and execution of the survey and highlights statistical results from representative questions in each section.

B. STUDY DESIGN

The study was designed as an empirical research survey to acquire insights and generate useful understandings about adoption of AM in the Navy based on user responses. USA and USAF personnel were included in the survey to provide a comparison between the services. The goal was to use the qualitative and quantitative research results to generate hypotheses or theories based on the data gathered and derive general conclusions that can be used to support the Naval AM adoption process. The survey is modeled after the questionnaire conducted by USMC Captain Matthew Friedell as part of his NPS thesis "Additive manufacturing in expeditionary operations: current needs, technical challenges, and opportunities" but extends his work with a focus on cybersecurity. Included in the survey are several demographic questions to allow for comparison between different ages, genders, service affiliations, primary jobs, ranks, time in service, and education level. The full text of the questionnaire is included in Appendix A. Following the demographic section are sections on use of technology and recreational resources, 3D printing, adoption, and cybersecurity.

C. METHODOLOGY

The survey development process began by identifying general categories of interest that were focused on cybersecurity and adoption of technology innovations, and researching previously conducted surveys that could be used as models. Then individual questions within each category were written, and question and answer format was established (i.e. Likert scale, drop-down menu, etc.). Most survey answers were quantitatively formatted but several areas allowed for qualitative follow-on responses from participants as well. Multiple versions of the survey were constructed and modified throughout the questionnaire development process. Once finalized, the survey and required documentation were submitted to the NPS IRB for approval; the author also developed the online version of the survey utilizing LimeSurvey provided tools (LimeSurvey server has been provided and maintained by NPS). Once IRB approval was received, the survey was activated and participant recruitment began. All participants were uncompensated volunteers who were solicited a maximum of three times through their NPS email account, the NPS student muster webpage or face-to-face requests. Only resident NPS students who are active duty Officers in the USA, USN or USAF were allowed to participate. IRB documentation, recruitment script, and full survey are included in Appendix A.

D. APPARATUS

Anonymous data collection was performed through LimeSurvey provided capabilities. Participants accessed the questionnaire through a hyperlink provided in the recruitment script leading to LimeSurvey, where data was collected and stored until survey deactivation. No PII was collected or stored during the survey.

E. SUBJECTS

A total of 124 participants accessed the questionnaire via Lime Survey. Of those, 96 completed the survey, and 15 partially completed it but did not provide enough responses to be of value for analysis. The remaining 13 people did not consent to taking the survey. Out of the 96 usable responses, 75 were from USN, 11 were from USAF, and

10 were from USA personnel. Among the 96 members who completed the survey, the average time spent answering it was approximately 13 minutes and 30 seconds.

F. RESULTS AND DISCUSSION

This section highlights the quantitative and qualitative findings from the 96 surveys completed. It addresses each of the major categories in the survey (demographics, use of technology and recreational resources, 3D printing, adoption, and cybersecurity).

1. Demographics

Questions in this section were designed to allow the researchers to parse information based on the following characteristics of respondents:

- age

- gender

- service affiliation and designator/MOS/AFSC

- rank

- time in service

- use of social media (Facebook, Twitter, Instagram, Snapchat, Pinterest, LinkedIn, Google+, MeetUp)

Tables 1, 2, 3, 4, 5, and 6 summarize responses to the demographics questions. AS Table 3 illustrates, USN officers greatly outnumbered the other respondents but this is expected being that the majority of resident students are USN Officers. However, having representation from USA and USAF participants allows for some comparison of views based on service affiliation.

Table 1.   Age Statistics in Years

Age				
	ALL	**USN**	**USAF**	**USA**
Avg	33.25	33.09	33.18	34.5
Max	46	46	41	44
Min	23	23	23	31
stdev	4.93	4.86	6.42	3.89

Table 2.   Gender Statistics

Gender								
Response	**All**		**USN**		**USAF**		**USA**	
	#	%	#	%	#	%	#	%
Male	75	78.13	60	80.00	6	54.55	9	90.00
Female	20	20.83	14	18.67	5	45.45	1	10.00
No response	1	1.04	1	1.33	0	0.00	0	0.00
Total	96	100	75	100	11	100	10	100

Table 3.   Service Affiliation Statistics

Service		
Response	#	%
USN	75	78.13
USAF	11	11.46
USA	10	10.42
Total	96	100

Table 4.   Rank Statistics

Response	All		USN		USAF		USA	
	#	%	#	%	#	%	#	%
O1	3	3.13	2	2.67	1	9.09	0	0.00
O2	7	7.29	6	8.00	1	9.09	0	0.00
O3	49	51.04	36	48.00	6	54.55	7	70.00
O4	34	35.42	29	38.67	3	27.27	2	20.00
O5	3	3.13	2	2.67	0	0.00	1	10.00
Total	96	100	75	100	11	100	10	100

Table 5.   Time in Service Statistics in Years

Time in Service	ALL	USN	USAF	USA
Avg	10.34	10.19	9.55	12.40
Max	23	23.00	19.00	22.00
Min	1	1.00	3.00	8.00
stdev	4.9	4.91	5.11	4.50

Table 6.   Social Media Membership Statistics

Response	All		USN		USAF		USA	
	#	%	#	%	#	%	#	%
Facebook	77	80.21	66	88.00	3	27.27	8	80.00
LinkedIn	38	39.58	30	40.00	2	18.18	6	60.00
Instagram	33	34.38	22	29.33	8	72.73	3	30.00
Snapchat	26	27.08	21	28.00	4	36.36	1	10.00
Twitter	24	25.00	15	20.00	6	54.55	3	30.00
Google+	19	19.79	17	22.67	0	0.00	2	20.00
Pinterest	18	18.75	10	13.33	7	63.64	1	10.00
None	9	9.38	0	0.00	0	0.00	0	0.00
MeetUp	7	7.29	7	9.33	0	0.00	0	0.00
Total	251	261.46	188	250.67	30	272.73	24	240

For social media questions, respondents were asked to select all of the types they are members of. Social media usage results can provide valuable insight into where to focus efforts to promote adoption. The collected data set suggests that the majority of surveyed participants (80.21%) use Facebook, and to a much smaller extent LinkedIn (39.58%), Instagram (34.38%) and other social media shown in Table 6. Facebook, due to its large audience, and LinkedIn, due to its connection to the professional community and specialized content, appear to be the best candidates to promote the use of AM.

2. Use of Technology, Exposure to Media, and Technology Influences

Questions in this section focus on the types of technology participants' use including video games and applications, and how they view their use of technology compared to others. Additionally, information was gathered on how respondents prefer to learn to use service provided recreational resources such as computer labs or gym equipment. Tables 7, 8, 9, 10 and 11 highlight some of the findings from this section of questions. Statistics in Table 7 suggest that the majority of respondents do not see themselves as early adopters, as 57.30% either "somewhat disagreed," "disagreed," or "strongly disagreed" with the question posed. However, they do appear to seek information on technology devices with 59.38% replying with "somewhat agree" or above as shown in Table 8.

Table 7.   Tendency to Purchase Technology Devices First

"I am among the first to purchase new technology devices"								
Response	All		USN		USAF		USA	
	#	%	#	%	#	%	#	%
Strongly disagree	22	22.92	17	22.67	3	27.27	2	20.00
Disagree	23	23.96	18	24.00	4	36.36	1	10.00
Somewhat disagree	10	10.42	8	10.67	0	0.00	2	20.00
Neither disagree or agree	11	11.46	5	6.67	3	27.27	3	30.00
Somewhat agree	26	27.08	24	32.00	1	9.09	1	10.00
Agree	4	4.17	3	4.00	0	0.00	1	10.00
Strongly agree	0	0.00	0	0.00	0	0.00	0	0.00
Total	96	100	75	100	11	100	10	100

Table 8. Tendency to Pursue Technology Device Information

"I stay updated on the latest information about technology devices"								
Response	All		USN		USAF		USA	
	#	%	#	%	#	%	#	%
Strongly disagree	5	5.21	3	4.00	1	9.09	1	10.00
Disagree	18	18.75	16	21.33	1	9.09	1	10.00
Somewhat disagree	7	7.29	3	4.00	3	27.27	1	10.00
Neither disagree or agree	9	9.38	6	8.00	2	18.18	1	10.00
Somewhat agree	27	28.13	20	26.67	4	36.36	3	30.00
Agree	20	20.83	17	22.67	0	0.00	3	30.00
Strongly agree	10	10.42	10	13.33	0	0.00	0	0.00
Total	96	100	75	100	11	100	10	100

Table 9 demonstrates the power that expert opinion has on the adoption of technology with 78.13% of responses indicating that they at least "somewhat agree" that they personally prefer to wait for expert opinions before purchasing technology (answers 'Somewhat agree', 'Agree', and 'Strongly agree' being added up; the same responses for USN population amounted to 76%). Similar results were given for question related to influence of peers' opinions on purchases of technology devices—Table 10 illustrates that majority of respondents declare high appreciation for opinions of their peers. The results suggest that 57.29% agree with that statement to some extent (responses 'Somewhat agree', 'Agree', and 'Strongly agree' being added up; results for USN were 53.33%). Similar questions were asked about purchasing video games and apps and in each case expert opinion was very influential in the purchase decision.

Table 9.   Expert Opinion Influence

"I wait for expert opinions before purchasing technology devices"								
Response	All		USN		USAF		USA	
	#	%	#	%	#	%	#	%
Strongly disagree	4	4.17	3	4.00	1	9.09	0	0.00
Disagree	5	5.21	5	6.67	0	0.00	0	0.00
Somewhat disagree	6	6.25	4	5.33	2	18.18	0	0.00
Neither disagree or agree	6	6.25	6	8.00	0	0.00	0	0.00
Somewhat agree	29	30.21	21	28.00	4	36.36	4	40.00
Agree	34	35.42	30	40.00	2	18.18	2	20.00
Strongly agree	12	12.50	6	8.00	2	18.18	4	40.00
Total	96	100	75	100	11	100	10	100

Table 10.   Peer Opinion Influence

"I wait for my peers' opinions before purchasing technology devices"								
Response	All		USN		USAF		USA	
	#	%	#	%	#	%	#	%
Strongly disagree	8	8.33	6	8.00	2	18.18	0	0.00
Disagree	9	9.38	9	12.00	0	0.00	0	0.00
Somewhat disagree	8	8.33	7	9.33	0	0.00	1	10.00
Neither disagree or agree	16	16.67	13	17.33	2	18.18	1	10.00
Somewhat agree	33	34.38	22	29.33	6	54.55	5	50.00
Agree	20	20.83	17	22.67	1	9.09	2	20.00
Strongly agree	2	2.08	1	1.33	0	0.00	1	10.00
Total	96	100	75	100	11	100	10	100

Table 11 displays the results when respondents were asked for their self-assessment regarding their new technology purchasing tendencies. The statement that provided the information for Table 11 is "I am among the last to purchase new technology devices." Subjects were asked to respond by choosing an answer by from the Likert scale provided, which used ranges from "strongly disagree" to "strongly agree." This question was purposefully designed to provide verification of the information gathered from the question in Table 7, which is "I am among the first to purchase new technology devices." There appears to be a correlation between answers provided to the inverse questions. For example, most respondents somewhat agreed (27.08%) that they

were among the first to purchase new technology devices, and somewhat disagreed (23.96%) that they were among the last to purchase new technology devices.

Table 11. Tendency to Purchase Technology Devices Last

"I am among the last to purchase new technology devices"								
Response	All		USN		USAF		USA	
	#	%	#	%	#	%	#	%
Strongly disagree	10	10.42	7	9.33	2	18.18	1	10.00
Disagree	16	16.67	13	17.33	1	9.09	2	20.00
Somewhat disagree	23	23.96	20	26.67	0	0.00	3	30.00
Neither disagree or agree	10	10.42	8	10.67	2	18.18	0	0.00
Somewhat agree	15	15.63	11	14.67	2	18.18	2	20.00
Agree	12	12.50	7	9.33	4	36.36	1	10.00
Strongly agree	10	10.42	9	12.00	0	0.00	1	10.00
Total	96	100	75	100	11	100	10	100

These questions and answers can be used to determine groups that are predisposed to technology adoption and who are more likely to be early adopters.

3.   Use of Applications, Exposure to Media and Application Influences

This portion of the survey was designed to further refine the profile of the respondents by determining their use of applications. The vast majority of technology devices used on an everyday basis on smart phones are reliant on applications so insight into applications usage also provides insight into technology use of the respondents. If the response to the first question, "Do you download and/or purchase applications" was "No," follow on questions in this section were omitted for that individual. The questions in this section are very similar to the technology devices section and results are displayed in Tables 12, 13, 14, 15, 16 and 17. The vast majority of survey participants (86.46%) said that they download or purchase applications as shown in Table 12, but most do not consider themselves among the first to do so with 71.87% (Table 13) responding with "Somewhat disagree," "Disagree," or "Strongly disagree."

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Table 12.　App Exposure

"Do you download and/or purchase applications (apps)"								
Response	All		USN		USAF		USA	
	#	%	#	%	#	%	#	%
Yes	83	86.46	64	85.33	10	90.91	9	90.00
No	13	13.54	11	14.67	1	9.09	1	10.00
Total	96	100	75	100	11	100	10	100

Table 13.　Tendency to Purchase Apps First

"I am among the first to download or purchase newly released apps"								
Response	All		USN		USAF		USA	
	#	%	#	%	#	%	#	%
Strongly disagree	26	27.08	19	25.33	3	27.27	4	40.00
Disagree	29	30.21	25	33.33	2	18.18	2	20.00
Somewhat disagree	14	14.58	12	16.00	2	18.18	0	0.00
Neither disagree or agree	9	9.38	6	8.00	2	18.18	1	10.00
Somewhat agree	4	4.17	2	2.67	0	0.00	2	20.00
Agree	0	0.00	0	0.00	0	0.00	0	0.00
Strongly agree	0	0.00	0	0.00	0	0.00	0	0.00
No response or N/A	14	14.58	11	14.67	2	18.18	1	10.00
Total	96	100	75	100	11	100	10	100

The results in Table 14 are similar to those in Table 13, as 68.75% of participants "Somewhat disagree," "Disagree," or "Strongly disagree" that they stay updated on the latest information about new applications. Even though overall application usage is high, it does not appear that there is enough interest in them to motivate respondents to seek out information or be early adopters of applications.

Table 14. Tendency to Pursue App Information

"I stay updated on the latest information about newly released apps"								
Response	All		USN		USAF		USA	
	#	%	#	%	#	%	#	%
Strongly disagree	20	20.83	14	18.67	3	27.27	3	30.00
Disagree	33	34.38	27	36.00	5	45.45	1	10.00
Somewhat disagree	13	13.54	9	12.00	1	9.09	3	30.00
Neither disagree or agree	9	9.38	7	9.33	1	9.09	1	10.00
Somewhat agree	5	5.21	4	5.33	0	0.00	1	10.00
Agree	3	3.13	3	4.00	0	0.00	0	0.00
Strongly agree	0	0.00	0	0.00	0	0.00	0	0.00
No response or N/A	13	13.54	11	14.67	1	9.09	1	10.00
Total	96	100	75	100	11	100	10	100

Table 15 indicates a fairly even distribution of responses regarding the influence of expert opinions on application purchasing decisions. Across all responses scores ranged from a low of 10.42% for "Strongly disagree" and "Somewhat disagree" to a high of 18.75% in the "Somewhat Agree" category. The one response that differed from this trend was "Strongly agree" with only 3.13% of participants (all Navy) choosing that option.

Table 15. Expert Opinion Influence

"I wait for expert opinions before downloading or purchasing newly released apps"								
Response	All		USN		USAF		USA	
	#	%	#	%	#	%	#	%
Strongly disagree	10	10.42	8	10.67	2	18.18	0	0.00
Disagree	15	15.63	13	17.33	2	18.18	0	0.00
Somewhat disagree	10	10.42	7	9.33	2	18.18	1	10.00
Neither disagree or agree	12	12.50	8	10.67	2	18.18	2	20.00
Somewhat agree	18	18.75	14	18.67	2	18.18	2	20.00
Agree	15	15.63	11	14.67	0	0.00	4	40.00
Strongly agree	3	3.13	3	4.00	0	0.00	0	0.00
No response or N/A	13	13.54	11	14.67	1	9.09	1	10.00
Total	96	100	75	100	11	100	10	100

Peer influence appears to have a slightly stronger influence than expert influence when deciding to acquire applications. According to survey answers shown in Table 16, 43.75% "Somewhat agree," "Agree," or "Strongly Agree" that they wait for peers opinions, while 37.51% felt the same way about waiting for expert opinions (Table 15).

Table 16. Peer Opinion Influence

"I wait for my peers opinions before downloading or purchasing newly released apps"								
Response	All		USN		USAF		USA	
	#	%	#	%	#	%	#	%
Strongly disagree	5	5.21	3	4.00	1	9.09	1	10.00
Disagree	16	16.67	14	18.67	2	18.18	0	0.00
Somewhat disagree	8	8.33	7	9.33	0	0.00	1	10.00
Neither disagree or agree	12	12.50	9	12.00	2	18.18	1	10.00
Somewhat agree	20	20.83	15	20.00	4	36.36	1	10.00
Agree	19	19.79	16	21.33	0	0.00	3	30.00
Strongly agree	3	3.13	0	0.00	1	9.09	2	20.00
No response or N/A	13	13.54	11	14.67	1	9.09	1	10.00
Total	96	100	75	100	11	100	10	100

Table 17 depicts that participants did not have strong opinions about whether they were among the last to purchase applications as 50% of responses were in the range from "Somewhat disagree" to "Somewhat agree."

Table 17. Tendency to Purchase Apps Last

"I am among the last to download or purchase newly released apps"								
Response	All		USN		USAF		USA	
	#	%	#	%	#	%	#	%
Strongly disagree	2	2.08	1	1.33	1	9.09	0	0.00
Disagree	8	8.33	6	8.00	0	0.00	2	20.00
Somewhat disagree	10	10.42	6	8.00	1	9.09	3	30.00
Neither disagree or agree	20	20.83	17	22.67	2	18.18	1	10.00
Somewhat agree	18	18.75	15	20.00	2	18.18	1	10.00
Agree	20	20.83	15	20.00	3	27.27	2	20.00
Strongly agree	5	5.21	4	5.33	1	9.09	0	0.00
No response or N/A	13	13.54	11	14.67	1	9.09	1	10.00
Total	96	100	75	100	11	100	10	100

4.   Recreational Resources

The survey questions on the use of recreational resources may translate into some techniques that could be useful to help increase the use of Fab Labs, and also in assessing preferences for learning how to use the resources provided. Tables 18, 19, and 20 summarize the responses for this portion of the survey. While a combination of training options is considered to give the best results (Tables 18, 19 and 20), respondents heavily preferred using "trial and error" techniques (Table 19) and Internet sources to learn how to use the equipment (Table 20). To encourage the use of Fab Labs, it will be important to market them as places to experiment and to ensure that patrons have access to Internet self-help websites such as YouTube.

Table 18. Likelihood to Ask Employee

"When using service provided recreational resources such as a library, computer lab, auto-hobby shop, or gym, how likely are you to ask an employee to teach you how to use the equipment"								
Response	All		USN		USAF		USA	
	#	%	#	%	#	%	#	%
Strongly disagree	23	23.96	19	25.33	3	27.27	1	10.00
Disagree	17	17.71	15	20.00	2	18.18	0	0.00
Somewhat disagree	16	16.67	12	16.00	2	18.18	2	20.00
Neither disagree or agree	9	9.38	5	6.67	1	9.09	3	30.00
Somewhat agree	18	18.75	16	21.33	0	0.00	2	20.00
Agree	12	12.50	7	9.33	3	27.27	2	20.00
Strongly agree	1	1.04	1	1.33	0	0.00	0	0.00
Total	96	100	75	100	11	100	10	100

Table 19. Likelihood of Trial and Error Approach

"When using service provided recreational resources such as a library, computer lab, auto-hobby shop, or gym, how likely are you to teach yourself how to use the equipment through trial and error type techniques"								
Response	All		USN		USAF		USA	
	#	%	#	%	#	%	#	%
Strongly disagree	3	3.13	3	4.00	0	0.00	0	0.00
Disagree	0	0.00	0	0.00	0	0.00	0	0.00
Somewhat disagree	1	1.04	0	0.00	1	9.09	0	0.00
Neither disagree or agree	6	6.25	3	4.00	2	18.18	1	10.00
Somewhat agree	32	33.33	27	36.00	2	18.18	3	30.00
Agree	30	31.25	23	30.67	2	18.18	5	50.00
Strongly agree	24	25.00	19	25.33	4	36.36	1	10.00
Total	96	100	75	100	11	100	10	100

Table 20. Likelihood of Using Internet Sources

"When using service provided recreational resources such as a library, computer lab, auto-hobby shop, or gym, how likely are you to use self-help guide or video, made available via internet by other users, to learn how to use the equipment"								
Response	All		USN		USAF		USA	
	#	%	#	%	#	%	#	%
Strongly disagree	2	2.08	1	1.33	1	9.09	0	0.00
Disagree	4	4.17	2	2.67	1	9.09	1	10.00
Somewhat disagree	7	7.29	6	8.00	1	9.09	0	0.00
Neither disagree or agree	4	4.17	3	4.00	1	9.09	0	0.00
Somewhat agree	24	25.00	19	25.33	1	9.09	4	40.00
Agree	29	30.21	22	29.33	4	36.36	3	30.00
Strongly agree	26	27.08	22	29.33	2	18.18	2	20.00
Total	96	100	75	100	11	100	10	100

5.   3D Printing

The 3D printing section of the questionnaire was designed to assess participants' knowledge, opinions, and experience with 3D printing. Additionally, participants provided qualitative responses regarding concerns they had about 3D printing in the military domain. Table 21 indicates that almost all participants felt that they know what 3D printing is with 90.62% responding with "Somewhat agree" or higher. Also, 58.33% at least "Somewhat agree" that 3D printing would be useful in their work center (Table

22) even though only 8% (Table 23) served in units that use 3D printed objects and 15% have a 3D printing capability as shown in Table 24.

Table 21.   Knowledge of 3D Printing

"I know what 3D printing is"								
Response	All		USN		USAF		USA	
	#	%	#	%	#	%	#	%
Strongly disagree	0	0.00	0	0.00	0	0.00	0	0.00
Disagree	2	2.08	2	2.67	0	0.00	0	0.00
Somewhat disagree	2	2.08	2	2.67	0	0.00	0	0.00
Neither disagree or agree	3	3.13	2	2.67	1	9.09	0	0.00
Somewhat agree	18	18.75	15	20.00	2	18.18	1	10.00
Agree	37	38.54	26	34.67	7	63.64	4	40.00
Strongly agree	32	33.33	26	34.67	1	9.09	5	50.00
No response or N/A	2	2.08	2	2.67	0	0.00	0	0.00
Total	96	100	75	100	11	100	10	100

Regardless of the answer to the question that Table 21 is based on, participants were next asked to describe 3D printing in their own words. Many of the qualitative responses demonstrated some understanding of 3D printing. Full responses are included in Appendix B Part A.

Table 22.   Opinion on Usefulness of 3D Printing in Work Center

"I believe 3D printing can be very useful in my Work Center"								
Response	All		USN		USAF		USA	
	#	%	#	%	#	%	#	%
Strongly disagree	1	1.04	1	1.33	0	0.00	0	0.00
Disagree	13	13.54	12	16.00	1	9.09	0	0.00
Somewhat disagree	6	6.25	5	6.67	1	9.09	0	0.00
Neither disagree or agree	15	15.63	10	13.33	2	18.18	3	30.00
Somewhat agree	19	19.79	12	16.00	3	27.27	4	40.00
Agree	23	23.96	19	25.33	3	27.27	1	10.00
Strongly agree	14	14.58	12	16.00	0	0.00	2	20.00
No response or N/A	5	5.21	4	5.33	1	9.09	0	0.00
Total	96	100	75	100	11	100	10	100

Table 23. Use of 3D Printed Objects at Current or Previous Unit

Response	"My unit currently has and uses 3D printed objects"							
	All		USN		USAF		USA	
	#	%	#	%	#	%	#	%
Yes	8	8.33	6	8.00	1	9.09	1	10.00
No	62	64.58	48	64.00	8	72.73	6	60.00
I don't know	23	23.96	19	25.33	1	9.09	3	30.00
No response	3	3.13	2	2.67	1	9.09	0	0.00
Total	96	100	75	100	11	100	10	100

Respondents answering "Yes" were asked to provide further explanation of what the 3D printed objects were. All responses are listed here together with service affiliation:

USN—"We use 3D printed housing parts for gas turbine research."
USN—"Prototype design parts"
USN—"Ordnance item mock-ups for training."
USN—"3D printers are part of the MOVES Savage Lab. Printed parts are used as markers for augmented reality trainer."
USN—"Personal use, hobby"
USN—"Satellite components"
USAF—"Prototypes for aircraft maintenance pieces—it shortens the process of sending technical drawings to the machine shop, waiting on it and then testing, and if not exact working prototype, having to resend—it helps to print overnight and test the next morning and repeat the process if necessary."
USA—"Mostly, there are just demonstrations of the systems capabilities. From small vehicle models to various common items (bolts, washers, etc.)"

Table 24. 3D Print Capability at Current or Previous Unit

Response	"My unit currently has a 3D printing capability"							
	All		USN		USAF		USA	
	#	%	#	%	#	%	#	%
Yes	15	15.63	12	16.00	2	18.18	1	10.00
No	59	61.46	46	61.33	7	63.64	6	60.00
I don't know	19	19.79	15	20.00	1	9.09	3	30.00
No response	3	3.13	2	2.67	1	9.09	0	0.00
Total	96	100	75	100	11	100	10	100

The 11.46% of respondents shown in Table 25 who answered "Yes" were asked to provide further explanation of what the 3D printed objects were. All responses are listed here with service affiliation:

USN—"We printed test parts for research."
USN—"Prototype design parts"
USN—"Ordnance item mock-ups for training."
USN—"Models of components found in naval reactors. "
USN—"Professor Research"
USN—"Teaching aids"
USN—"Thesis work"
USN—"Satellite components"
USAF—"Aircraft maintenance prototype pieces"
USAF—"Thesis"
USA—"Items related to thesis/dissertation and instructor research"

Table 25. Unit 3D Printed Objects for Work Use

"My unit printed 3D objects for use in the work environment"								
Response	All		USN		USAF		USA	
	#	%	#	%	#	%	#	%
Yes	11	11.46	8	10.67	2	18.18	1	10.00
No	69	71.88	55	73.33	8	72.73	6	60.00
No response	16	16.67	12	16.00	1	9.09	3	30.00
Total	96	100	75	100	11	100	10	100

Tables 26 shows that most respondents do not feel that they personally could use 3D printing to make their workplace more efficient, but Tables 27 and 28 show that they believe 3D printing is useful. The responses in Table 26 are most likely indicative of a lack of training on 3D printing, and not an indictment on the ability of the technology to make a positive impact on the efficiency of the workplace.

Table 26. Immediate Workplace Impact of 3D Printing

"If given a 3D printing capability at my workplace, I could use it immediately to make my workplace more efficient"								
Response	All		USN		USAF		USA	
	#	%	#	%	#	%	#	%
Strongly disagree	6	6.25	5	6.67	0	0.00	1	10.00
Disagree	18	18.75	13	17.33	3	27.27	2	20.00
Somewhat disagree	10	10.42	7	9.33	2	18.18	1	10.00
Neither disagree or agree	28	29.17	19	25.33	4	36.36	5	50.00
Somewhat agree	12	12.50	12	16.00	0	0.00	0	0.00
Agree	9	9.38	7	9.33	1	9.09	1	10.00
Strongly agree	8	8.33	8	10.67	0	0.00	0	0.00
No response or N/A	5	5.21	4	5.33	1	9.09	0	0.00
Total	96	100	75	100	11	100	10	100

Table 27. Opinion on Impact of 3D Printing on Supply Chain and Part Storage

"I believe that a 3D printing capability would reduce the amount of spare parts that my unit stores or orders/purchases because we could print them as they are needed"								
Response	All		USN		USAF		USA	
	#	%	#	%	#	%	#	%
Strongly disagree	6	6.25	5	6.67	1	9.09	0	0.00
Disagree	10	10.42	7	9.33	3	27.27	0	0.00
Somewhat disagree	6	6.25	6	8.00	0	0.00	0	0.00
Neither disagree or agree	16	16.67	11	14.67	3	27.27	2	20.00
Somewhat agree	18	18.75	13	17.33	2	18.18	3	30.00
Agree	21	21.88	18	24.00	0	0.00	3	30.00
Strongly agree	12	12.50	10	13.33	0	0.00	2	20.00
No response or N/A	7	7.29	5	6.67	2	18.18	0	0.00
Total	96	100	75	100	11	100	10	100

Table 28.   Opinion on Usefulness of 3D Printing to Service

"I believe 3D printing can be very useful for my service"								
Response	All		USN		USAF		USA	
	#	%	#	%	#	%	#	%
Strongly disagree	0	0.00	0	0.00	0	0.00	0	0.00
Disagree	1	1.04	1	1.33	0	0.00	0	0.00
Somewhat disagree	4	4.17	4	5.33	0	0.00	0	0.00
Neither disagree or agree	16	16.67	12	16.00	4	36.36	0	0.00
Somewhat agree	21	21.88	13	17.33	3	27.27	5	50.00
Agree	30	31.25	24	32.00	2	18.18	4	40.00
Strongly agree	19	19.79	16	21.33	2	18.18	1	10.00
No response or N/A	5	5.21	5	6.67	0	0.00	0	0.00
Total	96	100	75	100	11	100	10	100

Regardless of the answer to the question that Table 28 is based on, participants were next asked to provide examples. Full responses are included in Appendix B Part B. Tables 29 and 30 signify decent awareness levels about service pursuit of 3D printing within the USN (52.00%) and USA (60.00%), but very low awareness of specific items being used (USN 8.00% and USA 20.00%).

Table 29.   Awareness of Service Pursuit of 3D Printing

"I am aware that my service is pursuing 3D printing technology"								
Response	All		USN		USAF		USA	
	#	%	#	%	#	%	#	%
Yes	48	50.00	39	52.00	3	27.27	6	60.00
No	37	38.54	26	34.67	7	63.64	4	40.00
I don't know	0	0.00	0	0.00	0	0.00	0	0.00
No response	11	11.46	10	13.33	1	9.09	0	0.00
Total	96	100	75	100	11	100	10	100

Table 30.   Awareness of Service Use of 3D Printed Objects

"I am aware of specific 3D printed objects currently being used in my service"								
Response	All		USN		USAF		USA	
	#	%	#	%	#	%	#	%
Yes	9	9.38	6	8.00	1	9.09	2	20.00
No	76	79.17	59	78.67	9	81.82	8	80.00
I don't know	0	0.00	0	0.00	0	0.00	0	0.00
No response	11	11.46	10	13.33	1	9.09	0	0.00
Total	96	100	75	100	11	100	10	100

Respondents answering "Yes" were asked to provide further explanation of what the 3D printed objects were. All responses are listed here with service affiliation:

> USN—"Replacement parts for the Osprey"
> USN—"Ordnance item mock-ups for training"
> USN—"I know they have used them, I do not remember exactly what it was"
> USN—"Don't know of specific places. Have heard of both surface fleet use and air use."
> USN—"I know some of the EOD units in San Diego are using 3D printers to print training aids"
> USN—"Fasteners"
> USAF—"Parts that are no longer being manufactured but are still being required for operations"
> USA—"Drone bodies and parts"
> USA—"Spare parts for M4 rifle"

Table 31 shows that there is some heavy doubt among respondents across all services that every command will have a 3D printer in the next 5 years. This could be due to a lack of belief in the services' investment in the technology, the wide-ranging usefulness of AM, or the need to have the capability at every command.

Table 31. Belief in Future Investment of 3D Printing

| "I believe every command within my service will have a 3D printer in the next 5 years" | | | | | | | | |
| Response | All | | USN | | USAF | | USA | |
	#	%	#	%	#	%	#	%
Yes	15	15.63	11	14.67	3	27.27	1	10.00
No	40	41.67	34	45.33	3	27.27	3	30.00
I don't know	37	38.54	26	34.67	5	45.45	6	60.00
No response	4	4.17	4	5.33	0	0.00	0	0.00
Total	96	100	75	100	11	100	10	100

The full verbatim responses to "what problem(s) do you see with respect to 3D printing" are included in Appendix B Part C, and are summarized by category in Table 32. These responses are excellent indicators of the current perception about issues involved with the adoption of 3D printing in the Naval domain and provides innovation leaders with concerns that can be directly addressed during the adoption process.

Table 32. Categories of Most Frequent Qualitative Responses to 3D Problems

| "What problem(s) do you see with respect to 3D printing" | | | | |
| Response Category | All | USN | USAF | USA |
	#	#	#	#
Cost	24	17	5	2
Quality control, certification	36	32	2	2
Safety & security	5	5	0	0
Maintenance	12	10	2	0
Non-official use & misuse	10	8	1	1
Time to make part	6	6	0	0

6.   Adoption

This section attempts to identify potential influences on the adoption of technology in the military domain including speed of adoption, leadership influence and knowledge at the service and unit levels.

Generally, the Navy's adoption speed was not highly rated with 71.89% of respondents replying with "fair" or worse as shown in Table 33. The capability to quickly

adopt new technologies is important in order for the military to compete for personnel who want to use new technologies and to stay competitive globally with countries that implement new technology quickly.

Table 33. Service Technology Adoption Speed

| "In your opinion, what is the speed with which your service adopts technology" | | | | | | | | |
| Response | All | | USN | | USAF | | USA | |
	#	%	#	%	#	%	#	%
Very poor	9	9.38	8	10.67	1	9.09	0	0.00
Poor	27	28.13	23	30.67	1	9.09	3	30.00
Fair	33	34.38	22	29.33	5	45.45	6	60.00
Good	16	16.67	14	18.67	1	9.09	1	10.00
Very good	8	8.33	6	8.00	2	18.18	0	0.00
Excellent	1	1.04	0	0.00	1	9.09	0	0.00
Exceptional	0	0.00	0	0.00	0	0.00	0	0.00
No response or N/A	2	2.08	2	2.67	0	0.00	0	0.00
Total	96	100	75	100	11	100	10	100

Service leadership (Table 34) is considered to have a large influence on the adoption of new technology, as demonstrated by over 75% of responses ranking it as "Important" or "Very important." Unit leadership results (Table 35) were slightly lower but the majority of respondents (57.29%) believe their endorsement and full support of new technology is "important" or higher as well.

Table 34. Service Leaderships' Impact on Technology Adoption

"In your opinion, how important is your service leaderships' endorsement and full support of new technology to adoption"								
Response	All		USN		USAF		USA	
	#	%	#	%	#	%	#	%
Very unimportant	4	4.17	4	5.33	0	0.00	0	0.00
Not important	1	1.04	1	1.33	0	0.00	0	0.00
Slightly not important	4	4.17	3	4.00	1	9.09	0	0.00
Neutral	7	7.29	5	6.67	0	0.00	2	20.00
Slightly important	4	4.17	4	5.33	0	0.00	0	0.00
Important	41	42.71	32	42.67	4	36.36	5	50.00
Very important	33	34.38	24	32.00	6	54.55	3	30.00
No response or N/A	2	2.08	2	2.67	0	0.00	0	0.00
Total	96	100	75	100	11	100	10	100

Table 35. Unit Leaderships' Impact on Technology Adoption

"In your opinion, how important is your unit leaderships' endorsement and full support of new technology to adoption"								
Response	All		USN		USAF		USA	
	#	%	#	%	#	%	#	%
Very unimportant	4	4.17	4	5.33	0	0.00	0	0.00
Not important	6	6.25	5	6.67	0	0.00	1	10.00
Slightly not important	5	5.21	4	5.33	0	0.00	1	10.00
Neutral	8	8.33	7	9.33	1	9.09	0	0.00
Slightly important	15	15.63	11	14.67	2	18.18	2	20.00
Important	32	33.33	25	33.33	3	27.27	4	40.00
Very important	23	23.96	16	21.33	5	45.45	2	20.00
No response or N/A	3	3.13	3	4.00	0	0.00	0	0.00
Total	96	100	75	100	11	100	10	100

Tables 36 and 37 illustrate that the perceived knowledge level about 3D printing is somewhat higher among service leadership (35.42% answered "Slightly knowledgeable" or better), than it is for unit leadership (28.13% answered "Slightly knowledgeable" or better).

Table 36. Service Leaderships' knowledge of 3D Printing

"In your opinion, how knowledgeable is your service's leadership about 3D Printing"								
Response	All		USN		USAF		USA	
	#	%	#	%	#	%	#	%
Very unknowledgeable	6	6.25	6	8.00	0	0.00	0	0.00
Not knowledgeable	12	12.50	9	12.00	2	18.18	1	10.00
Slightly unknowledgeable	10	10.42	7	9.33	2	18.18	1	10.00
Neutral	14	14.58	10	13.33	2	18.18	2	20.00
Slightly knowledgeable	16	16.67	13	17.33	1	9.09	2	20.00
Knowledgeable	17	17.71	13	17.33	2	18.18	2	20.00
Very knowledgeable	1	1.04	1	1.33	0	0.00	0	0.00
No response or N/A	20	20.83	16	21.33	2	18.18	2	20.00
Total	96	100	75	100	11	100	10	100

Table 37. Unit Leaderships' knowledge of 3D Printing

"In your opinion, how knowledgeable is your unit leadership about 3D printing"								
Response	All		USN		USAF		USA	
	#	%	#	%	#	%	#	%
Very unknowledgeable	11	11.46	8	10.67	2	18.18	1	10.00
Not knowledgeable	12	12.50	12	16.00	0	0.00	0	0.00
Slightly unknowledgeable	9	9.38	5	6.67	2	18.18	2	20.00
Neutral	20	20.83	16	21.33	2	18.18	2	20.00
Slightly knowledgeable	15	15.63	12	16.00	1	9.09	2	20.00
Knowledgeable	10	10.42	8	10.67	1	9.09	1	10.00
Very knowledgeable	2	2.08	2	2.67	0	0.00	0	0.00
No response or N/A	17	17.71	12	16.00	3	27.27	2	20.00
Total	96	100	75	100	11	100	10	100

Tables 38 and 39 suggest that while there is some apparent support for 3D printing at the service and unit leadership levels, most respondents were "Neutral" on the topic (37.50% in Table 38, 42.71% in Table 39).

Table 38. Service Leaderships' Support of 3D Printing

"In your opinion, how supportive is your service's leadership of 3D Printing"								
Response	All		USN		USAF		USA	
	#	%	#	%	#	%	#	%
Very unsupportive	3	3.13	2	2.67	1	9.09	0	0.00
Not supportive	3	3.13	2	2.67	1	9.09	0	0.00
Slightly unsupportive	1	1.04	1	1.33	0	0.00	0	0.00
Neutral	36	37.50	30	40.00	3	27.27	3	30.00
Slightly supportive	10	10.42	6	8.00	1	9.09	3	30.00
Supportive	18	18.75	14	18.67	2	18.18	2	20.00
Very supportive	2	2.08	1	1.33	1	9.09	0	0.00
No response or N/A	23	23.96	19	25.33	2	18.18	2	20.00
Total	96	100	75	100	11	100	10	100

Table 39. Unit Leaderships' Support of 3D Printing

"In your opinion, how supportive is your unit's leadership of 3D printing"								
Response	All		USN		USAF		USA	
	#	%	#	%	#	%	#	%
Very unsupportive	5	5.21	4	5.33	1	9.09	0	0.00
Not supportive	5	5.21	4	5.33	1	9.09	0	0.00
Slightly unsupportive	2	2.08	1	1.33	0	0.00	1	10.00
Neutral	41	42.71	35	46.67	2	18.18	4	40.00
Slightly supportive	5	5.21	4	5.33	0	0.00	1	10.00
Supportive	12	12.50	9	12.00	2	18.18	1	10.00
Very supportive	3	3.13	2	2.67	1	9.09	0	0.00
No response or N/A	23	23.96	16	21.33	4	36.36	3	30.00
Total	96	100	75	100	11	100	10	100

7. Cyber

Prior to answering questions in this section of the survey, participants were provided with the following definition of cyber security:

The prevention of damage to, protection of, and restoration of computers, electronic communications systems, electronic communications systems services, wire communication, and electronic communication, including information contained therein, to ensure its availability, integrity, authentication, confidentiality and non-repudiation. (The White House, 2008)

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All surveys participants who answered the question regarding whether they had cyber security training in the past, had received some type of cyber security training per Table 40.

Table 40. Cyber Security Training Exposure

"I have received cyber security training in the past"								
Response	All		USN		USAF		USA	
	#	%	#	%	#	%	#	%
Yes	90	93.75	71	94.67	9	81.82	10	100.00
No	0	0.00	0	0.00	0	0.00	0	0.00
I don't know	0	0.00	0	0.00	0	0.00	0	0.00
No response	6	6.25	4	5.33	2	18.18	0	0.00
Total	96	100	75	100	11	100	10	100

Additionally, Table 41 shows that most (77.08%) had cyber security training in the past six months and all had it within the last year. General military training requirements are the most likely reason for the high positive response to this question.

Table 41. Cyber Security Training Timeframe

"When was the last time you received cyber security training"								
Response	All		USN		USAF		USA	
	#	%	#	%	#	%	#	%
Within the past 6 months	74	77.08	64	85.33	3	27.27	7	70.00
Within the last year	16	16.67	7	9.33	6	54.55	3	30.00
Within the last two years	0	0.00	0	0.00	0	0.00	0	0.00
More than two years ago	0	0.00	0	0.00	0	0.00	0	0.00
Other	0	0.00	0	0.00	0	0.00	0	0.00
No response or N/A	6	6.25	4	5.33	2	18.18	0	0.00
Total	96	100	75	100	11	100	10	100

Table 42 reflects that even though most participants had recently had cyber security training, they were still concerned about security of their personal devices with 81.26% replying they were at least "Slightly concerned."

Table 42. Level of Concern about Cyber Security for Personal Devices

"What is your attitude towards cyber security related issues when using your personal technology devices"								
Response	All		USN		USAF		USA	
	#	%	#	%	#	%	#	%
Very unconcerned	3	3.13	1	1.33	1	9.09	1	10.00
Not concerned	2	2.08	2	2.67	0	0.00	0	0.00
Slightly not concerned	6	6.25	5	6.67	1	9.09	0	0.00
Neutral	3	3.13	2	2.67	1	9.09	0	0.00
Slightly concerned	17	17.71	11	14.67	3	27.27	3	30.00
Concerned	33	34.38	26	34.67	1	9.09	6	60.00
Very concerned	28	29.17	26	34.67	2	18.18	0	0.00
No response or N/A	4	4.17	2	2.67	2	18.18	0	0.00
Total	96	100	75	100	11	100	10	100

Table 43 shows that the majority of respondents (58.33%) had not experienced a cyber security problem on their personal technology devices, but for those who did the timeframe for that incident is displayed in Table 44. Furthermore, most participants (81.26%) were at least "Slightly concerned" about cyber security for their personal devices even if they had not personally experienced issues. These results suggest that current and future military innovators care about cyber security, and it should be addressed when adopting new technology in the military.

Table 43. Personally Experienced Cyber Security Problem

"I have experienced cyber security related problems when using my personal technology devices"								
Response	All		USN		USAF		USA	
	#	%	#	%	#	%	#	%
Yes	32	33.33	26	34.67	3	27.27	3	30.00
No	56	58.33	44	58.67	6	54.55	6	60.00
I don't know	0	0.00	0	0.00	0	0.00	0	0.00
No response	8	8.33	5	6.67	2	18.18	1	10.00
Total	96	100	75	100	11	100	10	100

Table 44. Cyber Security Problem Timeframe

"When was the last time you experienced a cyber security related problem"								
Response	All		USN		USAF		USA	
	#	%	#	%	#	%	#	%
Within the past 6 months	11	11.46	10	13.33	1	9.09	0	0.00
Within the last year	6	6.25	3	4.00	1	9.09	2	20.00
Within the last two years	7	7.29	6	8.00	1	9.09	0	0.00
More than two years ago	8	8.33	7	9.33	0	0.00	1	10.00
Other	0	0.00	0	0.00	0	0.00	0	0.00
No response or N/A	64	66.67	49	65.33	8	72.73	7	70.00
Total	96	100	75	100	11	100	10	100

Tables 45 and 46 suggest that most participants do not feel the need for additional cyber security training (86.47% responded with "Fair" or better) and have confidence in the cyber security capabilities of their work systems.

Table 45. Amount of Cyber Security Training

"In terms of protecting your work, how would you qualify the amount of cyber security training you received"								
Response	All		USN		USAF		USA	
	#	%	#	%	#	%	#	%
Very poor	4	4.17	3	4.00	1	9.09	0	0.00
Poor	4	4.17	3	4.00	1	9.09	0	0.00
Fair	22	22.92	18	24.00	2	18.18	2	20.00
Good	27	28.13	18	24.00	5	45.45	4	40.00
Very good	17	17.71	15	20.00	0	0.00	2	20.00
Excellent	10	10.42	9	12.00	0	0.00	1	10.00
Exceptional	7	7.29	6	8.00	0	0.00	1	10.00
No response or N/A	5	5.21	3	4.00	2	18.18	0	0.00
Total	96	100	75	100	11	100	10	100

Table 46. Cyber Security Protection of Technology Devices Used at Work

"What is your level of confidence in the cyber security capabilities of the technology devices you use on the job to protect you work"								
Response	All		USN		USAF		USA	
	#	%	#	%	#	%	#	%
Very poor	6	6.25	5	6.67	1	9.09	0	0.00
Poor	6	6.25	6	8.00	0	0.00	0	0.00
Fair	19	19.79	15	20.00	3	27.27	1	10.00
Good	20	20.83	16	21.33	0	0.00	4	40.00
Very good	27	28.13	19	25.33	5	45.45	3	30.00
Excellent	9	9.38	8	10.67	0	0.00	1	10.00
Exceptional	4	4.17	3	4.00	0	0.00	1	10.00
No response or N/A	5	5.21	3	4.00	2	18.18	0	0.00
Total	96	100	75	100	11	100	10	100

Table 47 indicates that most respondents were divided about whether cyber security measures prevent access to helpful work-related material with 38.55% "Somewhat disagreeing" or below, and 41.67% "Somewhat agreeing" or above.

Table 47. Prevention of Access to Helpful Content Due to Cyber Security

"Cybersecurity measures prevent me from accessing content that would be helpful in my job"								
Response	All		USN		USAF		USA	
	#	%	#	%	#	%	#	%
Strongly disagree	4	4.17	3	4.00	0	0.00	1	10.00
Disagree	22	22.92	20	26.67	1	9.09	1	10.00
Somewhat disagree	11	11.46	8	10.67	1	9.09	2	20.00
Neither disagree or agree	13	13.54	10	13.33	3	27.27	0	0.00
Somewhat agree	22	22.92	16	21.33	1	9.09	5	50.00
Agree	10	10.42	9	12.00	1	9.09	0	0.00
Strongly agree	8	8.33	6	8.00	2	18.18	0	0.00
No response or N/A	6	6.25	3	4.00	2	18.18	1	10.00
Total	96	100	75	100	11	100	10	100

The results in Table 48 suggest that there is not a clear connection for most participants between cyber security and 3D printing as 41.67% answered at most "Neither disagree or agree" to the question.

Table 48. Relationship Between 3D Printing and Cyber Security

"Cyber security is a concern related to 3D printing"								
Response	All		USN		USAF		USA	
	#	%	#	%	#	%	#	%
Strongly disagree	2	2.08	2	2.67	0	0.00	0	0.00
Disagree	3	3.13	2	2.67	1	9.09	0	0.00
Somewhat disagree	4	4.17	3	4.00	0	0.00	1	10.00
Neither disagree or agree	31	32.29	23	30.67	6	54.55	2	20.00
Somewhat agree	15	15.63	10	13.33	1	9.09	4	40.00
Agree	17	17.71	16	21.33	1	9.09	0	0.00
Strongly agree	13	13.54	10	13.33	0	0.00	3	30.00
No response or N/A	11	11.46	9	12.00	2	18.18	0	0.00
Total	96	100	75	100	11	100	10	100

Participants had mixed opinions regarding the trustworthiness of 3D printed objects and files. Table 49 showed that 26.05% of respondents disagreed at some level that they would have confidence in the trustworthiness of 3D printed objects at work, while 42.71% agreed at some level. However, Table 50 conveys the same amount of trust for a 3D digital file, as 42.71% of applicants "somewhat agreed," "agreed," or "strongly agreed" that they would have confidence that the file would be protected from compromise or modification.

Table 49. Trust of 3D Printed Object

"If my unit provided 3D printed objects at work, I would have confidence that the object is trustworthy to accomplish the intended purpose"								
Response	All		USN		USAF		USA	
	#	%	#	%	#	%	#	%
Strongly disagree	5	5.21	4	5.33	1	9.09	0	0.00
Disagree	10	10.42	10	13.33	0	0.00	0	0.00
Somewhat disagree	10	10.42	8	10.67	0	0.00	2	20.00
Neither disagree or agree	18	18.75	12	16.00	4	36.36	2	20.00
Somewhat agree	20	20.83	14	18.67	3	27.27	3	30.00
Agree	18	18.75	14	18.67	1	9.09	3	30.00
Strongly agree	3	3.13	3	4.00	0	0.00	0	0.00
No response or N/A	12	12.50	10	13.33	2	18.18	0	0.00
Total	96	100	75	100	11	100	10	100

Table 50. Trust of 3D Digital File

"I have confidence that a digital 3D file provided by my unit would be properly protected from compromise or modification"								
Response	All		USN		USAF		USA	
	#	%	#	%	#	%	#	%
Strongly disagree	7	7.29	6	8.00	1	9.09	0	0.00
Disagree	12	12.50	11	14.67	0	0.00	1	10.00
Somewhat disagree	9	9.38	8	10.67	0	0.00	1	10.00
Neither disagree or agree	15	15.63	10	13.33	5	45.45	0	0.00
Somewhat agree	16	16.67	11	14.67	2	18.18	3	30.00
Agree	22	22.92	16	21.33	1	9.09	5	50.00
Strongly agree	3	3.13	3	4.00	0	0.00	0	0.00
No response or N/A	12	12.50	10	13.33	2	18.18	0	0.00
Total	96	100	75	100	11	100	10	100

G. CHAPTER SUMMARY

This chapter provided insight into the research survey's creation, approval and implementation process, as well as participant recruitment and access to the survey. Additionally, statistics were provided to support noteworthy conclusions regarding the opinions of survey participants. While a larger and more diverse population would be desirable, the findings are a good indicator of the opinions of current and future military technology innovation leaders or "change agents."

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V. CONCLUSIONS AND RECOMMENDATIONS

A. MAIN CONCLUSIONS

Generally, cyber is an unknown, at times mysterious, and misunderstood domain. IT users often believe that cybersecurity creates extra work when they want to be able to use technology as effortlessly as possible. Providing user education and sufficient, easy to follow documentation can help alleviate user frustrations but overly laborious or complicated cybersecurity measures can impede potential adoption of new technology. However, acceptable security must be achieved that balances user trust in the system with potential vulnerabilities that exist based on human interaction with the data, data creation, data storage, data sharing, and data translation into physical form.

1. Layered Solutions

Cybersecurity for AM requires layered solutions applied at all stages of the life cycle. Addressing cybersecurity while Naval AM capabilities are still in their infancy allows for broad, built-in, proactive solutions that minimize costly reactive patches that only address specific threats later in the life cycle. Additionally, cybersecurity supports adoption of AM technology by building trust in the technology from end-users and decision makers. Just as cyber touches all other warfare areas, AM technology can benefit all warfare areas as well. Programs like annual required cybersecurity training for all Sailors and NPS's newly piloted "All Hands General Cyber Course" help, but tailored, system specific AM training is still needed to reduce the greatest threat, the human threat, to AM cybersecurity.

2. Stand-Alone Ability

Fully operationalizing AM requires the ability to utilize it in a stand-alone configuration. This would necessitate preloading all digital files, having trained maintenance personnel, developing access and authentication methods, and having supporting policy in place for accounting for printed objects. The more connected and network dependent the AM system is, the more vulnerable it is to cyber-attacks and the

less useful and reliable it will be to Sailors. Navy ships are ideal locations for incorporating AM technology because they have the capability to operate independently of the shore-based power grids. Their ability to create their own electricity means they can deliver AM capabilities to any mission anywhere in the world.

3. Adoption Impediments

Cybersecurity poses a very real threat to the potential for large-scale adoption of AM technology in the Naval domain. If Navy leadership does not trust that the technology is safe from cyber threats, they will not substantially invest in it. Additionally, if Sailors do not trust the products they get from AM or if the AM process is overly encumbered by non user friendly security measures, they will default to traditional methods and resist mandatory change implemented from a top down approach. Accepting that users are the biggest threats, targets, and vulnerabilities in the cybersecurity domain, means investing in improving user behavior through training designed to produce security outcomes that provide more fundamental protection.

The survey results show that leadership plays an extremely important role in the large-scale adoption of innovation at both the service and unit level. Leaders are critical to the process and should not be expected to effectively implement innovation without appropriate training. Creating a culture of innovation with the Navy is a difficult challenge. However, adding innovation into the curriculum at Naval Officer education programs such as ROTC units, NPS and Naval War College would be a great start towards training innovation leaders. Beyond infusing the Officer ranks with innovation training, every service member can be an innovation leader if the culture embraces it.

B. THESIS CONTRIBUTIONS

The Navy is becoming more reliant on the civilian technology sector and utilizing COTS solutions whenever possible. This reliance does not come without added risk because the adversary can purchase the same systems that the Navy has, and find ways to compromise them. Military organizations like DIUX are making procurement of those technologies faster and more affordable then ever before, and the Secretary of the Navy Tours with Industry (SNTWI) program helps provide the Navy with personnel that have

valuable knowledge and skills about practices that can translate from the civilian domain to the Naval domain. However, adoption of those technologies and practices relies on developing a culture of innovation within the Navy. Building that culture requires an investment in teaching Sailors to think like innovators by embedding innovation training at all levels of the Chain of Command. Innovation should not be limited to R&D and procurement organizations; it should be the responsibility of leaders at every level (Hamel & Tennant, 2015).

The same is true in regards to cybersecurity. According to the National Military Strategy for Cyberspace Operations, "leaders at all levels are accountable for ensuring readiness and security to the same degree as in any other domain" (Office of the Chairman of the Joint Chiefs of Staff, 2006). NPS provides an excellent opportunity to teach approximately 500 Naval Officers per year about innovation and cyber if those topics were included in all curriculums as shown in Figure 11 (Naval Postgraduate School Command Brief, 2016).
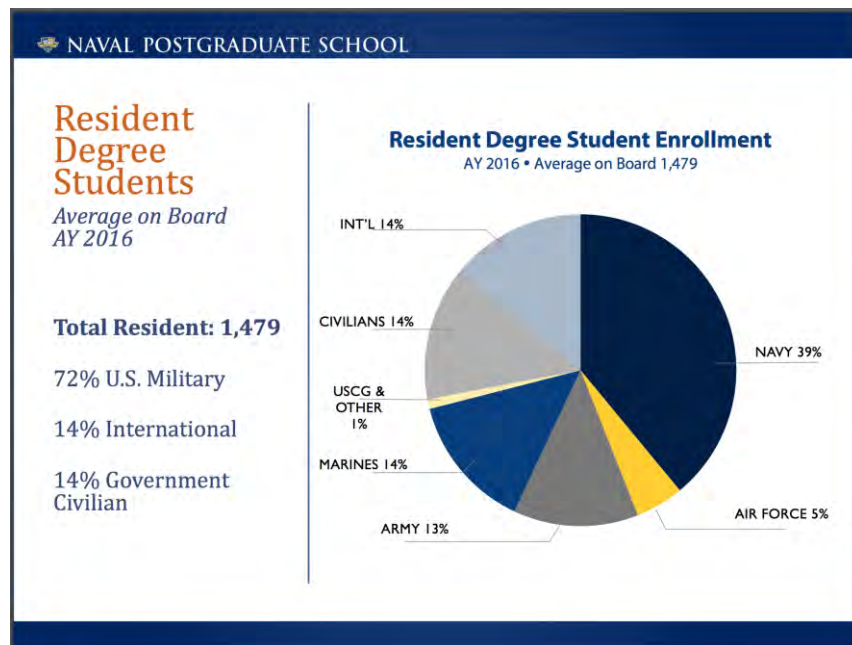
Figure 11. NPS Resident Student Enrollment.
Source: NPS Command Brief (2016).

Currently at NPS, the Innovation Leadership course provides theoretical concepts, practical exercises, and applications that lay the groundwork to transform students into innovation leaders. However, this is an elective course with a small throughput relative to the NPS student population. If the Navy is serious about promoting a culture of cybersecurity awareness and innovation, NPS is one option for planting the seed for both in future Naval leaders.

Additionally, the environment should be conducive to challenging traditional methods. The Navy is often slow to change and heavily reliant on precedent, factors that can be counter productive to innovation. This does not suggest that everyone should be or is even capable of being an innovator, some individuals are naturally more inclined towards the practice than other—but rather as a Navy it is highly recommended that service members be generally trained about how to innovate and encourage our Sailors to challenge the status quo. The Navy practice is heavily inclined towards quantifying and justifying everything based on metrics, but it is important to recognize that metrics for innovation are difficult and the requirement for metrics may hinder the speed of innovation.

There are two primary methods for AM implementation in the Navy. The first is providing AM capabilities and training to commands and the second is in the form of Naval Fabrication Labs. Commands provided with AM would need trained personnel and guidance as to what and who are authorized to utilize the equipment. A case can be made for every ship and command in the Navy to have some type of 3D printing capability. Consider the increased capabilities of the Navy's hospital ships if they were equipped with bio printers. These ships spend most of their time assigned to Humanitarian and Disaster Relief (HADR) missions and have the capacity to serve as up to a 1,000 bed mobile hospital (Department of the Navy [DON], n.d.). With bio printers capable of printing human tissue and organs, these ships could provide advanced medical treatment that technologically is not available in the majority of the World. Rapid deployment of printing platforms for testing and also for use in 3D production of bio materials to support HADR missions, such as USNS Comforts recent assignment to Puerto Rico in the aftermath of Hurricane Maria (Garamone, 2017) would be impressive, but adding it to

the medical services provided to warfighters in a combat zone would be extraordinary and would undoubtedly save service members' lives.

C. FUTURE WORK

This section suggests further research into the development of a Joint AM solution to aid in adoption, which would allow all services to benefit from shared AM capabilities. Additionally, the emergence of Blockchain technology may provide an answer to securing a large portion of the AM life cycle and warrants further study.

1. Joint AM

Current AM approaches vary greatly throughout the U.S. military services and appear to be allowing each service to develop AM capabilities in a bubble, isolated from one another. This will undoubtedly result in separate solutions in each service that will likely be incompatible, especially if each service has different digital infrastructures and cybersecurity solutions for AM. However, in order for the DOD to fully capitalize on the potential of AM, a solution that can be applied to a joint environment is necessary. Joint operations are the norm in modern day military environments and officers throughout the services are expected to pursue Joint Professional Military Education (JPME) and achieve joint qualifications.

Future application of AM could result in forward deployed service members 3D printing parts and supplies while engaged in joint operations around the world. Speaking at the Air Force Association's Air, Space, and Cyber Conference, Commander Air Force Material Command General Pawlikowski stated, "The future of Air Force logistics will find Airmen tapping into a secure digital network or archived additive manufacturing specifications, allowing for the 3D-printed creation of a weapons system component whenever and wherever needed" (National Center For Manufacturing Sciences [NCMS], 2017). The same vision can be applied in each of the armed forces but it would be wasteful for each service to bring a separate AM capability to an operation when a joint AM solution could be developed for all services. Additionally, if the separate service AM solutions are incompatible, then the benefits of redundancy that could be available from a joint solution are minimized and an AM system failure of any one system could cripple

that unit's combat readiness. However, if a joint AM solution were deployed, all units with AM capability could serve as backups to each other.

If forward deployed AM capabilities are going to be used in joint operations, then they must be developed with joint standards, qualifications, accreditation, security infrastructure, and processes to enable sharing across the DOD. More research should be done into how best to develop and implement a collaborative AM solution that aligns the development of AM between the services towards the goal of achieving a joint solution. Organizations such as Defense Innovation Unit Experimental (DIUX) and Joint Interoperability Test Command (JITC) have experience developing joint solutions and should be leveraged against the AM problem set with the goal of developing a Unified Additive Manufacturing Services Management Office.

2.   Blockchain applicability

The scope of this thesis did not include investigating technical cybersecurity solutions to the cyber-physical AM problem set but that is certainly an area for follow on research and devolvement. A possible way forward is through the application of Blockchain technology, which can create a secure, immutable record of anything that is describable in digital form. Since the Blockchain concept was first introduced by Satoshi Nakamoto in his paper "Bitcoin: A Peer-to-Peer Electronic Cash System," applications and variations of Blockchains have grown exponentially. Nakamoto's implementation, which relies on public and private keys, constant proof-of-work effort by participants to create the next block, and incentives for participant based on transaction fees, included the necessity to publicly announce all transactions (Nakamoto, 2008). However, privacy-friendly solutions such as Gaurdtime Federal's Keyless Signature Infrastructure are now available that would allow permission-based participation in an AM Blockchain across a distributed network that could track the full AM life cycle including hardware development, digital thread, and part provenance. Applying this type of solution in a communications degraded or denied environment could present some unique challenges, and classification levels would have to be considered as AM technology and capabilities grow to the point of being able to create classified objects.

APPENDIX A. IRB DOCUMENTATION AND SURVEY

Naval Postgraduate School
Human Research Protection Program

From: President, Naval Postgraduate School (NPS)
To: Dr. Amela Sadagic, Modeling, Virtual Environments, and
Simulation (MOVES) Institute
LCDR Michael Grimshaw, USN
Via: Vice Chairman, Institutional Review Board (IRB)

SUBJ: OWNERSHIP AND USE OF TECHNOLOGY

Encl: (1) Approved IRB Initial Review Protocol

1. The NPS IRB is pleased to inform you that the NPS President
has approved your initial review protocol (NPS IRB#
NPS.2018.0006-IR-EP7-A). The approved IRB Protocol is found in
enclosure (1). Completion of the CITI Research Ethics Training
has been confirmed.

2. This approval expires on 25 October 2018. If additional
time is required to complete the research, a continuing review
report must be approved by the IRB and NPS President prior to
the expiration of approval. At expiration all research (subject
recruitment, data collection, analysis of data containing PII)
must cease.

3. You are required to obtain documented consent as outlined in
the approval protocol.

4. You are required to report to the IRB any unanticipated
problems or serious adverse events to the NPS IRB within 24
hours of the occurrence.

5. Any proposed changes in IRB approved research must be
reviewed and approved by the NPS IRB and NPS President prior to
implementation except where necessary to eliminate apparent
immediate hazards to research participants and subjects.

6. As the Principal Investigator (PI) it is your responsibility
to ensure that the research and the actions of all project
personnel involved in conducting this study will conform with
the IRB approved protocol and IRB requirements/policies.

SUBJ: OWNERSHIP AND USE OF TECHNOLOGY

7. At completion of the research, no later than expiration of approval, the PI will close the protocol by submitting an End of Experiment Report.

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DN: c=US, o=U.S. Government, ou=DoD,
ou=PKI, ou=USN,
cn=COX BRENNAN DANIEL 1392564132
Date: 2017.11.01 11:04:06 -07'00'

LCDR Brennan D. Cox, PhD, MSC, USN
Vice Chair
Institutional Review Board

Ronald A. Route
Vice Admiral, U.S. Navy (Ret.)
President, Naval Postgraduate School

Date: NOV 0 1 2017

NPS IRB
Initial Review Checklist
last updated 3-6-17

Title of Research:	Ownership and use of technology		
Principal Investigator:	Dr. Amela Sadagic	Department:	MOVES
Co-Investigator(s):			
Student Investigator(s):	LCDR Michael Grimshaw, USN		

1.	PREREQUESITES	YES	NO	N/A
a.	CITI training has been completed by all investigators and engaged research personnel.	☒	☐	
b.	Research proposal is provided.	☒	☐	
c.	An adequate scientific review has been completed and forwarded to the IRB. If exempt check "N/A." *Completed by dept. Chair or designated reviewer.*	☒	☐	☐
d.	Conflict of interest disclosure form is signed by all engaged researchers and forwarded to the IRB.	☒	☐	
e.	All investigators are covered by an appropriate assurance to conduct research involving human subjects.	☒	☐	
f.	Data collection tools are attached.	☐	☐	☒
g.	Any question as to whether research was conducted prior to final approval has been resolved & documented.	☐	☐	☒
h.	Application is signed by the principal investigator.	☒	☐	
i.	The following areas of research cannot be approved by the NPS IO. *If checked yes to any of the below, contact DON HRPP for guidance.*	YES	NO	N/A
	Waiver of consent of experimental subjects (SECNAV)	☐		☒
	Exemption of informed consent requirements for emergency research (FDA) under 21 CFR 50. (SECNAV)	☐		☒
	Waiver of requirements of DON HRPP policy (SECNAV)	☐		☒
	Severe or unusual intrusions, either physical or psychological (UNSECNAV)	☐		☒
	Prisoners (UNSECNAV)	☐		☒
	Potentially or inherently controversial topics (UNSECNAV)	☐		☒
	Exposure of human subjects to nuclear, biological or chemical warfare agents or weapons (DDR&E)	☐		☒
	Protocols that require action by an official of DHHS (DDR&E)	☐		☒
	Classified research (SECDEF)	☐		☒
	Research involving Marine population (USMC IRB)	☐		☒
2.	SUBJECT POPULATION(S) & RECRUITMENT	YES	NO	N/A
a.	Subject selection is equitable (32 CFR 219.111 (a)(3)). *Consider factors such as the purposes of the research, the setting in which research will be conducted, special problems of research involving vulnerable populations, recruitment & enrollment procedures, influence of payments.*	☒	☐	
b.	Access to a population that will allow recruitment of the necessary number of subjects. *If no subjects are recruited skip to question 3.*	☒	☐	☐
c.	Protocol provides rationale for stated sample size.	☒	☐	☐
d.	Adequate information was provided as to how subjects are to be recruited.			
	· Describes how subjects are contacted.	☒	☐	
	· States when and how often subjects will be recruited.	☒	☐	
	· States where subjects will be recruited.	☒	☐	
	· States who will be contacting potential subjects.	☒	☐	
	· Includes how subject contact information was obtained.	☒	☐	
	· Senior leadership will not be present during the recruitment procedure.	☒	☐	
	· If Service members are recruited in a group setting the IRB has considered the possible need of an ombudsman (DoDI 3216.02. Encl 1, 7.e.(1) (d)).	☐	☐	☒

65

			YES	NO	N/A
e.	Recruitment procedures ensure voluntary participation.		☒	☐	
f.	Recruitment materials are attached. If exempt check "N/A" and skip to Q3.		☒	☐	☐
	Recruitment materials include the following:				
	· Statement that project is research.		☒	☐	
	· Identifies NPS as the institution performing the research.		☒	☐	
	· Clearly states the purpose of the research.		☒	☐	
	· Describes procedures subjects are asked to perform.		☒	☐	
	· States participation is voluntary.		☒	☐	
	· Describes the sign-up process.		☒	☐	
	· Includes contact information for the PI and IRB Chair.		☒	☐	
3.	**VULNERABLE POPULATIONS - MILITARY & DOD CIVILIANS** (DoDI 3216.02 Encl. 3 Para. 7)		YES	NO	N/A
a.	If the data will be collected from subjects in a command other than NPS, evidence that the Commanding Officer is aware of the research and agrees to it being conducted is provided.		☐	☐	☒
b.	Senior officers are not present during, or responsible for, the recruitment or consent process of junior officers		☐	☐	☒
c.	Investigators consider a plan to manage military members who deploy.		☐	☐	☒
d.	Supervisors are not present during recruitment or consent of process involving DoD Civilians.		☐	☐	☒
4.	**VULNERABLE POPULATIONS - Other (32 CFR 219.111(7)(b))**		YES	NO	N/A
a.	Use of pregnant women, neonates, or fetuses. All regulatory requirements of 32 CFR 46, subpart B are met.		☐	☐	☒
b.	Use of children. All regulatory requirements of 32 CFR 46, subpart D are met.		☐	☐	☒
c.	Use of prisoners. All regulatory requirements of 32 CFR 46, subpart C are met.		☐	☐	☒
5.	**METHODOLOGY/DATA DISPOSITION**		YES	NO	N/A
a.	Adequate description of all activities involving human subjects. *Who, what, when, where & how*		☒	☐	☐
b.	Detailed summary of data collection (questionnaires, interviews, observations, standardized tests, data sets other).		☒	☐	
c.	Detailed summary of methods of data recording (field notes, audiotape, videotape, computer entry, etc).		☒	☐	
d.	Sufficient explanation of storage of data.		☒	☐	
e.	Description of data use plan.		☒	☐	
6.	**POTENTIAL RISKS & BENEFITS**		YES	NO	N/A
	Please note that the IRB: · should consider physical, psychological, social, economic <u>and</u> legal risks · should consider <u>only</u> those risks & benefits resulting from the research · should <u>not</u> consider possible long-range effects of applying knowledge gained in the research				
a.	Adequate descriptions of risks, benefits and alternatives.		☒	☐	
b.	Risks to subjects are minimized (32 CFR 219.111(a)(1)):				
	· by using procedures that are consistent with sound research design and that do not unnecessarily expose subjects to risk		☒	☐	
	· whenever appropriate, by using procedures already being performed on subjects for diagnostic or treatment purposes		☐	☐	☒
c.	Risks to subjects are reasonable in relation to (32 CFR 219.111 (a)(2)):				
	· anticipated benefits, if any, to subjects		☐	☐	☒
	· importance of knowledge reasonably expected to result		☒	☐	
d.	Adequate provisions to protect the <u>privacy</u> of subjects (32 CFR 219.111(a)(7)). *Only personal data that are relevant and necessary is collected. Data are properly stored and coded if necessary.*		☒	☐	
e.	Adequate provisions to maintain the <u>confidentiality</u> of data (32 CFR 219.111(a)(7)). *Only members of the research team will have access to data.*		☒	☐	☐
7.	**MONITORING OF DATA**		YES	NO	N/A
a.	Monitoring of data required to ensure safety of subjects (32 CFR 219.111(a)(6)). *(i.e. the research poses greater than minimal risk)*		☐	☐	☒
b.	Adequate provisions for data monitoring to ensure safety of subjects (*i.e. changes in frequency/character of adverse events will be detected & reported in a time frame that ensures protection of subjects*)		☐	☐	☒
c.	If NPS is the lead site of a multi-site study, the plan for management of research information is provided.		☐	☐	☒

8.	INFORMED CONSENT	YES	NO	N/A
a.	Legally effective informed consent will be sought from each prospective subject or legally authorized representative in accordance with, and to the extent required by Sec. 219.117 (32 CFR 219.111(a)(4)). *If exempt check "N/A" and skip to Q9.* *If no skip to question 9 and remember to complete Q13 Consent Waivers*	☒	☐	☐
b.	Information is in language understandable to subjects or representatives.	☒	☐	
c.	There is no exculpatory language through which subjects or representatives are made to: · waive or appear to waive any legal rights OR · release or appear to release the investigator, the sponsor, the institution or its agents from liability for negligence.	☒	☐	
d.	Informed consent will be obtained prior to research activity.	☒	☐	
e.	Informed consent will be appropriately documented in accordance with, and to the extent required by Sec. 219.117 (32 CFR 219.111(a)(5)). *If a waiver of documentation is requested please complete Question 13 Consent Waivers*	☒	☐	
f.	A copy of the consent form will be given to the person signing the consent document.	☐	☒	
g.	The circumstances of the consent process minimize the possibility of coercion or undue influence.	☒	☐	
h.	The subject or the subject's legally authorized representative will sign the consent document. *If no a waiver of documented consent should be requested.*	☒	☐	
	Basic Elements - 32 CFR 219.116(a)			
i.	Statement that the study involves research. *Statement includes PI and institution name.*	☒	☐	
j.	Explanation of the purposes of the research. *Matches purpose stated in application Q6.*	☒	☐	
k.	Expected duration of subject's participation. *Matches duration stated in application Q8.*	☒	☐	
l.	Description of procedures to be followed.	☒	☐	
m.	Identification of any procedures which are experimental.	☐	☐	☒
n.	Description of <u>reasonably foreseeable</u> risks or discomforts. *Any risks/discomforts disclosed in the IRB application should be listed in the consent form.*	☒	☐	
o.	Description of any benefits to the subjects or to others. *If there is no benefit to the subject, the consent form should state "There is no direct benefit to you for participating in the research."*	☒	☐	
p.	Disclosure of appropriate alternative procedures or courses of treatments, if any. *If there are not alternatives the consent form should state "The alternative to participating in the research is to not participate."*	☒	☐	☐
q.	Description of how confidentiality will be maintained. *(i.e. password protected computer, locked office)*	☒	☐	
r.	Information on availability of medical treatment if injury occurs; an explanation as to whether any compensation is provided; and the name and contact information of the medical monitor (if research poses greater than minimal risk).	☐	☒	
s.	Who to contact with questions about the research. *PI name and phone #*	☒	☐	
t.	Who to contact with questions about subject's rights. *IRB Chair name and phone #*	☒	☐	
u.	Who to contact in the event of a research related injury.	☒	☐	
v.	Statement that participation is voluntary, refusal to participate will involve no penalty or lost of benefits to which a subject is otherwise entitled; and, the subject may discontinue participation at any time without penalty or loss of benefits to which the subject is otherwise entitled.	☒	☐	
	Additional Elements (When appropriate) **- 32 CFR 219.116(b)**			
w.	A statement that the treatment or procedure may involve risks to the subject (or to the embryo or fetus, if the subject is or may become pregnant) which are currently unforeseeable.	☐	☐	☒
x.	Anticipated circumstances under which the subject's participation may be terminated by the investigator without regard to the subject's consent.	☐	☐	☒
y.	Any additional costs to the subject that may result from participation in the research. *If there is no cost state "There are no costs to participate in the research."*	☒	☐	☐
z.	The consequences of a subject's decision to withdraw from the research and procedures for orderly termination of participation by the subject.	☒	☐	☐
aa.	The approximate number of subjects involved in the study. *Matches number stated in application Q15.*	☒	☐	☐
	Short Form Consent Document - 45 CFR 46.117(b)(2)	YES	NO	N/A
bb.	Will a short form be used to obtain informed consent? *If yes complete Appendix B.*	☐	☐	☒
9.	INTERNATIONAL RESEARCH	YES	NO	N/A
a.	Is any part of the research conducted internationally? *If no skip to question 10.*	☐	☒	

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			YES	NO	N/A
b.	Host country approval has been forwarded to the IRB.		☐	☐	
c.	Host country ethics review has been forwarded to the IRB.		☐	☐	
10.	**COMPENSATION** - DoDI 3216.02 Encl 3 Para 11. *For Non-DoD Conducted research reference DoDI 316.02 Encl 3 Para 11.*		YES	NO	N/A
a.	Is compensation provided to subjects? *If no skip to question 11.*		☐	☒	
b.	Are subjects federal employees (civil servants and/or service members)? *If no skip to 10e.*		☐	☐	
b.	On duty personnel (civil servants and service members) will not receive compensation.		☐	☐	
c.	Payment to off- duty federal personnel is reasonable amount according to the nature of the research.		☐	☐	
d.	Payment to off-duty federal personnel is not directly from a federal source.		☐	☐	
e.	Payment to non-federal personnel is reasonable amount according to the nature of the research.		☐	☐	
11.	**RISK DETERMINATION**		YES	NO	N/A
a.	**Minimal Risk:** the probability and magnitude of harm or discomfort anticipated in the research are not greater, in and of themselves, than those ordinarily encountered in daily life, or during the performance of routine physical or psychological examinations or tests (32 CFR 2019.102(i)). *If yes skip to Q12.*		☒	☐	
b.	**Greater than Minimal Risk:** human subject research that is not minimal risk		☐	☐	
	· There is an appropriate emergency treatment plan with sufficient supplies and equipment is available to administer immediate care.		☐	☐	
	· If research involves service members and recruitment occurs in a group setting an ombudsman is appointed (ombudsman may also be research monitor). (DoDI 3216.02 Encl. 3 Para. 8).				
	· There is a research monitor assigned to the research. (DoDI 3216.02 Encl. 3 Para. 8).		☐	☐	
	· Contact info for the research monitor is provided in the consent form. (DoDI 3216.02 Encl. 3 Para. 8)		☐	☐	
	· Assignment of the research monitor and his/her duties, authorities and responsibilities are documented in the meeting minutes and by the monitor. (DoDI 3216.02 Encl. 3 Para. 8)		☐	☐	
12.	**CONSENT WAIVERS**		Yes	No	N/A
a.	Is the investigator requesting a waiver of documented consent? *If no, skip to question 12b.*		☒	☐	
	· Researcher is requesting to waive the requirement to obtain a signature on the consent form.		☒	☐	
	· Information sheet will be provided to subjects.		☒	☐	
	A waiver of documentation of consent may be granted if it is found that either:			☐	
	· The only record linking the subject to the research is the consent form **and,**		☒	☐	
	· The **principal risk** would be potential harm resulting from a breach of confidentiality **and,**		☒	☐	
	· Each subject will be asked whether the subject wants documentation linking the subject with the research, and the subject's wishes will govern;		☐	☒	
	OR				
	· The research involves no more than minimal risk to the subjects **and,**		☒	☐	
	· involves no procedures for which written consent is normally required outside of the research context.		☒	☐	
	Is the investigator required to provide a written statement to the subjects?		☒	☐	
b.	Is the investigator requesting a waiver or alteration of consent? *If no, skip to Initial Review Summary.*		☐	☒	
	Does the protocol include experimental subjects? (10 USC 980) *If yes, you may not approve a waiver of informed consent.*		☐	☐	
	Waiver or alternation of informed consent may be granted if it is found that either:				
	(32 CFR 219.116c) · · The research or demonstration project is to be conducted by, or subject to the approval of, state or local government officials, and is designed to study, evaluate, or otherwise examine (i) public benefit or service programs; (ii) procedures for obtaining benefits or services under those programs; (iii) possible changes in or alternatives to those programs or procedures; (iv) possible changes in methods or levels of payment for benefits or services under those programs **and,**		☐	☐	
	· The research could not practicably be carried out without the waiver or alteration.		☐	☐	

OR			
(32 CFR 219.116d)		☐ ☐	
· The research involves no more than minimal risk to the subjects **and,**		☐ ☐	
· The waiver or alteration will not adversely affect the rights and welfare of the subjects **and,**		☐ ☐	
· The research could not practicably be carried out without the waiver or alteration; **and**		☐ ☐	
· Whenever appropriate, the subjects will be provided with additional pertinent information after participation.		☐ ☐ ☐	

CONSENT WAIVER REVIEW SUMMARY

Review Type:	☒ Waiver of Documentation	☐ Waiver or alteration
Review Results:	☐ Approve	☐ Dissaprove
Reviewer Comments:		

INITIAL REVIEW SUMMARY

Name of Reviewer:	COX.BRENNAN.DANIEL.139 2564132	Digitally signed by COX.BRENNAN.DANIEL.1392564132 DN: c=US, o=U.S. Government, ou=DoD, ou=PKI, ou=USN, cn=COX.BRENNAN.DANIEL.1392564132 Date: 2017.10.26 15:07:17 -07'00'	Date: 26 OCT 17		
Review Type:	☐ Exempt Category:	Review Results:	☐ Determined Exempt	☐ Modifications Req'd	☐ Determined Not Exempt
	☒ Expedited Category: 7	Review Results:	☐ Approve	☒ Modifications Req'd	☐ Defer
	☐ Convened	Review Results:	☐ Approve	☐ Modifications Req'd	☐ Defer
			☐ Dissaprove		

Continuing Review/ Status Update: *(Use graduation date for student research)* 30 DEC 2017

Initial Review Comments: Any modification needed to confirm the criteria for approval (32 CFR 219.111) are met must be reviewed by the IRB Chair or Vice Chair prior to recommending approval.

completed 10/30/17

On initial review application: BC
-Item 27(c) should be "no"
-Appendix A.2., uncheck the "Waive the requirement to provide subjects with a consent form" box   BC
On consent form:
- Confidentiality and Privacy Act paragraph line 5, missing apostrophe for "Participant's"
BC

NPS Institutional Review Board
Initial Review Application
(new research protocol)

Purpose:
The Initial Review Application is used to submit new research projects involving the use of human subjects to the IRB for review and approval by the NPS President.

Form Instructions:
Only complete packages are reviewed by the HRPP Specialist. To ensure your application package is complete, refer to the initial review guidance document at the end of this application. Please note all IRB application packages must include a copy of each investigator's completion of CITI ethics training. Submit packages to IRB@nps.edu for review. An IRB administrator will contact you if additional information is required. For questions regarding this form or process, call the HRPP Specialist at 831-656-2998 or send an email to IRB@nps.edu.

MAC users, please use Adobe Reader for Macintosh. Do not use Apple Preview. Free Adobe reader can be found here.

Form Updated 3/24/17   (IRB Office Only) Protocol Number: *NPS.2018.0086 → IR-EP7-A*

A. Protocol Basics

1. Title of the research. Ownership and use of technology

2. Researchers. List all researchers. Attach CITI Training Completion Reports for each investigator. The IRB does not keep copies of CITI completion reports on file.

Principal Investigator			
Name	Title or Rank	Dept. or Outside Org. Name	Investigator Roles and Responsibilities in the Research
Dr. Amela Sadagic	Research Assoc. Prof.	MOVES	Advisor
Co-Investigators and Student Investigators			
Name	Title or Rank	Dept. or Outside Org. Name	Investigator Roles and Responsibilities in the Research
Michael Grimshaw	LCDR	Computer Science	Master's Student

3. Estimated completion date of the research. If student research, list student graduation date.   15 Dec 2017

4. Is this research part of a sponsored project (e.g., reimbursable, RIP, NRP)?
☐ No

☒ Yes. List the job order number (JON):   W7B30

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5. Are you requesting an Exempt IRB review? If you believe the research meets an exempt review category please check "Yes" and provide the category number. A description of the categories is provided in the IRB Guidance Document found at the end of this application. If requesting an exempt review the following documents are not required:

- Scientific Review Form
- Recruitment Script
- Consent Form
- Consent Waiver Forms

If determined "not exempt" by the IRB, the above documents will be required.

☒ No.

☐ Yes. Exempt review category: _____

B. Research Summary

6. Summarize the objective(s) of the research including purpose, research question, hypothesis & background information, literature, etc.

Area of Research
The research is focused on a range of factors that influence adoption of Additive Manufacturing and other digital technologies.

Scope of the study: The scope of this study is on ownership, attitudes and use of technology by individual and units; this includes Additive Manufacturing (AM) and users' perception of potential impact that cyber security may have on adoption of AM. The study investigates the full life cycle of data and processes used in additive manufacturing from a cyber security perspective. Potential vulnerabilities exist based on human interaction with the data, data creation, data storage, data sharing, and data translation into physical form.

Research Questions
(1) What are the trends in terms of ownership, attitudes and use of technology?
(2) What is users' perception of cyber security risks in AM domain?
(3) What additions should be made to cyber security taxonomy that specifically address the AM domain?
(4) What issues stand in the way of successful large-scale adoption of AM?

7. Describe the research study design.

Methodology:
-- Conduct a study on the factors influencing adoption of technology with a focus on Additive Manufacturing and Cyber Security. The study will consist of an on-line survey.
-- Analyze collected data and use the results of this analysis to better inform the approach to large scale adoption of Additive Manufacturing and Cyber Security.
-- Summarize the findings.

8. Describe in detail the tasks subjects will be asked to perform and the amount of time it will take to complete each task.

Subjects will participate in a survey, which consists of a set of demographic questions and questions about their use and understanding of different types of technology, including Additive Manufacturing and Cyber Security. It is estimated that the survey should take approximately 30 minutes.

9. Where will the research be performed?

At NPS using LimeSurvey.

10. Are research subjects or research data located OCONUS?

☒ No

☐ Yes. Attach host country approval and ethics review.

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11. Does the research involve the use of existing records?
Example of existing records are AARs, personnel records, medical records, databases, etc.

☒ No. Skip to question 12.

☐ Yes. Describe the records below. Include the data variables and the number of records to which you will have access.

11b. Are the records private (not available to the general public)?

☐ No

☐ Yes, attach proof of approval from the organization that owns the data stating you may access the data for your research.

11c. For what purpose will these records be used?

☐ To collect data that will be analyzed in the research.

☐ To identify potential subjects.

☐ Other. Describe below.

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12. The following areas of research require approval outside of NPS. Check all that apply.

☐ Classified research

☐ Severe or unusual intrusions, either physical or physiological

☐ Potential or inherent controversial topics (those likely to attract media coverage or challenge by interest groups)

☐ Research involving Marine Corps population (requires USMC IRB administrative review and possibly USMC Survey Manager review)

C. Subject Population & Recruitment

13. Subject Populations. Check all that apply.

☐ Military Personnel (outside NPS)	☐ Government Contractors	☐ Foreign Nationals outside the U.S.
☐ DoD Personnel (outside NPS)	☐ Children, *under 18 years old*	☐ Pregnant Women or Fetuses
☒ NPS Students	☐ Elderly, *over 70 years old*	☐ Non-English Speakers
☐ NPS Civilian Employees	☐ General Public	

14. Describe subject inclusion and exclusion criteria.

Subjects will be U.S. Navy, U.S. Army, and U.S. Air Force active duty. Other services, foreign nationals, and the general public are excluded from participation.

15. Provide the sample size (ex: 75) or range (ex: 75-100) and the rationale for why that number is chosen.

The sample size will be up to 300 subjects. That number is chosen to provide a large enough sample to analyze the data within the amount of time allocated to complete the research.

16. Will compensation be given to research subjects? Compensation may be monetary, raffles, meals/snacks, extra credit, etc. Reference DoDI 3216.02 for guidance on compensating research subjects.

☒ No

☐ Yes. Describe what the compensation consists of and the purpose for offering it.

17. Describe how potential subjects will be recruited to participate in the research.

NPS is the place recruitment will take place. The Student Investigator will recruit via email, face to face requests and snowball technique. The face to face requests will be made to students known to the Student Investigator. Student Investigator will work with students services office and ITACS to obtain email addresses. Individuals will be solicited up to three times and then removed from consideration if they do not respond.

18. How will you minimize coercion and undue influence during the recruitment process?

Each person will have a clear understanding that participation in this surveys is voluntary, and that no incentives will be offered. No senior leadership will be suggesting, requesting or claiming support of the research and participation is strictly voluntary.

D. Risk & Benefits

19. Does the research involve any of these possible risks or discomforts to subjects? Check all that apply.

☐ Use of deception   ☐ Social or economical risk   ☐ Presentation of materials that might be considered
☐ Physiological risk   ☐ Physical risk   sensitive, offensive, threatening or degrading
☐ Employment risk   ☐ Probing for personal or sensitive info   ☐ Manipulation of physiological or social variables
☐ Legal risk   ☐ Possible invasions of privacy of subjects or   such as sensory deprivation, social isolation,
    family   psychological stresses

20. Describe any foreseeable risks or discomforts associated with the research.

No identity of any individual will be disclosed (identifiable) in the final results. Possible breach of confidentiality exists.

21. Explain what steps will be taken to minimize risks and discomforts (mentioned in Q19-20) and to protect subjects' welfare.

All data collected will be safeguarded. All data will be transferred via encrypted emails or server download using encrypted access. The data for analysis will be stored on a secure, password protected server at the Naval Postgraduate School. Only the PIs and authorized researchers will have access to the data.

22. Provide a description of the potential benefits of this research for individuals, subjects, society, military or DoD/DoN. Explain how risks are reasonable in relation to anticipated benefits.

This thesis will benefit the Navy by creating an understanding of what the current obstacles are for user adoption of technology including Additive Manufacturing, and how best to mitigate those obstacles to encourage large scale adoption.

E. Data Security & Monitoring

23. Will you record identifiers such as name, social security number, DoD ID #, address, telephone number or any combination of demographic data that could lead to the identification of a participant?

☐ No

☒ Yes. Explain below why it is necessary to collect these identifiers, state if you will use a coding system to protect against disclosure of identifiers and state when PII will be destroyed.

Several demographics questions are included in the survey such as Rank, Time in Service and Designator. The survey also includes questions about Additive Manufacturing experiences at participants commands. Names, DoD ID #, address, telephone numbers, and Social Security numbers are NOT included in the survey.

24. Will you audio or video record subjects?
☒ No

☐ Yes. Describe what will be recorded, why you are recording, if the recording will be transcribed and how you will safeguard the recording.

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25. How will data and consent forms be kept confidential during collection, analysis, and long term storage after completion of the research? Please note electronic PII may only be stored on the NPS network.

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The analytical files will be sent via encrypted transmissions. The data for analysis will be stored on a secure, password protected server
at the Naval Postgraduate School. Only the PIs and authorized researchers can access the data files. Subject name and other identifiers
will be removed after the research is complete. De-identified data will be stored by the PI under NPS password protected server.
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26. When appropriate, a research plan is required to make adequate provisions for monitoring the data to ensure safety of subjects. Will you monitor data collection?

☒ No

☐ Yes. Describe the monitoring procedure below.

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F. Consent Procedure (If requesting exempt review skip to Q29)

27(a). DoD regulations require that you obtain consent from subjects prior to data collection unless a waiver is approved by the IRB. Are you requesting a waiver of consent? *A waiver of consent is required if you do not intend to have subjects read and sign a consent form.*

☒ No

☐ Yes. *Complete Appendix A and skip to question 28.*

27(b). DoD regulations require subjects to sign the consent form unless a waiver is approved by the IRB. Are you requesting a waiver of signed consent? *A waiver of documented consent is required if you plan to provide a consent form to subjects, subjects will read and acknowledge it, but will not sign a consent form (e.g. online survey, phone interview, etc.)*

☐ No

☒ Yes. *Complete Appendix B.*

27(c). DOD regulations require that you provide a consent document to subjects (electronically or in hard copy) unless waived by the IRB. Are you requesting a waiver from the requirement to provide subjects with a consent form?

☒ No

☐ Yes.*Complete Appendix B.*

27(d). DOD regulations list 14 elements of informed consent that are required to be provided to subjects in the consent form script unless waived by the IRB. Are you requesting to exclude any of these elements? A waiver is required if the research involves deception.

☒ No

☐ Yes. *Complete Appendix A.*

28. Will you quote subjects? Please note: when quoting, signed informed consent is required.

☒ No

☐ Yes

29. Describe how you will obtain consent from subjects and how the potential for coercion or undue influence will be minimized. Note: if requesting a consent waiver please state that here.

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There will be an online consent form on the first page the participants see before beginning the survey. There will be a "live button" that
says "Yes" at the bottom of the online consent form. If the participant agrees to the consent, the participant is asked to click on the "Yes"
button to proceed with the survey. The online consent form will include a statement as follows: "By clicking on the "Yes" button, I am
acknowledging that I have read and understand this information, and that I agree to voluntarily participate in this research." Upon
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clicking the "Yes" button, subjects are actively demonstrating their consent to participate. Contact information will be provided in the consent form if the participants have questions.

Appendix A - Request Waiver of Documented Consent

1. Did you check "Yes" on question 27(b) or 27(c)?

☒ No, skip to Appendix B.

☐ Yes

2. Waiver request type.

☒ Waive the requirement to collect a signature on the consent form.

☐ Waive the requirement to provide subjects with a consent form.

3. Waiver applies to the following subject populations:
Note: Please state if the waiver request is for all subjects or certain subject populations. For example if your research involves only a online survey the waiver will request will befor the entire population. If your research involves interviews then the waiver request will only apply to subjects who participate over the phone.

Research involves only an online survey so the waiver request is for the entire population.

Waiver Criteria
To be approved waiver criteria found in 4a or 4b must be affirmative.

4a. Does the research meet the following criteria?
- The research involves no more than minimal risk to subjects.
- Research involves no procedures for which written consent is normally required outside the research context.
- The information to be presented to subjects (which must be provided in written form as part of the IRB application), includes all required and any additional elements of informed consent.

☐ No, continue to 4b.

☒ Yes, skip to Appendix B.

4b. Does the research meet the following criteria?
- The only record linking the subject and the research is the consent document.
- Each subject will be asked whether he or she wants documentation linking the participant with the research, and the subjects' wishes will
 govern.
- The information to be presented orally to subjects (which must be provided in written form as part of the IRB application) includes all required and any additional elements of informed consent.

☐ Yes.

☐ No, research does not qualify for a waiver of consent.

Appendix B - Request Waiver of Consent or Elements of Consent

1. Did you check "Yes" on question 27(a) or 27(d)?

☒ No, skip to Principal Investigator Statement of Assurance.

☐ Yes

2. Are you requesting a waiver of consent?

☐ No, skip to Principal Investigator Statement of Assurance.

☐ Yes

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3. Does the research involve experimental subjects?

Research involving a human being as an experimental subject: An activity, for research purposes, where there is an intervention or interaction with a living individual for the primary purpose of obtaining data regarding the effect of the intervention or interaction (DODI 3216.02).

☐ No

☐ Yes, waiver requires Secretary of Defense approval (10 USC 980).

4. Is the research regulated by the FDA?

☐ No

☐ Yes, consent may not be waived (32 CFR 219.116)

5. Are you requesting to waive one or more elements of informed consent (use of deception)?

☐ No

☐ Yes, list the elements of informed consent you wish to waive. For a listing of elements see 32 CFR 219.116.

6. Waiver applies to the following subject populations:

Note: Please state if the waiver request is for all subjects or certain subject populations. For example, if your research involves use of pre-collected data (personnel records, training records, lessons learned, etc.) this request would be for all persons represented in the data set.

<div align="center">

Waiver Criteria
To be approved waiver criteria found in 7a _or_ 7b must be affirmative.

</div>

7a. Does the research meet the following conditions?

- The research involves no more than minimal risk to subjects. Minimal risk means that the probability and magnitude of harm or discomfort anticipated is not greater in and of themselves than those ordinarily encountered in daily life.
- The waiver or alteration will not adversely affect the rights and welfare of subjects by not obtaining consent.
- The research cannot practicably be carried out without the waiver or alteration.
- When appropriate, the subjects will be provided with additional pertinent information after participation.

☐ Yes, skip to Principal Investigator Statement of Assurance.

☐ No, continue to 7b.

7b. Does the research meet the following conditions?

- The research is conducted by or subject to the approval of state or local government officials.
- The research is designed to study, evaluate, or otherwise examine:
    - Public benefit or service programs
    - Procedures for obtaining benefits or services under those programs
    - Possible changes in methods or levels of payment for benefits or services under those programs
- The research cannot practicably be carried out without the waiver or alteration.

☐ Yes, skip to Principal Investigator Statement of Assurance.

☐ No, your research does not qualify for a waiver of documented consent.

Principal Investigator Statement of Assurance

I certify that the information provided in this application is complete and accurate.

I understand that as the Principal Investigator (PI), I have ultimate responsibility for the conduct of the study, the activities of all other investigators listed on the protocol, the ethical performance of the project, the protection of the rights and welfare of human subjects, and strict adherence to the study protocol.

I understand that human subject research activities, including recruitment, may not commence until the Institutional Review Board (IRB) completes its review and, if determined not to be exempt, the Institutional Official (IO) approves.

I will not implement changes to approved research without IRB and IO approval except when necessary to eliminate apparent immediate hazards to the subject and will submit an amendment to the IRB within 5 business days.

I will inform the IRB Chair or Vice Chair, and the Medical Monitor (if one is assigned) of any unanticipated problems involving risks to subjects or others (UPIRTSOs) within 24 hours. I will submit a UPIRTSO report form to the IRB within 5 business days.

I have no conflict of interest preventing me from performing this research.

I will maintain all research records on file. Records include but are not limited to: approved initial review protocol/amendments/ continuing reviews, CITI ethics training records for each member of the research team, correspondence with the IRB, research data and notes, consent forms, UPIRTSO reports, and research agreements.

I recognize that the IRB has the authority to observe (or have a third party observe) the consent process and the conduct of research, and to inspect all research records at any time.

I understand that a continuing review of the research must be reviewed by the IRB and approved by the IO before the expiration date or all research activities including interaction with subjects and personally identifiable data must stop.

I understand that I must submit a final report to the IRB upon expiration of the protocol for all non-exempt research.

I have read, understand, and agree to follow the NPS Instruction on the Protection of Human Subjects.

Principal Investigator Signature: SADAGIC.AMEL A.1279418901 Digitally signed by SADAGIC.AMELA.1279418901 Date: 2017.10.30 10:11:41 -07'00'

Date: 30 Oct, 2017

Initial Review Application Checklist		
Before submitting your application package please ensure the following is included.		

Yes	N/A	Item
☐		IRB Initial Review Application is complete and signed by the PI. (For student research the PI is the advisor.)
☐		Conflict of Interest Disclosure form signed by each member of the research team.
☐	☐	Consent form(s) is/are attached. Not required if requesting an exempt review.
☐	☐	All data collection tools are attached (survey, questionnaire, interview questions, etc.).
☐	☐	Recruitment materials are attached (phone scripts, e-mail scripts, flyers, presentations, URLs, etc.). Not required if requesting an exempt review.
☐		Scientific Review form is signed by your Department Chair (area chairs sign in GSBPP) or other designated reviewer. Not required if requesting an exempt review.
☐	☐	If subjects are from another command, institution, or agency, attach approval from that organization. Approval may be provided through email or on official letter head.
☐		Copy of the approved thesis or research proposal (student or funded research proposal) is attached.
☐		Copy of CITI ethics training certificates for each member of the research team is attached. For information on CITI training see below.

SUBJ: Request for Research Participation on Ownership and Use of Technology Survey

As a resident USA, USN, or USAF Active Duty Naval Postgraduate School (NPS) student you are invited to participate in a survey that will benefit a research study entitled "Ownership and Use of Technology."

This research study is a degree requirement for the Master of Science in Computer Science degree at the Naval Postgraduate School and is being conducted by Michael D. Grimshaw.

This user study is focused on the ownership, use, and experiences with technology.

Participants will not be identified in the results of the study, and your participation in this research study is strictly voluntary. No IP addresses or personally identifiable information (PII) will be collected. All records of the study will be stored by the PI in a secure environment.

You can access the survey by clicking on the survey link provided below. After reading the online consent form on LimeSurvey, by clicking on the "Yes" button, you are acknowledging that you have read and understand this information and that you agree to voluntarily participate in this research survey. The survey will take approximately 30 minutes and will be conducted online via LimeSurvey.

Questions about your rights as a research participant or any other concerns may be addressed to the Naval Postgraduate School, Institution Review Board Chair, Dr. Larry Shattuck, 831-656-2473, lgshattu@nps.edu. If you have any questions or comments about the research, please contact the Principal Investigator, Dr. Amela Sadagic, 831-656-3819, asadagic@nps.edu.

If you decide to participate in this research study, I thank you in advance for your support of my research.

Here is the link to the survey: [insert LimeSurvey Link here]

Very respectfully,

Michael Grimshaw
LCDR USN
NPS-CS
mdgrimsh@nps.edu
904-312-4567

Naval Postgraduate School
Consent to Participate in Research

Introduction. You are invited to participate in a research study entitled *"Ownership and Use of Technology"*. The purpose of the research is to survey U.S. Army, Navy and Air Force NPS active duty students about their familiarity with and use of commercial technologies.

Procedures. You are being asked to complete a web-based anonymous survey. The survey should take about 30 minutes to complete, must be taken in one sitting, and can be taken during working hours. The expected number of participants who will have the opportunity to participate in this research study is approximately 300. There will be no compensation given for participation in the study.

Location. The survey will take place online using LimeSurvey.

Cost. There is no cost to participate in this research study.

Voluntary Nature of the Study. Your participation in this study is strictly voluntary. If you choose to participate you can change your mind at any time and withdraw from the study. You will not be penalized in any way or lose any benefits to which you would otherwise be entitled if you choose not to participate in this study or to withdraw.

Potential Risks and Discomforts. The potential risks of participating in this study are: minimal risk of breach of confidentiality. This survey is anonymous and strictly voluntary. No IP addresses or personally identifiable information (PII) will be collected.

Anticipated Benefits. Anticipated benefits from this study are creating an understanding of current trends in ownership and use of technologies. You will not directly benefit from your participation in this research.

Confidentiality & Privacy Act. Any information that is obtained during this study will be kept confidential to the full extent permitted by law. All efforts, within reason, will be made to keep your personal information in your research record confidential but total confidentiality cannot be guaranteed. All survey responses are anonymous and will not be shared with anyone outside the investigating research team. Participant's submissions are immediately sent to LimeSurvey and responses are not stored locally on their computers or networks. Only the researcher and principal investigator will have access to the collected data for analysis. The data will be stored in a secured database and the principal investigator will maintain all electronic data upon completion of the study for 10 years.

Points of Contact. If you have any questions or comments about the research, or you experience an injury or have questions about any discomforts that you experience while taking part in this study please contact the Principal Investigator, *Dr. Amela Sadagic, 831-656-3819*, asadagic@nps.edu. Questions about your rights as a research subject or any other concerns may be addressed to the Navy Postgraduate School IRB Chair, Dr. Larry Shattuck, 831-656-2473, lgshattu@nps.edu.

Statement of Consent. I have read the information provided above. I have been given the opportunity to ask questions and all the questions have been answered to my satisfaction. I have been provided a copy of this form for my records and I agree to participate in this study. I understand that by agreeing to participate in this research and signing this form, I do not waive any of my legal rights.

☐ I consent to participate in the research.

☐ Version #
Date:

I do not consent to participate in the research.

Version #
Date:

Scientific Review Form
(required for all new non-exempt research protocols)

Purpose:
Navy regulation require an independent review of research for scientific merit or scholarship prior to IRB review. A completed scientific review form is required in all applications for IRB review and approval of new research.

Form Instructions:
Please submit this Scientific Review Form to your Department Chair, Director, or Dean (if in GSBPP), along with your IRB application package. Scientific Reviewers will review the IRB application and research proposal when determining the scientific merit of the research. Reviewers can require investigators to revise their submissions if they find that the submission inadequately addresses the points below. Scientific Reviewers may not conduct a scientific review for their own studies. Scientific Reviewers must meet the CITI Ethics training requirements for Scientific Reviewers.

MAC users please use Adobe Reader for Macintosh. Do not use Apple Preview. Fee Adobe reader can be found here.

For questions regarding this form or process send an e-mail to IRB@nps.edu.   Form Updated 3-8-17

A. Protocol Basics

Protocol #

Title of the research: **Ownership and Use of Technology**

Principal Investigator: **Dr. Amela Sadagic**

Co-Investigators:

Student Researchers: **Michael Grimshaw**

B. Scientific Review Criteria

Research Team	Yes	No	NA
To the best of your knowledge, does the membership of the research team provide adequate expertise to perform all aspects of the proposed study? *See IRB application Q2.*	☒	☐	
Scientific Merit Review	**Yes**	**No**	**NA**
Does the proposal have a valid research hypothesis and/or appropriate objectives? *See IRB application Q6.*	☒	☐	
Does the protocol provide sufficient information to justify the conduct of the study?	☒	☐	
Is the study design adequate to achieve study objectives? *See IRB application Q7.*	☒	☐	
Is there a method to investigate the research question(s) that would not require the use of human subjects?	☐	☒	
Is the target subject group appropriate for this study? *See IRB application Q13-15.*	☒	☐	
Has the PI demonstrated careful consideration of subject inclusion and exclusion criteria? *See IRB application Q14.*	☒	☐	
Has the PI provided an adequate rationale for the stated sample size? *See IRB application Q15.*	☒	☐	
Is it likely that the PI will be able to meet his/her enrollment goals?	☒	☐	
If the study warrants a data safety monitoring plan is it appropriate? *See IRB application Q26.*	☐	☐	☒
In your opinion should the IRB review the research sooner than annually or monitor the process?	☐	☒	
Research Risks and Benefits	**Yes**	**No**	
Is the risk/benefit ratio favorable? *See IRB application Q19-Q22.*	☒	☐	
Have risks to subjects been minimized by employing sound scientific design? *See IRB application Q7 & Q21.*	☒	☐	
Could risk to subjects be further reduced in any way? If yes, please explain.	☐	☒	

	Yes	No	
Have all potential risks been accurately and fully described in the application and consent form? *See IRB application Q20 and IRB consent form.*	☒	☐	
Should this study be submitted to the safety office? If yes, please explain.	☐	☒	

Conflict of Interest	Yes	No	
Do you have a conflict of interest with the proposed research?	☐	☒	

Required Revisions	Yes	No	
If you have required revisions list them below.	☐	☒	

C. Reviewer Recommendation

☒ This research can be submitted to the IRB as currently written.

☐ This project requires the revisions described above and must be re-reviewed by the scientific reviewer prior to submission to the IRB.

☐ This project was revised, re-reviewed, and found acceptable to submit to the IRB.

☐ This project does not possess scientific merit.

Scientific Reviewer Name: *Peter J Denning*

Scientific Reviewer Signature: *Peter Denning*

Date: 10/17/17

Naval Postgraduate School
Institutional Review Board
Conflict of Interest Disclosure Form

Update 8-13-12

Principal Investigator:	Dr. Amela Sadagic	Requeseted Start Date:	10/25/2017
Title of Research	Ownership and use of technology		

About: The purpose of this form is to identify and evaluate potential conflicts of interest in research that may affect the rights and welfare of human subjects.

Instructions: The principal investigator must also identify each person involved with the project who, by the definition given below, qualifies as an "investigator." It is the principal investigator's responsibility to insure that each investigator has been advised of the conflict of interest disclosure (COID) policy and has reviewed and signed this COID form. Proposals will not be reviewed until all investigators have signed the form. The principal investigator must complete and submit to the IRB this COID statement along with the appropriate IRB application form in each of the following circumstances.

- Each time a new proposal is submitted to the IRB for review whether it is funding by a federal agency or a non-governmental (for-profit or not-for-profit) sponsor.

- Any time a new investigator is added to the project.

- Any time during the term of an ongoing award that an Investigator has a change in reportable Significant Financial Interest or acquires a new Significant Financial Interest that was not reported on the original disclosure form.

List all Research Sponsors:	1.		2.	
List all business entities owning or licensing technologies being tested:	1.		2.	
List any additional business entities involved in or potentially affected by the research project:	1.		2.	
	3.		4.	

List Investigators to be paid through NPS as employees:		List Investigators to be paid through NPS as consultants:		List Investigators to be paid through Subcontractors:		List Investigators not paid by NPS or unpaid investigators.	
1.		1.		1.		1.	
2.		2.		2.		2.	
3.		3.		3.		3.	
4.		4.		4.		4.	

Who designed the study?	Dr. Amela Sadagic & LCDR Michael Grimshaw
Where was the study designed?	NPS
Where will the results be analyzed?	NPS
Who will analyze the results?	LCDR Michael Grimshaw

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Conflict of Interest Questions		Yes	No
a.	Do you, or does any member of your family have or receive a significant financial interest in or from the research sponsor or from a related business entity affected by the research?	☐	☒
b.	Do you, or does any member of your family receive income including any payment such as salary or consulting fees, royalty payments, reimbursement of expenses of $5,000 or more from the research sponsor or a related business entity?	☐	☒
c.	Do you or does any member of your family own or have any other financial interest in an entity that is proposed as a subcontractor, consortium member or lesser, that is involved in the project?	☐	☒
d.	Do you or does any member of your family have any agreement to receive financial benefit from the research beyond what is described in the proposal budget?	☐	☒
e.	Do you or does any member of your family have outside employment that could appear to cause a potential conflict with this research or raise questions about your professional commitments in undertaking the research, or your primary allegiance to NPS?	☐	☒
f.	Do you or does any member of your family have a position as a director, officer, partner, trustee, manager or employee of an outside entity that conducts business in an area related to the research?	☐	☒
g.	Do you or any member of your family have equity interests such as stocks, stock options or other ownership interests in the research sponsor or related business entities that represent more than 5% equity interest?	☐	☒
h.	Do you or any member of your family have an inventive or ownership interest in any Intellectual property that will be utilized in this project?	☐	☒
i.	Have you assigned any student, postdoctoral fellow or other trainee, officer, support staff or other individual to a project sponsored by the research sponsor or related businesses entities?	☐	☒
j.	Do you serve on the Board of Directors or Scientific Advisory Board of the research sponsor or related business entities?	☐	☒
k.	Are you a member of a 'Speakers Bureau' or other list of approved speakers concerning the products or services of the research sponsor or related business entities?	☐	☒
l.	Have you taken any administrative action within the University which is likely to benefit the research sponsor or related business entities?	☐	☒
m.	Do you participate in research on a technology owned or contractually obligated (including by license or exercise of an option to license) to the research sponsor or related business entities?	☐	☒
n.	Have you participated in or otherwise influenced any university transaction to buy, sell, lease, or license real or intellectual property to or from the research sponsor or related business entities?	☐	☒

List below the names of each member of the research team and check whether they have answered "Yes" to the conflict of interest questions listed below. Each member with a conflict of interest will be contacted by the IRB for additional information.

Name of Research Member	Signature	Conflict of Interest Exists	
Amela Sadagic	SADAGIC.AMELA.1279418901 *Digitally signed by SADAGIC.AMELA.1279418901 Date 2017 10 13 14 15:56 -0700*	Yes ☐	No ☒
Michael Grimshaw	*[signature]* 10/13/2017	Yes ☐	No ☒
		Yes ☐	No ☐
		Yes ☐	No ☐
		Yes ☐	No ☐
		Yes ☐	No ☐

Principal Investigator Certification:
I certify that all members of the study team have answered the conflict interest questions and those with a conflict of interest are listed above with the box "Conflict of Interest Exists" checked and a description of the conflict of interest is attached.

PI Signature Field.
Digital signatures now accepted.   Sadagic Amela   Date 10/13/2017

IRB Conflict of Interest Definitions

"Business Entity" of a researcher means any trust, organization or enterprise other than the University over which the researcher, alone or together with his family, exercises a controlling or significant interest.

The **Family** of a researcher includes his spouse or dependent children, whose financial holdings are known to the researcher.

Research Sponsor means any entity providing financial support for the research activity involving human subjects described in this application.

Technology means any methodology, information, system or procedure.

Significant Financial Interests means anything of monetary value, including but not limited to, salary or other payments for services (e.g. consulting fees or honoraria); equity interests (e.g. stocks, stock options or other ownership interests); intellectual property rights (e.g. patents, copyrights and royalties from such rights).

The term, "Significant Financial Interest" does not include the following (42 CFR 50.603):

1. Salary, royalties or other remuneration from the Naval Postgraduate School;
2. Income from seminars, lectures, or teaching engagements sponsored by public or non-profit entities;
3. Income from services on advisory committees or review panels for public or nonprofit entities;
4. Equity interest that when aggregated for the investigator and the investigators spouse and dependent children, meets both of the following tests: does not exceed $5,000 in value as determined through reference to public prices or other reasonable measures of fair market value, and does not represent or represent more than a 5% ownership interest in any single entity; and
5. Salary, royalties or other payments that, when aggregated for the investigator and the investigators spouse and dependent children, are not expected to exceed $5,000 over the subsequent twelve month period.

However, the term Significant Financial Interest does include the following (42 CFR 50.603):

1. Payments in excess of $5,000 including salary, consulting fees, royalty or licensing payments from intellectual property, honoraria and/or gifts received within the past 12 months or anticipated for the next 12 months.
2. Equity interest worth more than $5,000 or more than 5% of the business entity as determined by reference to its publicly listed price (excluding mutual funds);
3. Any equity interest if the value cannot be determined by reference to publicly listed prices (e.g., start up companies);
4. Patent rights or royalties from such rights whose value may be affected by the outcome of the research, including royalties under any royalty-sharing agreement involving a business entity.

1) Date of completing questionnaire: [Insert Calendar]

2) Year of birth: [Drop down menu selection]

3) Gender: (Select one): [Male / Female]

4) Select your Service [Drop down menu selection: USN, USAF, USA]

5) Select you Designator, MOS or AFSC [Drop down menu selection based on answer to service]

6) Select your rank [Drop down menu selection]

7) How long have you served in the military? Please enter your total time in service (TIS):

_____ years

8) Select your highest education level (select one):

- o High School Diploma or equivalent
- o Partial work towards Associate's Degree
- o Associate's Degree
- o Partial work towards BS / BA
- o BS / BA
- o Partial work towards Master's Degree
- o Master's Degree
- o partial work towards Doctorate's PhD
- o Doctorates PhD

GUIDANCE: For questions 9-13, the term "technology devices" refers to items such as computers, smartphones, tablets, gaming devices (gaming consoles), Internet of Things (IOT) devices (examples: Google Home, Amazon Echo, Smart Home Devices such as locks, thermostats), etc.

Please select the answer from the scale that best describes you:

9) I am among the first to purchase new technology devices (select one).
   1. Strongly disagree
   2. Disagree
   3. Somewhat disagree
   4. Neither agree or disagree
   5. Somewhat agree

6. Agree
7. Strongly agree

10) I stay updated on the latest information about technology devices (select one).
1. Strongly disagree
2. Disagree
3. Somewhat disagree
4. Neither agree or disagree
5. Somewhat agree
6. Agree
7. Strongly agree

11) I wait for expert opinions before purchasing technology devices (select one).
1. Strongly disagree
2. Disagree
3. Somewhat disagree
4. Neither agree or disagree
5. Somewhat agree
6. Agree
7. Strongly agree

12) I wait for my peers' opinions before purchasing technology devices (select one).
1. Strongly disagree
2. Disagree
3. Somewhat disagree
4. Neither agree or disagree
5. Somewhat agree
6. Agree
7. Strongly agree

13) I am among the last to purchase new technology devices (select one).
1. Strongly disagree
2. Disagree
3. Somewhat disagree
4. Neither agree or disagree
5. Somewhat agree
6. Agree
7. Strongly agree

14) Do you play video games?
   [Yes / No]

If Yes, please answer questions 15-19, otherwise skip to question 20.

15) I am among the first to purchase newly released games (select one).
    1. Strongly disagree
    2. Disagree
    3. Somewhat disagree
    4. Neither agree or disagree
    5. Somewhat agree
    6. Agree
    7. Strongly agree

16) I stay updated on the latest information about newly released games (select one).
    1. Strongly disagree
    2. Disagree
    3. Somewhat disagree
    4. Neither agree or disagree
    5. Somewhat agree
    6. Agree
    7. Strongly agree

17) I wait for expert opinions before purchasing newly released games (select one).
    1. Strongly disagree
    2. Disagree
    3. Somewhat disagree
    4. Neither agree or disagree
    5. Somewhat agree
    6. Agree
    7. Strongly agree

18) I wait for my peers' opinions before purchasing newly released games (select one).
    1. Strongly disagree
    2. Disagree
    3. Somewhat disagree
    4. Neither agree or disagree
    5. Somewhat agree
    6. Agree
    7. Strongly agree

19) I am among the last to purchase newly released games (select one).
    1. Strongly disagree
    2. Disagree
    3. Somewhat disagree
    4. Neither agree or disagree

5. Somewhat agree
6. Agree
7. Strongly agree

20) Do you download or purchase applications (apps)? (select one)
   [Yes / No]

If Yes, please answer questions 21-25, otherwise skip to question 26.

21) I am among the first to download or purchase newly released apps (select one).
   1. Strongly disagree
   2. Disagree
   3. Somewhat disagree
   4. Neither agree or disagree
   5. Somewhat agree
   6. Agree
   7. Strongly agree

22) I stay updated on the latest information about newly released apps (select one).
   1. Strongly disagree
   2. Disagree
   3. Somewhat disagree
   4. Neither agree or disagree
   5. Somewhat agree
   6. Agree
   7. Strongly agree

23) I wait for expert opinions before downloading or purchasing newly released apps (select one).
   1. Strongly disagree
   2. Disagree
   3. Somewhat disagree
   4. Neither agree or disagree
   5. Somewhat agree
   6. Agree
   7. Strongly agree

24) I wait for my peers' opinions before downloading or purchasing newly released apps (select one).
   1. Strongly disagree
   2. Disagree
   3. Somewhat disagree
   4. Neither agree or disagree

5. Somewhat agree
6. Agree
7. Strongly agree

25) I am among the last to download or purchase newly released apps (select one).
   1. Strongly disagree
   2. Disagree
   3. Somewhat disagree
   4. Neither agree or disagree
   5. Somewhat agree
   6. Agree
   7. Strongly agree

26) When using service provided recreational resources such as a library, computer lab, auto-hobby shop, or gym, how likely are you to ask an employee to teach you how to use the equipment? (select one)
   1. Never true
   2. Rarely true
   3. Sometimes but infrequently true
   4. Neutral
   5. Sometimes true
   6. Usually true
   7. Always true

27) When using service provided recreational resources such as a library, computer lab, auto-hobby shop, or gym, how likely are you to teach yourself how to use the equipment through trial and error type techniques? (select one)
   1. Never true
   2. Rarely true
   3. Sometimes but infrequently true
   4. Neutral
   5. Sometimes true
   6. Usually true
   7. Always true

28) When using service provided recreational resources such as a library, computer lab, auto-hobby shop, or gym, how likely are you to use self-help guide or video made available via internet by other users, to learn how to use the equipment? (select one)
   1. Never true
   2. Rarely true
   3. Sometimes but infrequently true
   4. Neutral
   5. Sometimes true
   6. Usually true
   7. Always true

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29) I know what 3D printing is. (select one)
1. Strongly disagree
2. Disagree
3. Somewhat disagree
4. Neither agree or disagree
5. Somewhat agree
6. Agree
7. Strongly agree

30) Describe 3D printing in your own words.

_____
_____
_____
_____
_____

31) I believe 3D printing can be very useful for personal projects (home, off-duty, leisure, etc.) (select one)
1. Strongly disagree
2. Disagree
3. Somewhat disagree
4. Neither agree or disagree
5. Somewhat agree
6. Agree
7. Strongly agree

32) Please provide examples of useful 3D printed objects for personal use:

(1) _____
(2) _____
(3) _____
(4) _____

33) I own 3D printed objects for personal use (home, off-duty, leisure, etc.) that were printed by someone other than myself (select one).
[Yes / No]

If 'Yes' please explain what they are:
(1) _____
(2) _____
(3) _____
(4) _____

34) I own 3D printed objects for personal use (home, off-duty, leisure, etc.) that I printed. (select one).
   [Yes / No]

   If 'Yes' please explain what they are:
   (1) _____
   (2) _____
   (3) _____
   (4) _____

35) I have printed 3D objects for personal use on a private (you own or someone you know owns) 3D printer. (select one)
   [Yes / No]

   If 'Yes' please explain what they are:
   (1) _____
   (2) _____
   (3) _____
   (4) _____

If 'Yes', what was the source of the object you printed? (select one)
   o I designed the object
   o I downloaded the file that describes that object from an internet web site
   o I received the file that describes that object via e-mail or some type of file transfer
   o Not sure
   o Other, please explain _____

If 'Yes', what training did you receive prior to using the 3D printer? (Check all that apply)
   o Someone else trained me
   o I trained myself using an instruction manual (example: vendor-provided manual)
   o I trained myself using a self-help guide or video made available via internet by other users
   o I did not receive training prior to using the 3D printer
   o Other, please explain _____

GUIDANCE: For the remainder of the survey, if the question is not directly applicable to your current status as an NPS student, please consider your previous duty station when answering the question.

36) I believe 3D printing can be very useful in my Work Center.
   1. Strongly disagree
   2. Disagree
   3. Somewhat disagree
   4. Neither agree or disagree

5. Somewhat agree
6. Agree
7. Strongly agree

37) My unit currently has and uses 3D printed objects. (select one)
   [Yes / No / I do not know]

   If 'Yes' please explain what they are:
   (1) _____
   (2) _____
   (3) _____
   (4) _____

38) My unit currently has a 3D printing capability. (select one)
   [Yes / No / I do not know]

   If 'Yes' please explain what are the printers being used for predominantly?
   (1) _____
   (2) _____
   (3) _____
   (4) _____

39) I have printed 3D objects for personal use on a service provided (in your Work Center or on base) 3D printer. (select one)
   - No, personal projects are not authorized
   - No, we don't have printer
   - No, we have a printer but I have not printed on it
   - Yes

If 'Yes' please explain what they are:
   (1) _____
   (2) _____
   (3) _____
   (4) _____

If 'Yes', what was the source of the object you printed?
   o I designed the object
   o I downloaded the file that describes that object from an internet site
   o I received the file that describes that object via e-mail or some type of file transfer
   o Not sure
   o Other, please explain _____

If 'Yes', what training did you receive prior to using the 3D printer? (Check all that apply)
   o Someone else trained me
   o I trained myself using an instruction manual (example: vendor-provided manual)

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- I trained myself using a self-help guide or video made available via internet by other users
- I did not receive training prior to using the 3D printer
- Other, please explain _____

40) My unit has 3D printed objects for use in the work environment. (select one)
  [Yes / No]

  If 'Yes' please explain what they are:
  (1) _____
  (2) _____
  (3) _____
  (4) _____

If 'Yes', what was the source of the object your unit printed?
  - I designed the object
  - Someone in my unit designed the object
  - I downloaded the file that describes that object from an internet web site
  - Someone in my unit downloaded the file that describes that object from an internet web site
  - I received the file that describes that object via e-mail or some type of file transfer
  - Someone in my unit received the file that describes that object via e-mail or some type of file transfer
  - Not sure
  - Other, please explain _____

41) If given a 3D printing capability at my workplace, I could use it immediately to make my workplace more efficient.
  1. Strongly disagree
  2. Disagree
  3. Somewhat disagree
  4. Neither agree or disagree
  5. Somewhat agree
  6. Agree
  7. Strongly agree

42) I believe that a 3D printing capability would reduce the amount of spare parts that my unit stores or orders/purchases because we could print them as they are needed.
  1. Strongly disagree
  2. Disagree
  3. Somewhat disagree
  4. Neither agree or disagree
  5. Somewhat agree
  6. Agree
  7. Strongly agree

43) NPS has 3D printers available for student use. (select one)
    [Yes / No / I do not know]

44) If 'Yes", please state where they are located:

_____
_____
_____

45) I believe 3D printing can be very useful for my service (USN, USAF, USA).
    1. Strongly disagree
    2. Disagree
    3. Somewhat disagree
    4. Neither agree or disagree
    5. Somewhat agree
    6. Agree
    7. Strongly agree

46) Please provide examples for the previous question:

_____
_____
_____
_____

47) I am aware that the Navy is pursuing 3D printing technology. (select one)
    [Yes / No]

48) I am aware of specific 3D printed objects currently being used in the service (USN, USAF, USA). (select one)
    [Yes / No]

    If 'Yes' please explain what they are:

    (1) _____
    (2) _____
    (3) _____
    (4) _____

49) I believe every service command (USN, USAF, USA) will have a 3D printer in the next 5 years. (select one)
    [Yes / No / I do not know]

50) What problem(s) do you see with respect to 3D printing?
    (1) _____
    (2) _____
    (3) _____

(4) _____

51) In your opinion, what is the speed with which the service (USN, USAF, USA) adopts technology?
   1. Very poor
   2. Poor
   3. Fair
   4. Good
   5. Very good
   6. Excellent
   7. Exceptional

52) In your opinion, how important is your service leaderships' endorsement and full support of new technology to adoption.
   1. Not important
   2. Moderately not important
   3. Slightly not important
   4. Neutral
   5. Slightly Important
   6. Moderately Important
   7. Very Important

53) In your opinion, how important is your unit leaderships' endorsement and full support of new technology to adoption.
   8. Not important
   9. Moderately not important
   10. Slightly not important
   11. Neutral
   12. Slightly Important
   13. Moderately Important
   14. Very Important

54) In your opinion, how knowledgeable is your service leadership about 3D Printing?
   1. Not knowledgeable
   2. Moderately not knowledgeable
   3. Slightly not knowledgeable
   4. Neutral
   5. Slightly knowledgeable
   6. Moderately knowledgeable
   7. Very knowledgeable

55) In your opinion, how knowledgeable is your unit leadership about 3D printing?
   1. Not knowledgeable
   2. Moderately not knowledgeable
   3. Slightly not knowledgeable
   4. Neutral

5. Slightly knowledgeable
6. Moderately knowledgeable
7. Very knowledgeable

56) In your opinion, how supportive is your service leadership of 3D printing.
   1. Not supportive
   2. Moderately not supportive
   3. Slightly not supportive
   4. Neutral
   5. Slightly supportive
   6. Moderately supportive
   7. Very supportive

57) In your opinion, how supportive is your unit leadership of 3D Printing.
   1. Strongly disagree
   2. Disagree
   3. Somewhat disagree
   4. Neither agree or disagree
   5. Somewhat agree
   6. Agree
   7. Strongly agree

GUIDANCE: For the remainder of the survey, *Cyber Security* is defined as:

"The prevention of damage to, protection of, and restoration of computers, electronic communications systems, electronic communications systems services, wire communication, and electronic communication, including information contained therein, to ensure its availability, integrity, authentication, confidentiality and non-repudiation." (NSPD-54/HSPD-23)

58) I have received cyber security training in the past. (select one)
   [Yes / No]

If 'Yes", when was the last time you received cyber security training?
   o Within the past 6 months
   o Within the last year
   o Within the last two years
   o More than two years ago
   o Other, please explain _____

59) What is your attitude towards cyber security related issues when using your personal technology devices.
   1. Not concerned
   2. Moderately not concerned
   3. Slightly not concerned

4. Neutral
5. Slightly concerned
6. Moderately concerned
7. Very concerned

60) I have experienced cyber security related problems when using my personal technology devices. (select one)

[Yes / No]

If 'Yes", when was the last time you experienced a cyber security related problem?
  ○ Within the past 6 months
  ○ Within the last year
  ○ Within the last two years
  ○ More than two years ago
  ○ Other, please explain _____

If 'Yes' please explain what they are:

(1) _____
(2) _____
(3) _____
(4) _____

61) In terms of protecting your work, how would you qualify the amount of cyber security training you received?
  1. Very poor
  2. Poor
  3. Fair
  4. Good
  5. Very good
  6. Excellent
  7. Exceptional

62) What is your level of confidence in the cyber security capabilities of the technology devices you use on the job to protect you work?
  1. Very poor
  2. Poor
  3. Fair
  4. Good
  5. Very good
  6. Excellent
  7. Exceptional

63) Cybersecurity measures prevent me from accessing content that would be helpful in my job.
  1. Strongly disagree

2. Disagree
3. Somewhat disagree
4. Neither agree or disagree
5. Somewhat agree
6. Agree
7. Strongly agree

64) Cyber security is a concern related to 3D printing
   1. Strongly disagree
   2. Disagree
   3. Somewhat disagree
   4. Neither agree or disagree
   5. Somewhat agree
   6. Agree
   7. Strongly agree

65) If my unit provided printed 3D object at work, I would have confidence that the object is trustworthy to accomplish the intended purpose.
   1. Strongly disagree
   2. Disagree
   3. Somewhat disagree
   4. Neither agree or disagree
   5. Somewhat agree
   6. Agree
   7. Strongly agree

66) I have confidence that a digital 3D file provided by my unit, would be properly protected from compromise or modification.
   1. Strongly disagree
   2. Disagree
   3. Somewhat disagree
   4. Neither agree or disagree
   5. Somewhat agree
   6. Agree
   7. Strongly agree

PMc
4/29/1
JME

Date: 5 April 2017

MEMORANDUM

From: LT Michael D. Grimshaw
Section(s):   368-131

To: Program Officer, CS Department

Via: (1) Thesis Advisor: Dr. Amela Sadagic
        (2) Co-Advisor or 2nd Reader: Enter title and name Prof. Victor (Bob) Garza
        (3) Academic Associate, CS Department
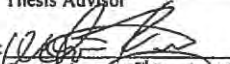   (4) Chair, CS Department

Subj: THESIS PROPOSAL

Encl: (1) Thesis Proposal
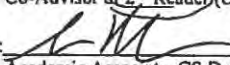   (2) Institutional Review Board (IRB) Student Research Checklist

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2. General Area of Proposed Thesis Research: Cyber Security, Additive Manufacturing, Technology Adoption
3. Enclosure (1) is the Thesis Proposal with a milestone plan (dates/events) for research and thesis completion.
4. I expect that my thesis will be unclassified. If Classified, I have read Chapter V of NAVPGSCOLINST 5510.2, and the NPS Research Admin web page concerning Classified Thesis (http://intranet.nps.navy.mil/ResAdmin/research1.html).
5. I reviewed the Institutional Review Board (IRB) web page concerning the use of humans in research (htt://www.nps.edu/research/IRB.html). Enclosure (2) is the completed IRB Student Research Checklist. This research does involve Human Subject Research.
6. I anticipate the following travel or other extraordinary requirements: As required to Naval Fabrication Laboratories located in San Diego, Norfolk and Mayport.
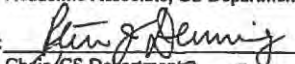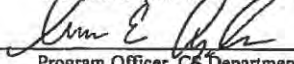
_____   N/A
Student Signature   Second Student Signature <if joint thesis>

1. Forwarded, recommending approval: Sadagic Amela   04/11/17
                                      Thesis Advisor   Date

2. Forwarded, recommending approval: _____   4/11/17
                                      Co-Advisor or 2nd Reader (Circle one)   Date

3. Forwarded, recommending approval: _____   14 APR 17
                                      Academic Associate, CS Department   Date

4. Forwarded, recommending approval: _____   4/18/17
                                      Chair, CS Department   Date

5. Approved, and retained: _____   23 APR 17
                                      Program Officer, CS Department   Date

100

Computer Science Thesis Proposal

A. General Information

1. Name: LT Michael D. Grimshaw

2. Email: mdgrimsh@nps.edu

3. Curriculum: Computer Science (368)

4. Thesis Advisor: Dr. Amela Sadagic

5. Co-Advisor or 2nd Reader: Prof. Victor (Bob) Garza

6. Academic Associate, CS Department: Dr. Alan Shaffer

7. Chair, CS Department: Dr. Peter J. Denning

8. Date of Graduation: 15 December 2017

B. Area of Research

The proposed topic of this thesis is in Human Computer Systems Interaction focused on large-scale adoption of Cyber Security for Additive Manufacturing.

The title of this thesis will be **Operational Cyber Security Risks and their Effect on Adoption of Additive Manufacturing in the Naval Domain**

C. Research Questions

Research questions being pursued in this work include:

- What is taxonomy of operational cyber security risks in Additive Manufacturing (AM) domain?

- What elements of digital data sets and processes used in AM can be targeted, and what techniques can and should be used by the Navy to best protect them?

- What types of cyber security measures do Naval Fabrication Labs (FABLABs) currently utilize and what additional cyber security measures should be implemented to properly archive and manage data and processes relevant to Additive Manufacturing processes?

- What issues stand in the way of successful large-scale adoption of Additive Manufacturing, and what type of Cyber Security Risks may affect it most? What measures could be introduced to address those issues?

D. Discussion

Additive Manufacturing (AM) technology continues to improve and the areas for application of that technology continue to grow as well. Within the Navy, AM can potentially provide a great deal of independence for deployed units by drastically reducing reliance on the Navy's supply chain. Additionally, AM has a potential to save resources, increase productivity, and reduce storage requirements. As the Navy increases its Additive Manufacturing capabilities and expands implementation of this cost saving technology, the need to ensure that the data Additive Manufacturing process creates and relies on is secure increases as well. Theoretically, deployed Strike Groups and even individual units will be able to 3-D print critical parts and supplies without having to utilize a potentially time consuming and costly supply chain. However, those units need to have confidence that the processes are correct and that the parts they are fabricating are going to fit and work correctly. If the digital model that the printer relies on hasn't been properly protected from creation through final delivery to the printer, then the potential exists for a major casualty, which could cripple the units' war-fighting capabilities. Much research has been done to identify barriers to the adoption of technology and the goal of this thesis is to apply those concepts to the capabilities of Naval Fabrication Labs and other resources used in naval domain, to arrive at recommendations at how to achieve maximum use of the technology without sacrificing Cyber Security.

E. Scope of the Thesis

This thesis will focus on collection and analysis of data about the capabilities and usage of Naval Fabrication Labs and other resources in the Naval domain, and development of taxonomy of cyber security risks and issues in the AM domain. The study will investigate the full life cycle of data and processes used in additive manufacturing from a Cyber Security perspective. Specifically, the study intends to develop recommendations for Cyber Security Taxonomy applied to Additive Manufacturing and identify potential target vectors vulnerable to attack based on the Navy's Additive Manufacturing implementation models. Potential vulnerabilities exist based on human interaction with the data, data creation, data storage, and data sharing and data translation into physical form. The study will also assess ways to implement successful large-scale adoption of Additive Manufacturing technology without compromising Cyber Security.

F. Methodology

The work on this thesis will be conducted in five steps:

(1) Literature review

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    (a) Available logs/records of usage

    (b) Tools available and capabilities

(c) Desired future implementation/growth

(d) Cyber security measures in place

(e) Data sharing strategies

(f) Collaborative processes

(g) Training and certification (required and recommended)

(h) Leadership endorsement, media coverage (local and service-wide)

(3) Conduct in-depth study of lab data results, which will be used as the basis for the user survey.

(4) Design and execution of a Naval Fabrication Lab User survey to identify the following:

(a) Extent of use, and knowledge of capabilities

(b) User expectations (expected performance levels)

(c) Attitudes and satisfaction level (providers of AM services and users)

(d) Recommendations

(5) Analyze collected data and identify potential impediments to future growth and large-scale adoption due to Cyber Security measures.

G. Chapter Outline

1. Introduction – discussion of Additive Manufacturing and the purpose of the study, research questions and overall structure.

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3. Methodology – Detailed description of the approach used in thesis

4. FABLAB study: Design and execution of data collection from naval FABLABs (objective data sets). Data analysis.

5. User study: Design and execution of user study (survey with questionnaires). Data analysis.

6. Findings - Recommendations based on analysis and areas for future work.

7. Appendices

H. Schedule

Thesis Stage	Completion Target Date
Literature review	1MAY17
Draft thesis, Cover through Chapter 2, and initial list of references	1JUNE17
Theoretical work on taxonomy of cyber security risks and technology adoption	15JULY17
Design of user study (survey), and data collection	JULY-AUG17
Data analysis, thesis writing	30SEP17
Draft thesis checked by thesis processor for format	3NOV17
Draft thesis to advisor(s)	17NOV17
Final thesis submission for signatures	1 DEC 17

I. Benefits of Study

Additive Manufacturing has the potential to help the Navy reach new levels of independence from current logistics restraints while saving valuable resources including time, manpower and money. However, failure to implement Additive Manufacturing technology with effective, user-focused, cyber security principles could result in wasted resources and increased vulnerability to cyber threats. This thesis will benefit the Navy by creating an understanding of what the current obstacles are for user adoption of Cyber Security in Naval Additive Manufacturing and how best to mitigate those obstacles to encourage large scale adoption of the capabilities available through Naval Fabrication Labs.

J. Anticipated Travel/Funding Requirements

Field trip to Southwest Regional Maintenance Center (San Diego, CA): $1,500.00
Field trip to Mid Atlantic Regional Maintenance Center (Norfolk, VA): $2,200.00
Field trip to Southeast Regional Maintenance Center (Mayport, FL): $2,200.00
TOTAL: $5,900.00

K. Preliminary Bibliography

[1] Susan M. Bridges, Ken Keiser, Nathan Sissom, and Sara J. Graves. Cyber Security for Additive Manufacturing. CISR '15 Proceedings of the 10th Annual Cyber and Information

Security Research Conference Article No. 14, 2015. ACM, 2015.

[2] Matthew Daniel Friedell. Additive Manufacturing (Am) In Expeditionary Operations: Current Needs, Technical Challenges, And Opportunities. Masters thesis, Monterey, California: Naval Postgraduate School, 2016.

[3] Davis, F. D. (1989). Perceived usefulness, perceived ease of use, and user acceptance of information technology. MIS Quarterly, Volume 13 Issue 3, p. 319–339

[4] Davis, F. D.(1993). User acceptance of information technology: system characteristics, user perceptions and behavioral impacts, *Int J. Man-Machine Studies*, (1993) 38, p. 475-487

[5] Rogers, Everett M. (2010). Diffusion of innovations, Free Press; 5th edition

[6] Sadagic, A., and Yates, F. (2015). Large Scale Adoption of Training Simulations: Are We There Yet?. Interservice/Industry Training, Simulation, and Education Conference (I/ITSEC-2015), Orlando, FL.

[7] Thomas Harte and Adrian G Bors. Watermarking 3d models. In Image Processing. 2002. Proceedings. 2002 International Conference on, volume 3, pages 661–664. IEEE, 2002.

[8] Benoʻit Macq, Patrice Rondao Alface, and Mireia Montanola. Applicability of watermarking for intel- lectual property rights protection in a 3d printing scenario. In Proceedings of the 20th International Conference on 3D Web Technology, pages 89–95. ACM, 2015.

[9] Venkatesh, V., Morris, M. G., Davis, G. B., & Davis, F. D. (2003). User Acceptance of Information Technology: Toward a Unified View. MIS Quarterly, 27, p. 425–478.

[10] L. D. Sturm, C. B. Williams, J. A. Camelio, J. White, R. Parker (2014). Cyber-physical vunerabilities in additive manufacturing systems.

IRB Student Research Checklist
(25 JAN 16)

Does the student plan to engage in any of the following activities? Check all that apply.
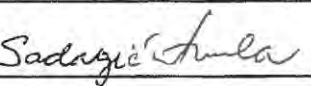
☑ Yes ☐ No   Administer a questionnaire or survey.

☑ Yes ☐ No   Conduct focus groups or interviews.

☐ Yes ☑ No   Observe human performance behavior or activity, directly or indirectly (e.g., online, through analysis of information systems, crowd sourcing, etc.) with or without individuals' knowledge.

☐ Yes ☑ No   Record human performance behavior or activity using audio, video, or digital recording methods.

☐ Yes ☑ No   Use of pre-collected data that contains any information about individuals and that is not available to the general public (i.e., cannot be obtained via a Google search).

☐ Yes ☑ No   Perform hardware and/or software tests that include representative users in the testing process.

If "Yes" is checked in any of the boxes above, a Human Subject Determination Request Form must be filled out, signed by the advisor, and sent to the HRPP Specialist at IRB@nps.edu. If the student and advisor are certain the proposed activity involves human subject research, they should proceed with submitting a full human subject research protocol. IRB forms are available at available at http://www.nps.edu/research/IRB.htm.

Student Statement of Assurance. Please check each box confirming you have read and agree with each statement.

☑ The answers provided above are accurate.

☑ I understand that if I have checked "Yes" to any of the activities I must submit a Human Subject Determination Request Form to the IRB and await the IRB's determination before engaging in that activity. (A full human subject research protocol may be submitted in lieu of a determination if the student and advisor are certain the proposed activity involves human subjects research).

☑ I agree that if all activities are checked "No" initially but the research evolves to include any of the above activities, I will request a new determination before engaging in that activity.

Student
Signature: _____   Date: 04/11/2017

Advisor
Signature: _____   Date: 04/11/2017

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Grimshaw, Michael's Thesis Information for Curriculum 368

Title:	Operational Cyber Security Risks and their Effect on Adoption of Additive Manufacturing in the Naval Domain

Type:	Thesis Note: Select "Dissertation" for PhD; select "Thesis" for Master's degree.

Abstract:

This thesis will focus on collection and analysis of data about the capabilities and usage of Naval Fabrication Labs and other resources in the Naval domain, and development of taxonomy of cyber security risks and issues in the AM domain. The study will investigate the full life cycle of data and processes used in additive manufacturing from a Cyber Security perspective. Specifically, the study intends to develop recommendations for Cyber Security Taxonomy applied to Additive Manufacturing and identify potential target vectors vulnerable to attack based on the Navy's Additive Manufacturing implementation models. Potential vulnerabilities exist based on human interaction with the data, data creation, data storage, and data sharing and data translation into physical form. The study will also assess ways to implement successful

Start Date: 3/31/2017

Note: If Proposal Approved is checked, thesis can no longer be deleted. If Final Approved is checked and Acceptance Date is entered, thesis can no longer be edited. Enter all dates in MM/DD/YYYY format.

Apply Changes	Close

Note: This will delete the thesis record from the database and remove all assignments. This should only be done in the case that the record was added erroneously.   **Delete This Thesis**

Administration Only

[ ] Proposal Approved   [ ] Final Approved

Acceptance Date:

Advisor Remarks:

Student(s) Assigned

Delete	Name	Section	Curric #	Is Primary Curric
	Grimshaw, Michael	368-163	368	Y

Add Partner

NPS Advisors

Edit / Delete	Advisor	Dept	Title	Email	Advisor Type
	Garza, Victor	630	Faculty	vrgarza@nps.edu	Advisor
	Sadagic, Amela	450	Research Associate Professor	asadagic@nps.edu	Advisor

Add NPS Advisor

Non-NPS Advisors

No Non-NPS Advisor(s) assigned.

Add Non-NPS Advisor

Date: 5 April 2017

MEMORANDUM

From: LT Michael D. Grimshaw
Section(s):   368-131

To: Program Officer, CS Department

Via: (1) Thesis Advisor: Dr. Amela Sadagic
        (2) Co-Advisor or 2nd Reader: Enter title and name Prof. Victor (Bob) Garza
        (3) Academic Associate, CS Department
        (4) Chair, CS Department

Subj: THESIS PROPOSAL

Encl: (1) Thesis Proposal
        (2) Institutional Review Board (IRB) Student Research Checklist

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6. I anticipate the following travel or other extraordinary requirements: As required to Naval Fabrication Laboratories located in San Diego, Norfolk and Mayport.

_____   N/A_____
Student Signature   Second Student Signature <if joint thesis>

1. Forwarded, recommending approval: _Sadagic Amela_____   04/11/17
                                      Thesis Advisor   Date

2. Forwarded, recommending approval:_____   4/11/17
                                      Co-Advisor or 2nd Reader (Circle one) Date

3. Forwarded, recommending approval:_____   14 APR 17
                                      Academic Associate, CS Department   Date

4. Forwarded, recommending approval:_____   4/18/17
                                      Chair, CS Department   Date

5. Approved, and retained:_____   23 APR 17
                                      Program Officer, CS Department   Date

Computer Science Thesis Proposal

A. General Information

 1. Name: LT Michael D. Grimshaw

 2. Email: mdgrimsh@nps.edu

 3. Curriculum: Computer Science (368)

 4. Thesis Advisor: Dr. Amela Sadagic

 5. Co-Advisor or 2nd Reader: Prof. Victor (Bob) Garza

 6. Academic Associate, CS Department: Dr. Alan Shaffer

 7. Chair, CS Department: Dr. Peter J. Denning

 8. Date of Graduation: 15 December 2017

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Draft thesis checked by thesis processor for format	3NOV17
Draft thesis to advisor(s)	17NOV17
Final thesis submission for signatures	1 DEC 17

I. Benefits of Study

Additive Manufacturing has the potential to help the Navy reach new levels of independence from current logistics restraints while saving valuable resources including time, manpower and money. However, failure to implement Additive Manufacturing technology with effective, user-focused, cyber security principles could result in wasted resources and increased vulnerability to cyber threats. This thesis will benefit the Navy by creating an understanding of what the current obstacles are for user adoption of Cyber Security in Naval Additive Manufacturing and how best to mitigate those obstacles to encourage large scale adoption of the capabilities available through Naval Fabrication Labs.

J. Anticipated Travel/Funding Requirements

Field trip to Southwest Regional Maintenance Center (San Diego, CA): $1,500.00

Field trip to Mid Atlantic Regional Maintenance Center (Norfolk, VA): $2,200.00

Field trip to Southeast Regional Maintenance Center (Mayport, FL): $2,200.00

TOTAL: $5,900.00

K. Preliminary Bibliography

[1] Susan M. Bridges, Ken Keiser, Nathan Sissom, and Sara J. Graves. Cyber Security for Additive Manufacturing. CISR '15 Proceedings of the 10th Annual Cyber and Information

Security Research Conference Article No. 14, 2015. ACM, 2015.

[2] Matthew Daniel Friedell. Additive Manufacturing (Am) In Expeditionary Operations: Current Needs, Technical Challenges, And Opportunities. Masters thesis, Monterey, California: Naval Postgraduate School, 2016.

[3] Davis, F. D. (1989). Perceived usefulness, perceived ease of use, and user acceptance of information technology. MIS Quarterly, Volume 13 Issue 3, p. 319–339

[4] Davis, F. D.(1993). User acceptance of information technology: system characteristics, user perceptions and behavioral impacts, *Int J. Man-Machine Studies*, (1993) 38, p. 475-487

[5] Rogers, Everett M. (2010). Diffusion of innovations, Free Press; 5th edition

[6] Sadagic, A., and Yates, F. (2015). Large Scale Adoption of Training Simulations: Are We There Yet?. Interservice/Industry Training, Simulation, and Education Conference (I/ITSEC-2015), Orlando, FL.

[7] Thomas Harte and Adrian G Bors. Watermarking 3d models. In Image Processing. 2002. Proceedings. 2002 International Conference on, volume 3, pages 661–664. IEEE, 2002.

[8] Beno^ıt Macq, Patrice Rondao Alface, and Mireia Montanola. Applicability of watermarking for intel- lectual property rights protection in a 3d printing scenario. In Proceedings of the 20th International Conference on 3D Web Technology, pages 89–95. ACM, 2015.

[9] Venkatesh, V., Morris, M. G., Davis, G. B., & Davis, F. D. (2003). User Acceptance of Information Technology: Toward a Unified View. MIS Quarterly, 27, p. 425–478.

[10] L. D. Sturm, C. B. Williams, J. A. Camelio, J. White, R. Parker (2014). Cyber-physical vunerabilities in additive manufacturing systems.

IRB Student Research Checklist
(25 JAN 16)

Does the student plan to engage in any of the following activities? Check all that apply.
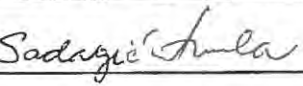
☑ Yes ☐ No   Administer a questionnaire or survey.

☑ Yes ☐ No   Conduct focus groups or interviews.

☐ Yes ☑ No   Observe human performance behavior or activity, directly or indirectly (e.g., online, through analysis of information systems, crowd sourcing, etc.) with or without individuals' knowledge.

☐ Yes ☑ No   Record human performance behavior or activity using audio, video, or digital recording methods.

☐ Yes ☑ No   Use of pre-collected data that contains any information about individuals and that is not available to the general public (i.e., cannot be obtained via a Google search).

☐ Yes ☑ No   Perform hardware and/or software tests that include representative users in the testing process.

If "Yes" is checked in any of the boxes above, a Human Subject Determination Request Form must be filled out, signed by the advisor, and sent to the HRPP Specialist at IRB@nps.edu. If the student and advisor are certain the proposed activity involves human subject research, they should proceed with submitting a full human subject research protocol. IRB forms are available at available at http://www.nps.edu/research/IRB.htm.

Student Statement of Assurance. Please check each box confirming you have read and agree with each statement.

☑ The answers provided above are accurate.

☑ I understand that if I have checked "Yes" to any of the activities I must submit a Human Subject Determination Request Form to the IRB and await the IRB's determination before engaging in that activity. (A full human subject research protocol may be submitted in lieu of a determination if the student and advisor are certain the proposed activity involves human subjects research).

☑ I agree that if all activities are checked "No" initially but the research evolves to include any of the above activities, I will request a new determination before engaging in that activity.

Student Signature: _____ Date: 04/11/2017

Advisor Signature: Sadagic Anula _____ Date: 04/11/2017

Grimshaw, Michael's Thesis Information for Curriculum 368

Title:	Operational Cyber Security Risks and their Effect on Adoption of Additive Manufacturing in the Naval Domain

Type:	Thesis	Note: Select "Dissertation" for PhD; select "Thesis" for Master's degree.

Abstract:

This thesis will focus on collection and analysis of data about the capabilities and usage of Naval Fabrication Labs and other resources in the Naval domain, and development of taxonomy of cyber security risks and issues in the AM domain. The study will investigate the full life cycle of data and processes used in additive manufacturing from a Cyber Security perspective. Specifically, the study intends to develop recommendations for Cyber Security Taxonomy applied to Additive Manufacturing and identify potential target vectors vulnerable to attack based on the Navy's Additive Manufacturing implementation models. Potential vulnerabilities exist based on human interaction with the data, data creation, data storage, and data sharing and data translation into physical form. The study will also assess ways to implement successful

Start Date: 3/31/2017

Note: If Proposal Approved is checked, thesis can no longer be deleted. If Final Approved is checked and Acceptance Date is entered, thesis can no longer be edited. Enter all dates in MM/DD/YYYY format.

Apply Changes	Close

Note: This will delete the thesis record from the database and remove all assignments. This should only be done in the case that the record was added erroneously.   Delete This Thesis

Administration Only

[ ] Proposal Approved   [ ] Final Approved

Acceptance Date:

Advisor Remarks:

Student(s) Assigned

Delete	Name	Section	Curric #	Is Primary Curric
	Grimshaw, Michael	368-163	368	Y

Add Partner

NPS Advisors

Edit / Delete	Advisor	Dept	Title	Email	Advisor Type
✎	Garza, Victor	630	Faculty	vrgarza@nps.edu	Advisor
✎	Sadagic, Amela	450	Research Associate Professor	asadagic@nps.edu	Advisor

Add NPS Advisor

Non-NPS Advisors

No Non-NPS Advisor(s) assigned.

Add Non-NPS Advisor

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COLLABORATIVE INSTITUTIONAL TRAINING INITIATIVE (CITI PROGRAM)
COMPLETION REPORT - PART 1 OF 2
COURSEWORK REQUIREMENTS*

* NOTE: Scores on this <u>Requirements Report</u> reflect quiz completions at the time all requirements for the course were met. See list below for details. See separate Transcript Report for more recent quiz scores, including those on optional (supplemental) course elements.

- **Name:**   Michael Grimshaw (ID: 6696669)
- **Institution Affiliation:** Department of The Navy (ID: 572)
- **Institution Email:**   mdgrimsh@nps.edu
- **Institution Unit:**   Computer Science
- **Phone:**   9043124567

- **Curriculum Group:**   Human Research
- **Course Learner Group:**   Investigators and Key Research Personnel - SBR
- **Stage:**   Stage 1 - Basic Course

- **Record ID:**   24861374
- **Completion Date:**   06-Oct-2017
- **Expiration Date:**   05-Oct-2020
- **Minimum Passing:**   80
- **Reported Score*:**   88

REQUIRED AND ELECTIVE MODULES ONLY	DATE COMPLETED	SCORE
Populations in Research Requiring Additional Considerations and/or Protections (ID: 16680)	05-Oct-2017	4/5 (80%)
DoD Requirements for Human Subject Research (ID: 15654)	05-Oct-2017	No Quiz
Avoiding Group Harms - U.S. Research Perspectives (ID: 14080)	05-Oct-2017	3/3 (100%)
Department of The Navy Introduction (ID: 1663)	05-Oct-2017	No Quiz
History and Ethical Principles - SBE (ID: 490)	06-Oct-2017	4/5 (80%)
Defining Research with Human Subjects - SBE (ID: 491)	06-Oct-2017	4/5 (80%)
The Federal Regulations - SBE (ID: 502)	06-Oct-2017	4/5 (80%)
Basic Institutional Review Board (IRB) Regulations and Review Process (ID: 2)	06-Oct-2017	5/5 (100%)
Assessing Risk - SBE (ID: 503)	06-Oct-2017	4/5 (80%)
Informed Consent - SBE (ID: 504)	06-Oct-2017	5/5 (100%)
Privacy and Confidentiality - SBE (ID: 505)	06-Oct-2017	4/5 (80%)
Records-Based Research (ID: 5)	06-Oct-2017	3/3 (100%)
Internet-Based Research - SBE (ID: 510)	06-Oct-2017	4/5 (80%)
Conflicts of Interest in Human Subjects Research (ID: 17464)	06-Oct-2017	5/5 (100%)
Department of The Navy - Information and References (ID: 877)	06-Oct-2017	No Quiz

For this Report to be valid, the learner identified above must have had a valid affiliation with the CITI Program subscribing institution identified above or have been a paid Independent Learner.

Verify at: www.citiprogram.org/verify/?kd1e881f3-a021-4876-8297-5186bc514036-24861374

COLLABORATIVE INSTITUTIONAL TRAINING INITIATIVE (CITI PROGRAM)
COMPLETION REPORT - PART 2 OF 2
COURSEWORK TRANSCRIPT**

** NOTE: Scores on this Transcript Report reflect the most current quiz completions, including quizzes on optional (supplemental) elements of the course. See list below for details. See separate Requirements Report for the reported scores at the time all requirements for the course were met.

- **Name:** Michael Grimshaw (ID: 6696669)
- **Institution Affiliation:** Department of The Navy (ID: 572)
- **Institution Email:** mdgrimsh@nps.edu
- **Institution Unit:** Computer Science
- **Phone:** 9043124567

- **Curriculum Group:** Human Research
- **Course Learner Group:** Investigators and Key Research Personnel - SBR
- **Stage:** Stage 1 - Basic Course

- **Record ID:** 24861374
- **Report Date:** 06-Oct-2017
- **Current Score**:** 88

REQUIRED, ELECTIVE, AND SUPPLEMENTAL MODULES	MOST RECENT	SCORE
History and Ethical Principles - SBE (ID: 490)	06-Oct-2017	4/5 (80%)
Defining Research with Human Subjects - SBE (ID: 491)	06-Oct-2017	4/5 (80%)
The Federal Regulations - SBE (ID: 502)	06-Oct-2017	4/5 (80%)
Records-Based Research (ID: 5)	06-Oct-2017	3/3 (100%)
Assessing Risk - SBE (ID: 503)	06-Oct-2017	4/5 (80%)
Informed Consent - SBE (ID: 504)	06-Oct-2017	5/5 (100%)
Privacy and Confidentiality - SBE (ID: 505)	06-Oct-2017	4/5 (80%)
Internet-Based Research - SBE (ID: 510)	06-Oct-2017	4/5 (80%)
Department of The Navy Introduction (ID: 1663)	05-Oct-2017	No Quiz
Avoiding Group Harms - U.S. Research Perspectives (ID: 14080)	05-Oct-2017	3/3 (100%)
Basic Institutional Review Board (IRB) Regulations and Review Process (ID: 2)	06-Oct-2017	5/5 (100%)
Populations in Research Requiring Additional Considerations and/or Protections (ID: 16680)	05-Oct-2017	4/5 (80%)
Conflicts of Interest in Human Subjects Research (ID: 17464)	06-Oct-2017	5/5 (100%)
Department of The Navy - Information and References (ID: 877)	06-Oct-2017	No Quiz
DoD Requirements for Human Subject Research (ID: 15654)	05-Oct-2017	No Quiz

For this Report to be valid, the learner identified above must have had a valid affiliation with the CITI Program subscribing institution identified above or have been a paid Independent Learner.

Verify at: www.citiprogram.org/verify/?kd1e881f3-a021-4876-8297-5186bc514036-24861374

Collaborative Institutional Training Initiative (CITI Program)
Email: support@citiprogram.org
Phone: 888-529-5929
Web: https://www.citiprogram.org

Ownership and Use of Technology

There are 88 questions in this survey

Naval Postgraduate School Consent to Participate in Research

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[]Introduction. You are invited to participate in a research study entitled *"Ownership and Use of Technology"*. The purpose of the research is to survey U.S. Army, Navy and Air Force NPS active duty students about their familiarity with and use of commercial technologies.

Procedures. You are being asked to complete a web-based anonymous survey. The survey should take about 30 minutes to complete, must be taken in one sitting, and can be taken during working hours. The expected number of participants who will have the opportunity to participate in this research study is approximately 300. There will be no compensation given for participation in the study.

Location. The survey will take place online using LimeSurvey.

Cost. There is no cost to participate in this research study.

Voluntary Nature of the Study. Your participation in this study is strictly voluntary. If you choose to participate you can change your mind at any time and withdraw from the study. You will not be penalized in any way or lose any benefits to which you would otherwise be entitled if you choose not to participate in this study or to withdraw.

Potential Risks and Discomforts. The potential risks of participating in this study are: minimal risk of breach of confidentiality. This survey is anonymous and strictly voluntary. No IP addresses or personally identifiable information (PII) will be collected.

Anticipated Benefits. Anticipated benefits from this study are creating an understanding of current trends in ownership and use of technologies. You will not directly benefit from your participation in this research.

Confidentiality & Privacy Act. Any information that is obtained during this study will be kept confidential to the full extent permitted by law. All efforts, within reason, will be made to keep your personal information in your research record confidential but total confidentiality cannot be guaranteed. All survey responses are anonymous and will not be shared with anyone outside the investigating research team. Participants submissions are immediately sent to LimeSurvey and responses are not stored locally on their computers or networks. Only the researcher and principal investigator will have access to the collected data for analysis. The data will be stored in a secured database and the principal investigator will maintain all electronic data upon completion of the study for 10 years.

Points of Contact. If you have any questions or comments about the research, or you experience an injury or have questions about any discomforts that you experience while taking part in this study please contact the Principal Investigator, *Dr. Amela Sadagic, 831-656-3819*, asadagic@nps.edu. Questions about your rights as a research subject or any other concerns may be addressed to the Navy Postgraduate School IRB Chair, Dr. Larry Shattuck, 831-656-2473, lgshattu@nps.edu.

Statement of Consent. I have read the information provided above. I have been given the opportunity to ask questions and all the questions have been answered to my satisfaction. I have been provided a copy of this form for my records and I agree to participate in this study. I understand that by agreeing to participate in this research and signing this form, I do not waive any of my legal rights. *

Please choose **only one** of the following:

○ Yes

○ No

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Demographics

[] Date questionnaire completed: *

Please enter a date:

[   ]

[]Birth year:

Only numbers may be entered in this field.

Please write your answer here:

[   ]

[]Gender:

Please choose **only one** of the following:

○ Female

○ Male

[]Select your Service: *

Please choose **only one** of the following:

○ US Army

○ US Navy

○ US Air Force

[]Select your MOS:

Only answer this question if the following conditions are met:
Answer was 'US Army' at question '5 [Demo4]' (Select your Service)

Please choose only one of the following:

- ○ 11A
- ○ 12A
- ○ 13A
- ○ 14A
- ○ 15
- ○ 19
- ○ 25A
- ○ 27A
- ○ 31A
- ○ 35
- ○ 36A
- ○ 37A
- ○ 38A
- ○ 42C
- ○ 56
- ○ 63
- ○ 64
- ○ 66
- ○ 67
- ○ 74A
- ○ 88A
- ○ 91A
- ○ 92A
- ○ Other [   ]

[]Select your Designator:

Only answer this question if the following conditions are met:
Answer was 'US Navy' at question '5 [Demo4]' (Select your Service:)

Please choose only one of the following:

○ 1100

○ 1110

○ 1120

○ 1130

○ 1140

○ 1160

○ 1170

○ 1180

○ 1190

○ 1200

○ 1210

○ 1220

○ 1230

○ 1300

○ 1301

○ 1310

○ 1311

○ 1312

○ 1320

○ 1321

○ 1322

○ 1372

○ 1392

○ 1440

○ 1460

○ 1500

○ 1510

○ 1511

○ 1512

○ 1520

○ 1540

○ 1541

○ 1542

○ 1650

○ 1660

○ 1710

○ 1712

○ 1720

○ 1800

○ 1802

- ○ 1810
- ○ 1820
- ○ 1830
- ○ 1840
- ○ 1850
- ○ 1860
- ○ 1900
- ○ 1910
- ○ 1920
- ○ 1930
- ○ 1950
- ○ 1960
- ○ 2000
- ○ 2100
- ○ 2102
- ○ 2200
- ○ 2300
- ○ 2302
- ○ 2500
- ○ 2900
- ○ 3100
- ○ 4100
- ○ 5100
- ○ 6000
- ○ 6110
- ○ 6120
- ○ 6130
- ○ 6150
- ○ 6160
- ○ 6180
- ○ 6200
- ○ 6210
- ○ 6230
- ○ 6260
- ○ 6280
- ○ 6290
- ○ 6310
- ○ 6320
- ○ 6321
- ○ 6330
- ○ 6360
- ○ 6390
- ○ 6410
- ○ 6430
- ○ 6470

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- ○ 6480
- ○ 6490
- ○ 6510
- ○ 6530
- ○ 6550
- ○ 6800
- ○ 6810
- ○ 6820
- ○ 6830
- ○ 7110
- ○ 7120
- ○ 7130
- ○ 7150
- ○ 7160
- ○ 7170
- ○ 7180
- ○ 7200
- ○ 7210
- ○ 7230
- ○ 7240
- ○ 7260
- ○ 7280
- ○ 7310
- ○ 7320
- ○ 7321
- ○ 7330
- ○ 7360
- ○ 7400
- ○ 7410
- ○ 7470
- ○ 7480
- ○ 7490
- ○ 7510
- ○ 7520
- ○ 7530
- ○ 7560
- ○ 7800
- ○ 7810
- ○ 7820
- ○ 7830
- ○ 7840
- ○ Other

125

[]Select your AFSC:

Only answer this question if the following conditions are met:
Answer was 'US Air Force' at question '5 [Demo4]' (Select your Service)

Please choose only one of the following:

○ 10CX Operations Commander

○ 11AX Airlift Pilot

○ 11BX Bomber Pilot

○ 11EX Experimental Test Pilot

○ 11FX Fighter Pilot

○ 11GX Generalist Pilot

○ 11HX Helicopter Pilot

○ 11KX Trainer Pilot

○ 11MX Mobility Pilot

○ 11RX Reconnaissance/Surveillance/ Electronic Warfare Pilot

○ 11SX Special Operations Pilot

○ 11TX Tanker Pilot

○ 11UX Remotely Operated Aircraft Pilot

○ 12AX Airlift Navigator

○ 12BX Bomber Combat Systems Operator

○ 12EX Experimental Test Combat Systems Officer

○ 12FX Fighter Combat Systems Officer

○ 12GX Generalist Combat Systems Officer

○ 12KX Trainer Combat Systems Officer

○ 12MX Mobility Combat Systems Officer

○ 12RX Reconnaissance/Surveillance/Electronic Warfare Combat Systems Officer

○ 12SX Special Operations Combat Systems Officer

○ 12UX Remotely Operated Aircraft Pilot

○ 13AX Astronaut

○ 13BX Air Battle Manager

○ 13DX Control and Recovery

○ 13LX Air Liaison Officer

○ 13MX Airfield Operation

○ 13SX Space and Missile

○ 14NX Intelligence

○ 15WX Weather

○ 16FX Regional Affairs Strategist

○ 16GX Air Force Operations Staff Officer

○ 16PX Political-Military Affairs Strategist

○ 16RX Planning and Programming

○ 17CX Cyber Operations Commander

○ 17DX Cyberspace Operations

○ 18AX Attack Remotely Piloted Aircraft Pilot

○ 20CX Logistics Commander

○ 21AX Aircraft Maintenance

- ○ 21MX Munitions and Missile Maintenance
- ○ 21RX Logistics Readiness
- ○ 30CX Support Commander
- ○ 31PX Security Forces
- ○ 32EX Civil Engineer
- ○ 33SX Communications and Information
- ○ 35BX Band 2
- ○ 35PX Public Affairs
- ○ 36PX Personnel Officer
- ○ 38FX Force Support Officer
- ○ 40CX Medical Commander
- ○ 41AX Health Services Administrator
- ○ 42BX Physical Therapist
- ○ 42EX Optometrist
- ○ 42FX Podiatrist
- ○ 42GX Physician Assistant
- ○ 42NX Audiology/Speech Pathologist
- ○ 42PX Clinical Psychologist
- ○ 42SX Clinical Social Worker
- ○ 42TX Occupational Therapist
- ○ 43AX Aerospace and Operational Physiologist
- ○ 43BX Biomedical Scientist
- ○ 43DX Dietitian
- ○ 43EX Bioenvironmental Engineer
- ○ 43HX Public Health
- ○ 43MX Medical Entomologist
- ○ 43PX Pharmacist
- ○ 43TX Biomedical Laboratory
- ○ 44AX Chief, Hospital/Clinic Services
- ○ 44BX Preventive Medicine
- ○ 44DX Pathologist
- ○ 44EX Emergency Services Physician
- ○ 44FX Family Physician
- ○ 44GX General Practice Physician
- ○ 44JX Clinical Geneticist
- ○ 44KX Pediatrician
- ○ 44MX Internist
- ○ 44NX Neurologist
- ○ 44PX Psychiatrist
- ○ 44RX Diagnostic Radiologist
- ○ 44SX Dermatologist
- ○ 44TX Radiotherapist
- ○ 44UX Occupational Medicine
- ○ 44YX Critical Care Medicine
- ○ 44ZX Allergist

○ 45AX Anesthesiologist

○ 45BX Orthopedic Surgeon

○ 45EX Ophthalmologist

○ 45GX OB/GYN

○ 45NX Otorhinolaryngologist

○ 45PX Physical Medicine Physician

○ 45SX Surgeon

○ 45UX Urologist

○ 46AX Nurse Administrator

○ 46FX Flight Nurse

○ 46NX Clinical Nurse

○ 46PX Mental Health Nurse

○ 46SX Operating Room Nurse

○ 46YX Privileged Advanced Practice Nurse

○ 47BX Orthodontist

○ 47DX Oral and Maxillofacial Pathologist

○ 47EX Endodontist

○ 47GX Dentist

○ 47HX Periodontist

○ 47KX Pediatric Dentist

○ 47PX Prosthodontist

○ 47SX Oral and Maxillofacial Surgeon

○ 48AX Aerospace Medicine Specialist

○ 48GX General Medical Officer Flight Surgeon

○ 48RX Residency Trained Flight Surgeon

○ 48VX Pilot-Physician

○ 51JX Judge Advocate

○ 52RX Chaplain

○ 60CX Program Director

○ 61AX Operations Research Analyst

○ 61BX Behaviorial Science/Human Scientist

○ 61CX Chemist

○ 61DX Physicist/Nuclear Engineer

○ 61SX Scientist

○ 62EX Developmental Engineer

○ 62SX Materiel Leader

○ 63AX Acquisition Manager

○ 63GX Senior Materiel Leader

○ 63SX Materiel Leader

○ 64PX Contracting

○ 65FX Financial Management

○ 65WX Cost Analysis

○ 71SX Special Investigations

○ 80CX Commander, Cadet Squadron, USAFA

○ 81CX Training Commander, OTS

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- ○ 81TX Instructor
- ○ 82AX Academic Program Manager
- ○ 83RX Recruiting Service
- ○ 85GX U.S. Air Force Honor Guard
- ○ 86MX Operations Management
- ○ 86PX Command and Control
- ○ 87GX Installation Inspector General
- ○ 88AX Aide-de-camp
- ○ 90GX General Officer
- ○ 91CX Commander
- ○ 91WX Wing Commander
- ○ 92JX Non-designated Lawyer
- ○ 92MX Medical Student
- ○ 92SX Student Officer Authorization
- ○ 92TX Pilot Trainee
- ○ 93PX Patient
- ○ 96DX Officer not avail in awarded AFSC
- ○ 96UX Unclassified Officer
- ○ 97EX Executive Officer
- ○ Other [_____]

[]Select your rank:

Please choose only one of the following:

- ○ O1
- ○ O2
- ○ O3
- ○ O4
- ○ O5
- ○ Other [_____]

[]How long have you served in the military? Please enter your total time in service (TIS) in years:

Only numbers may be entered in this field.

Please write your answer here:

[_____]

[]Select your highest education level:

Please choose only one of the following:

○ High School Diploma or equivalent

○ partial work towards Associates

○ Associates Degree

○ BS / BA

○ partial work towards Masters

○ Masters Degree

○ partial work towards Doctorates

○ PhD

[]What social networking platforms are you a member of? (check all that apply)

Please choose all that apply:

☐ Facebook

☐ Twitter

☐ Instagram

☐ Snapchat

☐ Pinterest

☐ LinkedIn

☐ Google+

☐ MeetUp

☐ None

☐ Other: [_____]

Technology Devices

GUIDANCE: For questions 9-13, the term "technology devices" refers to items such as computers, smartphones, tablets, gaming devices (gaming consoles), Internet of Things (IOT) devices (examples: Google Home, Amazon Echo, Smart Home Devices such as locks, thermostats), etc.

Please select the answer from the scale that best describes you:

[]

I am among the first to purchase new technology devices.

Please choose the appropriate response for each item:

	1: Strongly disagree	2: Disagree	3: Somewhat disagree	4: Neither disagree or agree	5: Somewhat agree	6: Agree	7: Strongly agree
Select one	O	O	O	O	O	O	O

[]

I stay updated on the latest information about technology devices.

Please choose the appropriate response for each item:

	1: Strongly disagree	2: Disagree	3: Somewhat disagree	4: Neither disagree or agree	5: Somewhat agree	6: Agree	7: Strongly agree
Select one	O	O	O	O	O	O	O

[]I wait for expert opinions before purchasing technology devices.

Please choose the appropriate response for each item:

	1: Strongly disagree	2: Disagree	3: Somewhat disagree	4: Neither disagree or agree	5: Somewhat agree	6: Agree	7: Strongly agree
Select one	O	O	O	O	O	O	O

[]I wait for my peers' opinions before purchasing technology devices (select one).

Please choose the appropriate response for each item:

	1: Strongly disagree	2: Disagree	3: Somewhat disagree	4: Neither disagree or agree	5: Somewhat agree	6: Agree	7: Strongly agree
Select one	O	O	O	O	O	O	O

[]I am among the last to purchase new technology devices.

Please choose the appropriate response for each item:

	1: Strongly disagree	2: Disagree	3: Somewhat disagree	4: Neither disagree or agree	5: Somewhat agree	6: Agree	7: Strongly agree
Select one	O	O	O	O	O	O	O

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Video Games

[]Do you play video games?

Please choose **only one** of the following:

○ Yes

○ No

[]How often do you play video games?

Only answer this question if the following conditions are met:
Answer was 'Yes' at question '18 [VG15]' (Do you play video games?)

Please choose **only one** of the following:

○ Less than monthly

○ Monthly

○ Twice a month

○ Weekly

○ Twice a week

○ More than twice a week

○ Daily

[]

What is the average duration of your video game sessions:

Only answer this question if the following conditions are met:
Answer was 'Yes' at question '18 [VG15]' (Do you play video games?)

Please choose **only one** of the following:

○ Up to one hour

○ Anywhere between 1 - 3 hours

○ Anywhere between 3 – 5 hours

○ More than 5 hours

[]

Please select the answer from the scale that best describes you:

I am among the first to purchase newly released games.

Only answer this question if the following conditions are met:
Answer was 'Yes' at question '18 [VG15]' (Do you play video games?)

Please choose the appropriate response for each item:

	1: Strongly disagree	2: Disagree	3: Somewhat disagree	4: Neither disagree or agree	5: Somewhat agree	6 Agree	7: Strongly agree
Select one	○	○	○	○	○	○	○

[]I stay updated on the latest information about newly released games.

Only answer this question if the following conditions are met:
Answer was 'Yes' at question '18 [VG15]' (Do you play video games?)

Please choose the appropriate response for each item:

	1: Strongly disagree	2: Disagree	3: Somewhat disagree	4: Neither disagree or agree	5: Somewhat agree	6: Agree	7: Strongly agree
Select one	O	O	O	O	O	O	O

[]I wait for expert opinions before purchasing newly released games.

Only answer this question if the following conditions are met:
Answer was 'Yes' at question '18 [VG15]' (Do you play video games?)

Please choose the appropriate response for each item:

	1: Strongly disagree	2: Disagree	3: Somewhat disagree	4: Neither disagree or agree	5: Somewhat agree	6: Agree	7: Strongly agree
Select one	O	O	O	O	O	O	O

[]I wait for my peers' opinions before purchasing newly released games.

Only answer this question if the following conditions are met:
Answer was 'Yes' at question '18 [VG15]' (Do you play video games?)

Please choose the appropriate response for each item:

	1: Strongly disagree	2: Disagree	3: Somewhat disagree	4: Neither disagree or agree	5: Somewhat agree	6: Agree	7: Strongly agree
Select one	O	O	O	O	O	O	O

[]I am among the last to purchase newly released games.

Only answer this question if the following conditions are met:
Answer was 'Yes' at question '18 [VG15]' (Do you play video games?)

Please choose the appropriate response for each item:

	1: Strongly disagree	2: Disagree	3: Somewhat disagree	4: Neither disagree or agree	5: Somewhat agree	6: Agree	7: Strongly agree
Select one	O	O	O	O	O	O	O

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Apps

[]Do you download and/or purchase applications (apps)?

Please choose only one of the following:

○ Yes

○ No

[]I am among the first to download or purchase newly released apps.

Only answer this question if the following conditions are met:
Answer was 'Yes' at question '26 [Apps23]' (Do you download and/or purchase applications (apps)?)

Please choose the appropriate response for each item:

	1: Strongly disagree	2: Disagree	3: Somewhat disagree	4: Neither disagree or agree	5: Somewhat agree	6: Agree	7: Strongly agree
Select one	○	○	○	○	○	○	○

[]I stay updated on the latest information about newly released apps.

Only answer this question if the following conditions are met:
Answer was 'Yes' at question '26 [Apps23]' (Do you download and/or purchase applications (apps)?)

Please choose the appropriate response for each item:

	1: Strongly disagree	2: Disagree	3: Somewhat disagree	4: Neither disagree or agree	5: Somewhat agree	6: Agree	7: Strongly agree
Select one	○	○	○	○	○	○	○

[]I wait for expert opinions before downloading or purchasing newly released apps.

Only answer this question if the following conditions are met:
Answer was 'Yes' at question '26 [Apps23]' (Do you download and/or purchase applications (apps)?)

Please choose the appropriate response for each item:

	1: Strongly disagree	2: Disagree	3: Somewhat disagree	4: Neither disagree or agree	5: Somewhat agree	6: Agree	7: Strongly agree
Select one	○	○	○	○	○	○	○

[]I wait for my peers' opinions before downloading or purchasing newly released apps.

Only answer this question if the following conditions are met:
Answer was 'Yes' at question '26 [Apps23]' (Do you download and/or purchase applications (apps)?)

Please choose the appropriate response for each item:

	1: Strongly disagree	2: Disagree	3: Somewhat disagree	4: Neither disagree or agree	5: Somewhat agree	6: Agree	7: Strongly agree
Select one	○	○	○	○	○	○	○

[]I am among the last to download or purchase newly released apps.

Only answer this question if the following conditions are met:
Answer was 'Yes' at question '26 [Apps23]' (Do you download and/or purchase applications (apps)?)

Please choose the appropriate response for each item:

	1: Strongly disagree	2: Disagree	3: Somewhat disagree	4: Neither disagree or agree	5: Somewhat agree	6: Agree	7: Strongly agree
Select one	○	○	○	○	○	○	○

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Recreational Resources

Please select the answer that best describes you

[]When using service provided recreational resources such as a library, computer lab, auto-hobby shop, or gym, how likely are you to ask an employee to teach you how to use the equipment?

Please choose the appropriate response for each item:

	Very Unlikely	Unlikely	Somewhat Unlikely	Neutral / Uncertain	Somewhat Likely	Likely	Very Likely
Select one	○	○	○	○	○	○	○

[]When using service provided recreational resources such as a library, computer lab, auto-hobby shop, or gym, how likely are you to teach yourself how to use the equipment through trial and error type techniques?

Please choose the appropriate response for each item:

	Very Unlikely	Unlikely	Somewhat Unlikely	Neutral / Uncertain	Somewhat Likely	Likely	Very Likely
Select one	○	○	○	○	○	○	○

[]When using service provided recreational resources such as a library, computer lab, auto-hobby shop, or gym, how likely are you to use self-help guide or video made available via internet by other users, to learn how to use the equipment?

Please choose the appropriate response for each item:

	Very Unlikely	Unlikely	Somewhat Unlikely	Neutral / Uncertain	Somewhat Likely	Likely	Very Likely
Select one	○	○	○	○	○	○	○

3D Printing

[]I know what 3D printing is.

Please choose the appropriate response for each item:

	1: Strongly disagree	2: Disagree	3: Somewhat disagree	4: Neither disagree or agree	5: Somewhat agree	6: Agree	7: Strongly agree
Select one	○	○	○	○	○	○	○

[]Describe 3D printing in your own words.

Please write your answer here:

[]I believe 3D printing can be very useful for personal projects (home, off-duty, leisure, etc.).

Please choose the appropriate response for each item:

	1: Strongly disagree	2: Disagree	3: Somewhat disagree	4: Neither disagree or agree	5: Somewhat agree	6: Agree	7: Strongly agree
Select one	○	○	○	○	○	○	○

[]Please provide examples of useful 3D printed objects for personal use:

Please write your answer here:

[]I own 3D printed objects for personal use (home, off-duty, leisure, etc.) that were printed by someone other than myself.

Please choose only one of the following:

○ Yes

○ No

[]Please explain what they are:

Only answer this question if the following conditions are met:
Answer was 'Yes' at question '39 [Print36]' (I own 3D printed objects for personal use (home, off-duty, leisure, etc.) that were printed by someone other than myself.)

Please write your answer here:

[]I own 3D printed objects for personal use (home, off-duty, leisure, etc.) that I printed.

Please choose only one of the following:

○ Yes

○ No

[]Please explain what they are:

Only answer this question if the following conditions are met:
Answer was 'Yes' at question '41 [Print37]' (I own 3D printed objects for personal use (home, off-duty, leisure, etc.) that I printed.)

Please write your answer here:

[]I printed 3D objects for personal use on a private (you own or someone you know owns) 3D printer.

Please choose only one of the following:

○ Yes

○ No

[]Please explain what they are:

Only answer this question if the following conditions are met:
Answer was 'Yes' at question '43 [Print38]' (I printed 3D objects for personal use on a private (you own or someone you know owns) 3D printer.)

Please write your answer here:

[]What was the source of the object(s) you printed?

Only answer this question if the following conditions are met:
Answer was 'Yes' at question '43 [Print38]' (I printed 3D objects for personal use on a private (you own or someone you know owns) 3D printer.)

Please choose all that apply:

☐ I designed the object(s)

☐ I downloaded the file(s) that describes the object(s) from an internet web site

☐ I received the file(s) that describes the object(s) via e-mail or some type of file transfer

☐ Not sure

☐ Other: _____

[]What training did you receive prior to using the 3D printer?

Only answer this question if the following conditions are met:
Answer was 'Yes' at question '43 [Print38]' (I printed 3D objects for personal use on a private (you own or someone you know owns) 3D printer.)

Please choose all that apply:

☐ Someone else trained me

☐ I trained myself using an instruction manual (example: vendor-provided manual)

☐ I trained myself using a self-help guide or video made available via internet by other users

☐ I did not receive training prior to using the 3D printer

☐ Other: _____

[]

GUIDANCE: For the remainder of the survey, if the question is not directly applicable to your current status as an NPS student, please consider your previous duty station when answering the question.

I believe 3D printing can be very useful in my Work Center.

Please choose the appropriate response for each item:

	1: Strongly disagree	2: Disagree	3: Somewhat disagree	4: Neither disagree or agree	5: Somewhat agree	6: Agree	7: Strongly agree
Select one	○	○	○	○	○	○	○

[]My unit currently has and uses 3D printed objects.

Please choose **only one** of the following:

○ Yes

○ No

○ I don't know

[]Please explain what they are:

Only answer this question if the following conditions are met:
Answer was 'Yes' at question '48 [Print40]' (My unit currently has and uses 3D printed objects.)

Please write your answer here:

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[]My unit currently has a 3D printing capability.

Please choose only one of the following:

○ Yes

○ No

○ I don't know

[]Please explain what the printers are predominantly being used for:

Only answer this question if the following conditions are met:
Answer was 'Yes' at question '50 [Print41]' (My unit currently has a 3D printing capability.)

Please write your answer here:

[]My unit printed 3D objects for use in the work environment.

Please choose only one of the following:

○ Yes

○ No

[]Please explain what they are:

Only answer this question if the following conditions are met:
Answer was 'Yes' at question '52 [Print43]' (My unit printed 3D objects for use in the work environment.)

Please write your answer here.

[]What was the source of the object(s) your unit printed?

Only answer this question if the following conditions are met:
Answer was 'Yes' at question '52 [Print43]' (My unit printed 3D objects for use in the work environment.)

Please choose all that apply:

☐ Someone in my unit designed the object(s)

☐ I downloaded the file(s) that describes the object(s) from an internet web site

☐ Someone in my unit downloaded the file(s) that describes the object(s) from an internet web site

☐ I received the file(s) that describes the object(s) via e-mail or some type of file transfer

☐ Someone in my unit received the file(s) that describes the object(s) via e-mail or some type of file transfer

☐ Not sure

☐ Other: _____

[]I printed 3D objects for personal use on a service provided (in your Work Center or on base) 3D printer.

Please choose only one of the following:

○ No, personal projects are not authorized

○ No, we don't have a printer

○ No, we have a printer but I have not printed on it

○ Yes

[]Please explain what they are:

Only answer this question if the following conditions are met:
Answer was 'Yes' at question '55 [Print42]' (I printed 3D objects for personal use on a service provided (in your Work Center or on base) 3D printer.)

Please write your answer here:

[]What was the source of the object(s) you printed?

Only answer this question if the following conditions are met:
Answer was 'Yes' at question '55 [Print42]' (I printed 3D objects for personal use on a service provided (in your Work Center or on base) 3D printer.)

Please choose all that apply:

☐ I designed the object(s)

☐ I downloaded the file that describes the object(s) from an internet site

☐ I received the file(s) that describes the object(s) via e-mail or some type of file transfer

☐ Not sure

☐ Other: [_____]

[]What training did you receive prior to using the 3D printer?

Only answer this question if the following conditions are met:
Answer was 'Yes' at question '55 [Print42]' (I printed 3D objects for personal use on a service provided (in your Work Center or on base) 3D printer.)

Please choose all that apply:

☐ Someone else trained me

☐ I trained myself using an instruction manual (example: vendor-provided manual)

☐ I trained myself using a self-help guide or video made available via internet by other users

☐ I did not receive training prior to using the 3D printer

☐ Other: [_____]

[]If given a 3D printing capability at my workplace, I could use it immediately to make my workplace more efficient.

Please choose the appropriate response for each item:

	1: Strongly disagree	2: Disagree	3: Somewhat disagree	4: Neither disagree or agree	5: Somewhat agree	6: Agree	7: Strongly agree
Select one	○	○	○	○	○	○	○

[]I believe that a 3D printing capability would reduce the amount of spare parts that my unit stores or orders/purchases because we could print them as they are needed.

Please choose the appropriate response for each item:

	1: Strongly disagree	2: Disagree	3: Somewhat disagree	4: Neither disagree or agree	5: Somewhat agree	6: Agree	7: Strongly agree
Select one	○	○	○	○	○	○	○

[]NPS has 3D printers available for student use.

Please choose only one of the following:

○ Yes

○ No

○ I don't know

○ Other [_____]

[]Please state where they are located:

Only answer this question if the following conditions are met:
Answer was 'Yes' at question '61 [Print46]' (NPS has 3D printers available for student use.)

Please write your answer here:

[]I believe 3D printing can be very useful for my service (USA, USN, USAF).

Please choose the appropriate response for each item:

	1: Strongly disagree	2: Disagree	3: Somewhat disagree	4: Neither disagree or agree	5: Somewhat agree	6: Agree	7: Strongly agree
Select one	O	O	O	O	O	O	O

[]Please provide examples for the previous question:

Please write your answer here:

[]I am aware that my service is pursuing 3D printing technology.

Please choose only one of the following:

O Yes

O No

[]I am aware of specific 3D printed objects currently being used in my service (USA, USN, USAF).

Please choose only one of the following:

O Yes

O No

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[]Please explain what they are:

Only answer this question if the following conditions are met:
Answer was 'Yes' at question '66 [Print51]' (I am aware of specific 3D printed objects currently being used in my service (USA, USN, USAF).)

Please write your answer here:

[ ]

[]I believe every command within my service (USN, USAF, USA) will have a 3D printer in the next 5 years.

Please choose **only one** of the following:

○ Yes

○ No

○ I don't know

[]What problem(s) do you see with respect to 3D printing?

Please write your answer here:

[ ]

Adoption

[]In your opinion, what is the speed with which your service (USA, USN, USAF) adopts technology?

Please choose the appropriate response for each item:

	Very poor	Poor	Fair	Good	Very good	Excellent	Exceptional
Select one	○	○	○	○	○	○	○

[]In your opinion, how important is your <u>service</u> leaderships' endorsement and full support of new technology to adoption?

Please choose the appropriate response for each item:

	Very unimportant	Not important	Slightly not important	Neutral	Slightly important	Important	Very important
Select one	○	○	○	○	○	○	○

[]In your opinion, how important is your <u>unit</u> leaderships' endorsement and full support of new technology to adoption?

Please choose the appropriate response for each item:

	Very unimportant	Not important	Slightly not important	Neutral	Slightly important	Important	Very important
Select one	○	○	○	○	○	○	○

[]In your opinion, how knowledgeable is your <u>service</u> leadership about 3D Printing?

Please choose the appropriate response for each item:

	Very unknowledgeable	Not knowledgeable	Slightly not knowledgeable	Neutral	Slightly knowledgeable	Knowledgeable	Very knowledgeable
Select one	○	○	○	○	○	○	○

[]In your opinion, how knowledgeable is your <u>unit</u> leadership about 3D printing?

Please choose the appropriate response for each item:

	Very unknowledgeable	Not knowledgeable	Slightly not knowledgeable	Neutral	Slightly knowledgeable	Knowledgeable	Very knowledgeable
Select one	○	○	○	○	○	○	○

[]In your opinion, how supportive is your <u>service's</u> leadership of 3D printing?

Please choose the appropriate response for each item:

	Very unsupportive	Not supportive	Slightly not supportive	Neutral	Slightly supportive	Supportive	Very supportive
Select one	○	○	○	○	○	○	○

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[]In your opinion, how supportive is your <u>unit's</u> leadership of 3D Printing?

Please choose the appropriate response for each item:

	Very unsupportive	Not supportive	Slightly not supportive	Neutral	Slightly supportive	Supportive	Very supportive
Select one	○	○	○	○	○	○	○

Cyber

GUIDANCE: For the remainder of the survey, *Cyber Security* is defined as:

"The prevention of damage to, protection of, and restoration of computers, electronic communications systems, electronic communications systems services, wire communication, and electronic communication, including information contained therein, to ensure its availability, integrity, authentication, confidentiality and non-repudiation." (NSPD-54/HSPD-23)

[]I have received cyber security training in the past.

Please choose only one of the following:

○ Yes

○ No

[]When was the last time you received cyber security training?

Only answer this question if the following conditions are met:
Answer was 'Yes' at question '77 [Cyber61]' (I have received cyber security training in the past.)

Please choose only one of the following:

○ Within the past 6 months

○ Within the last year

○ Within the last two years

○ More than two years ago

○ Other [   ]

[]What is your attitude towards cyber security related issues when using your personal technology devices.

Please choose the appropriate response for each item:

	Very unconcerned	Not concerned	Slightly not concerned	Neutral	Slightly concerned	Concerned	Very concerned
Select one	○	○	○	○	○	○	○

[]I have experienced cyber security related problems when using my personal technology devices.

Please choose only one of the following:

○ Yes

○ No

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[]When was the last time you experienced a cyber security related problem?

Only answer this question if the following conditions are met:
Answer was 'Yes' at question '80 [Cyber63]' (I have experienced cyber security related problems when using my personal technology devices.)

Please choose only one of the following:

○ Within the past 6 months

○ Within the last year

○ Within the last two years

○ More than two years ago

○ Other [_____]

[]Please explain what they were:

Only answer this question if the following conditions are met:
Answer was 'Yes' at question '80 [Cyber63]' (I have experienced cyber security related problems when using my personal technology devices.)

Please write your answer here:

[   ]

[] In terms of protecting your work, how would you qualify the amount of cyber security training you received?

Please choose the appropriate response for each item:

	Very poor	Poor	Fair	Good	Very good	Excellent	Exceptional
Select one	○	○	○	○	○	○	○

[]What is your level of confidence in the cyber security capabilities of the technology devices you use on the job to protect you work?

Please choose the appropriate response for each item:

	Very poor	Poor	Fair	Good	Very good	Excellent	Exceptional
Select one	○	○	○	○	○	○	○

[]Cybersecurity measures prevent me from accessing content that would be helpful in my job.

Please choose the appropriate response for each item:

	Strongly disagree	Disagree	Somewhat disagree	Neither agree or disagree	Somewhat agree	Agree	Strongly agree
Select one	○	○	○	○	○	○	○

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[]Cyber security is a concern related to 3D printing.

Please choose the appropriate response for each item:

	Strongly disagree	Disagree	Somewhat disagree	Neither agree or disagree	Somewhat agree	Agree	Strongly agree
Select one	○	○	○	○	○	○	○

[]If my unit provided 3D printed objects at work, I would have confidence that the object is trustworthy to accomplish the intended purpose.

Please choose the appropriate response for each item:

	Strongly disagree	Disagree	Somewhat disagree	Neither agree or disagree	Somewhat agree	Agree	Strongly agree
Select one	○	○	○	○	○	○	○

[]I have confidence that a digital 3D file provided by my unit would be properly protected from compromise or modification.

Please choose the appropriate response for each item:

	Strongly disagree	Disagree	Somewhat disagree	Neither agree or disagree	Somewhat agree	Agree	Strongly agree
Select one	○	○	○	○	○	○	○

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Submit your survey.
Thank you for completing this survey.

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APPENDIX B. QUALITATIVE SURVEY RESPONSES

A. FULL ANSWERS TO "DESCRIBE 3D PRINTING IN YOUR OWN WORDS," LISTED BY SERVICE.

1. USN

1. Not sure
1. I really don't know. I assume you can create a three dimensional design and it is then created for you, but I am not sure what it would really look like.
2. Making multidimensional items using strings of a material.
3. A method to create a tangible 3D model using some computer interface.
4. You upload drawings into a computer, attatch a printer with 3D capabilities, and hit print.
5. Using a box like printer to dynamically create a three-dimensional object.
6. Print a 3D object
7. A machine which maintains digital 3D models of objects and then forms those digital objects into real objects by "printing" them from melted plastics and/or metals on to a surface in successive layers.
8. Similar to a CNC machine, the ability to create an object vice a 2D image
9. 3D printing allows a user to create an object out of a raw product, the object thus existing in the x,y,z plane. The creation of the object is controlled through a user input computer based program, which transmits those inputs to a device which either adds raw material to create an object or carves an object out of raw stock.
10. A printer uses synthetic material to build an object in layers based on the design sent from a computer program.
11. Creating 3D objects.
12. Instead of paper, the 3D printer takes a compound, such as a metal or plastic and instead of text or pictures it creates an object with length, width and height.
13. model imaging in three dimensions
14. You use computer programs to design a three-dimensional object, then you choose a material for it to be 'printed' on / made of, then use the 3D printer to physically build a 3D representation of the object you designed.
15. Using 3D printers to create 3D objects such as parts for aircraft, models, etc.
16. Printing 3D models
17. A printer that turns a computer design/concept into a printed tangible object.
18. The use of lasers and technology to print items in 3d form without actually building anything

19. Using a machine to layer different materials (plastic, metals) into different objects.
20. 3D printing is the use of a special device which, given a coded 3D design and a base material, can create individual machine components. Usually the base material is some sort of powdered polymer resin, but more advanced printers can use a powdered titanium.
21. Constructing objects via simple plastic first designed/rendered digitally
22. Replicating three dimensional objects, usually produced with a plastic composite, from a digital file. The digital file is created by scanning a "real world" item.
23. Melt plastic cording and deposit it in layers to build up a 3D shape that has been designed on a computer.
24. You upload the specs of a 3D object and then a machine takes the material you've made available to it to then layer and affix the material in a programmed way, ultimately creating the desired object.
25. Printing 3D plastic structures for miscellaneous use.
26. This is building items using a printer-like machine with instructions provided by a digital design.
27. Additive technique for constructing small volume models with a 3d CAD tool
28. A plastic or metal object is built in its complete form, layer by layer, as opposed to fabricating pieces (by reduction from stock) and joining them.
29. Using a machine and material, take a drawing/schematic from a file and have a computer printer create that item in real life layer by layer
30. Geek method of manufacture at low rate of production and low quality.
31. Instead of putting ink on paper, 3D printers carve or laser-cut an object out of often softer material (potentially any solid). Kind of like milling on metal, but without a massive industrial machine.
32. converting a digital plan into a three dimensional object using a printer which uses the design to stacks/builds material into the planned object.
33. Making an object through deposition of a material, usually controlled through a CAD program.
34. 3D printing is a technology that is slowly making its way to the average consumer market. Most simply, it is a way of printing items one layer at a time out of the 3D printer's supported material (many exist) until it is a finished three-dimensional object.
35. 3D printing is a way to print tangible 3D objects from a computer-based 3D image.
36. Layers of material printed on top of layers
37. Literally printing a figure that has been designed in 3-dimensional space using layers of materials.
38. Printing an abstract object into the 3D plane via printer capable of that function
39. Technology that creates a 3D replication based on a scan of an original object.

40. Able to print material such as parts or other simple objects.
41. The ability to use a specialized printer to make items out of different materials.
42. A manufacturing technology that takes a 3D schematic and "prints" it with some sort of medium, such as a plastic.
43. Printing in 3d. can be lazer bonding or glue usually built in many many layers
44. Use CAD software to design an item that you wish to print. Upload the CAD design to your 3D printer. 3D printer then builds the design by precisely laying down layers of plastic until he design is completed.
45. Using a piece of machinery to recreate an object in a three dimensional form.
46. Additive production technique utilizing material extruded onto a bed, usually in 3-axes.
47. Additive manufacturing using computer code and software to develop physical objects.
48. Rapid prototyping of designs in 3D space using plastics, powders, or metals.
49. It is a computer controlled additive manufacturing process that deposits material (plastic or metal) in layers to build an object from a digital model of the object.
50. Printing solid objects from a design file.
51. A 3D object is created using a program that is compatible with the printer. Once completely designed, it will print on the 3D printer. Here at NPS, it is a plastic medium that is printed. It takes a while, but the final object is a 3D object. The hope is to be able to use such printers (metal-type) eventually in the fleet to enable quick repairs.
52. Recreating a physical 3D object from a virtual object, usually through some software application
53. Printing 3D objects from CAD diagrams
54. A manufacturing process where a computer model is sent to a printing system that adds layers up to form a artifact that may be otherwise impossible to create through traditional manufacturing processes.
55. 3D printing is the manufacture of small-scale items using a printer head that can maneuver in a three dimensional plan and print composite material.
56. A printer that can take a set of input plans and print something three dimensional, like a house (see Russian 3D house printer).
57. 3D printing is an additive process where layers of a material are stacked on previous layers laid down based on a file. A common type is a printer that uses plastic filament to print out a 3D object by melting and forming the filament in layers on previous layers.
58. A machine that creates an object from a base material.

59. An additive manufacturing technique that allows the user to define a model to be constructed in three dimensions using a computer aided design program. See the RoboDojo for more information.
60. Printing 3D artifacts of various materials and purposes.
61. Creating tangible objects from computer design
62. create objects by designing on the computer and then printing by carving or pouring usually in polymer but other materials are possible.
63. Using high-temperature malleable filaments to construct 3D models
64. The ability to take a document, that electronically defines the edges and planes of an object, and use a specialized printer to create a copy of the object from the file.
65. An additive manufacturing process that creates 3D objects.
66. 3D printing is the ability to construct various objects from the ground up with different materials as opposed to construction through an assembly of parts.
67. The ability to print basically anything that you can design into the software and have it print and be used. For example, printing an engine for a car.
68. Using molten plastic/medium to create 3D objects based off digital input.

2.   USAF

1. Equipment used to create inanimate objects and sometimes even food.
2. The ability of a machine to create or sculpt a plastic (or other material) 3D object from an electronic representation of it.
3. Printing that gives a dimensional look to give a more "life like" appearance
4. A machine that uses coordinate based software such as CAD to build objects/shapes out of layered material
5. Process where object is created in 3 dimensional printer via thin layers upon layers instead of cutting/hollowing out/molding a material to create an object.
6. Creating a 3D (volume) object
7. Image scan, followed by printing of that model using small plastic filaments—"builds up"
8. It's a printer that allows one to print in 3D and abstract.
9. Printing technology that makes 3D functional products from a particular material
10. Printer capable of producing 3D objects from a programmed specification.

3.   USA

1. Using some sort of material extruded by a printer head to create an object
2. Using computer software and compatible machinery to print 3D objects using a special made plastic either by designing a 3D object using software or by scanning it.

3. Using an automated system to build a device through a plan.
4. Additive manufacturing; squirting material together to form an object rather than cutting excess away from a block.
5. Producing (printing) 3-dimensional objects given a data file, printing device and a material to construct with.
6. Additive manufacturing. Creating something by adding layers of various composites as opposed to removing material to generate the end product.
7. Creating a object by "printing" material in small amounts, controlled by a computer model to create a total object.
8. Using a type of CAD software, a model is created whereby it is uploaded to the 3D printer. The printer then uses a material (normally a plastic type) to extrude material into layers that build up the design uploaded.
9. Upload a design and a "printer" cuts away on a block of plastic or other material, in a 3D method.

B.   **FULL ANSWERS TO EXAMPLES FOR HOW "3D PRINTING CAN BE USEFUL FOR MY SERVICE," LISTED BY SERVICE.**

1.   **USN**

1. Small, low value, disposable and non-critical parts.
2. Printing parts on ships
3. I would need more information on the applications of the technology to make a judgment call. Hypothetically any new technology can make a service better, but what is the cost?
4. We already have a robust supply system. 3D printing probably doesn't meet design specs for a lot of military equipment. Maybe as a quick temp fix, but limited value on a ship.
5. i'm sure there are some that can be built to meet operational specifications...
6. Not sure what the application is.
7. Able to produce low-load replacement parts
8. Temporary parts for ships engineering department.
9. 3D printing will be useful for components with inconsistent failure rates and in low-risk applications. For example, it would make no sense to use 3D printers to make items like gaskets, since these are designed to fail over time, and a ready stockpile of them can be held onboard and utilized.
10. Parts needed for immediate repair. However, I would be concerned about copyright issues.
11. Possibly improves morale by allowing sailors the opportunity to print components for hobby projects.
12. It would require testing for suitability but parts or tools could of use.
13. Reduce needed parts inventory.
14. Depending on the material limitations, and specifications of the parts, it could be used to "build" spare parts underway.
15. Parts for vehicles, aircraft, building models.

16. 3D printing could provide a very limited supply capability for very specific types of materials. I'm thinking retainer packing, O-rings, etc. But, only for those applications where the material the printer uses is IAW the milspec of the part, and a failure of the part wouldn't be catastrophic (ie I wouldn't put it in an aviation system critical to flight)
17. Parts, tools, etc.
18. Temporary repair parts, tool manufacturing.
19. printing replacement parts
20. If ship parts could be printed, it would be useful. I think certifying the parts would be the hurdle to overcome.
21. Gives the ability to fabricate and duplicate
22. Parts repair underway
23. Various small fasteners are commonly lost, many of which are "OEM"--very difficult to find replacements for--these could be printed. Some companies are the sole producer of parts and when they go out of business/discontinue a line of product, we can no longer get repair parts--many of these could be printed. Sailors are very innovative at finding solutions/betterments, but have no way to implement ideas--printers would give them a way to do that, increasing ownership and pride (which is sorely needed).
24. Small parts replacement, engineering solutions where standard repair parts aren't the answer
25. May create a temporary repair part while at sea until full replacement parts become available.
26. Spare Parts. Models.
27. Maintenance
28. Spare parts on demand
29. Printing spare parts or not often used tools.
30. Spare parts can be printed instead of stored.
31. Parts for warfare platforms that are rare and infrequently used.
32. Print replacement parts and tools that are unavailable.
33. Spare part reproduction
34. Printable replaceable parts for high fail items. Avoiding the stock system.
35. spare parts
36. Printing of parts to ensure material is on-hand JIT.
37. If spare parts could be generated on a 3D printer it could save a lot of space on ships for easily replaceable parts.
38. Tools onboard a ship
39. Nuts, bolts, pipefittings
40. Naval Deployed parts
41. Manufacture of hard to procure, high failure rate items. Manufacture of custom items that otherwise would be unavailable for use in repairs.
42. A high quality 3D printer could be used to print valve covers, fasteners and a variety of other material at sea. Being able to 3D print parts at sea would result in faster repair times.

43. Supply parts, electronics, medical and healthcare, prototyping, production components
44. Replacement tools, parts, etc
45. Printing parts for systems while out to sea instead of waiting to pull into port and have a tech ready to bring the part. (This puts OPSEC in jeopardy in many situations.)
46. Replacement parts, medical equipment not on hand, custom-made medical equipment
47. Fabrication of small parts that take weeks/months to order a replacement: safety lanyards, unique screws, special tools, etc.
48. Cost effective construction with immediate use.
49. Ship parts, satellite parts, basically anything
50. On ships we have false decking in many or our combat spaces. This decking is held down with plastic screws that always break and that is a hit on inspections. We could much more easily print them than have to order and stock them all the time.

2. **USAF**

1. A 3D printer can help the IT community by providing a way to replace small plastic items used to repair machines/telephones/racks.
2. No use in the Contracting career field
3. Checking the fit for a part before one is procured and manufactured
4. Education, briefings, advertising
5. Printing aircraft spare parts. Especially parts that are no longer in production.
6. Modeling aerodynamics for fuselages, air foils...

3. **USA**

1. Emergency repair parts. 3D maps/terrain models
2. Spare parts, terrain models, etc.
3. Produce generic repair parts while deployed as opposed to shipping them overseas. However, the benefit would have to outweigh the costs.
4. Only as it pertains to making parts for projects or small parts for vehicles, but I am unsure if the current technology supports that ability.
5. Spare parts when deployed do not need to be shipped
6. Small devices and parts are good but quality and economy of scale seem to limit the utility for now.
7. I believe centrally controlled designs and processes for spare parts would be value added to the warfighter. It's affect on defense acquisition is another story.
8. Printing out parts for equipment or designing and creating accessories that can help improve current Soldier equipment.

C. FULL ANSWERS TO "WHAT PROBLEMS DO YOU SEE WITH RESPECT TO 3D PRINTING," LISTED BY SERVICE.

1. USN

1. Toughness of parts. Can they replace metal fasteners? what NDT or DT requirements will the parts need to meet and can the ships do it them selves onboard?
2. People using it fraudulently (wasting government supplies and funds) for personal use.
3. It can be a huge time distraction when not being used for a specific purpose.
4. Expense, stock system, material needs
5. Material viability for applications that require high strength or resistance to wear.
6. Printed parts would not be always an option. 3D printer would be underutilized and value not gained to the unit. Most likely only used in emergency situation where OEM parts are not readily available.
7. Cost to implement
8. Availability of various materials required (mostly metals). Quality control. Health issues with microparticles that are released especially with metal usage.
9. The issue of testing and safety. Will the Navy test every single component that can be 3D printed with every type of 3D printer to make sure that it can be made safely? IF the Navy decides that would cost too much, how much risk will operating have to assume in figuring it out? Further, what are the costs of testing 3D printed parts and keeping electronic designs? There are 2nd and 3rd order costs that we may not adequately understand at the moment.
10. Are the printers compatible with computer systems available on ships now? Who will conduct maintenance on the printers when they break and a ship is at sea (will this add additional work to over-tasked maintenanced WS's? How will the parts be certified for use in critical CS or ENG equipment. Who is going to train Sailors in proper use and maintenance on the printers when installed? Will this require additional CINS/NEC's and what timeline will these classes be rolled out in support of printers?
11. It is very time consuming to make a single item.
12. How do you certify a 3D printed component meets the standards and ensure that it is repeatable?
13. Durability, cost
14. Standardization & quality assurance.
15. The printer can always break and then you don't have ANY parts.
16. Real world replication of weapons/explosive design components for nefarious purposes.
17. Cost. Ability to perform on board ships. Copyright issues. Material used that may be incompatible for the machine the item was printed for. The

potentially unaware user that know the compatibility needs resulting in injury or death. Manpower specific to printing is not likely with fiscal constraints. Public perception will be wary that the military is using these for 'toys' and not intentional use.

18. Not enough quality control, plastic not strong enough material for many applications, not practical

19. Security, proper training, and efficiency.

20. Structural integrity, high upkeep/maintenance, limited work-related (non-recreational) usefulness.

21. My biggest concern with 3D printing spare parts is that, any random part that we keep in stock meets unique specifications for use in specific systems, such as high temperature, tensile stress, etc. There may be hundreds of parts on a single system with different specifications for each part. There are thousands of systems on our ships. Using 3D printers will require many different types of base materials and the 3D printer would have to be rated to produce the highest quality materials consistently. In addition, there would have to be a method to QA those parts to ensure they are meeting those specifications. Lastly, if we rely on a 3D printer and it breaks, or the data is corrupted, or the computer component fails, it's likely that we would not be able to support the ship's material requirement until a contractor flew out to fix the printer.

22. Verification and Validation. Ensure the current print is what was intended, ensure this medium meets stress models

23. Certifying the printed parts for aircraft use will be troublesome.

24. Possibly quality control and tracking

25. Reliability of the printed products under harsh conditions.

26. Ensuring a level surface in an at sea environment conducive for printing

27. Allotting time and materials so all divisions have a chance to use it. I can see it becoming a political game easily. Also not sure how easy supplies are to get/ship (any hazmat, etc?), or what type of maintenance is associated with them. And I don't know how stable the printer needs to be in order to print (can it be done in heavier seas? do we need to be in port? etc.). Would also need to ensure we have all of the correct materials--specifically types of metal. Printing a fastener in the wrong metal because it's cheaper/more available may cause bi-metallic or other corrosion issues in places it wouldn't otherwise be. Lastly, knowing how the Navy works, I can see people printing items to 'cover up' issues as opposed to actually fixing them correctly. Perception is reality, so some people will want to hide major issues with a nice shiny printed cover that perhaps INSURV won't look underneath...

28. Quality control of manufactured items

29. The total life cycle cost of owning, operating, maintaining, training, and disposal will not be properly researched before purchases are made.

30. Not reliable. Not consistent. Weak when compared to cast or machined parts. Different printers produce very different products with the same

supply material. Limited in scale and accuracy. Limited in moldability and finish options.

31. Durability/strength of the printed product. Cost compared to traditional manufacturing.
32. Durability, reliability, meeting operational specifications.
33. Printed parts not working as required.
34. Maintenance issues, proper functionality while on a boat (rolling), being used for personal reasons
35. Maintaining a stock of the composite material needed by the 3D printer.
36. Strength of the composite material once printed as comparable to traditional materials (aluminum, stainless steel, etc.)
37. Precision parts printing may not be cost effective. If a precision printer costs $250,000, and only prints precision fasteners that cost $1.00 a piece, through the life of a ship 250,000 new fasteners may never be needed.
38. Using it responsibly and not wasting material. Many commands have an issue with ink for printers. It will be even worse for 3D printers.
39. Very expensive
40. Cost, interfacing to the Shipmain process, 3d material properties not to spec for replacement part.
41. Current fidelity of printed artifacts, business process integration, interfacing, durability in tactical environments
42. Consistency
43. Computer Design capability of Sailors
44. Build quality, issues with temperature/humidity tolerance, proficiency
45. I have only heard the slightest mention of ideas on how these could be used. I have never seen anything scholarly to support high-quality parts coming out of a 3D printer in some industrial grade metal meeting/exceeding milspec.
46. So: what is the best quality these machines are capable of? With what materials and to what tolerances? what about composite parts like electronic circuitry?
47. Logistics in the Navy is a nightmare we are always behind the curve. The Navy is three years into an update to mitigate a critical information system vulnerability, THREE YEARS!
48. Cyber security. Integration into ShipMain. How qualify parts as safe with and without a DFS.
49. Funding, rules/requirements surrounding, maintenance specifications for printer itself and materials produced, bureaucracy
50. Waste from lack of training; abuse of printer for fun
51. Time
52. Materials needed
53. Ease to acquire thing that is supposed to be printed
54. Expensive and not necessary for every work center.
55. Biggest problem: lack of approval for use of 3D printer created items in systems. Availability of resources and materials.

56. I don't know enough about 3D printing to answer intelligently.
57. No idea.
58. The concern would be the durability of things made from 3D printing. Would the material required to print offset the space and energy cost of making tools? My guess is it would.
59. Slow, difficult to create plans for objects. Does not meet MILSPEC.
60. Materiel
61. High cost of equipment, maintenance, training, etc.
62. The applicability of 3D printing to ordinary users and general awareness/education of 3D printing.
63. As 3D printing can be helpful to us it is also technology and research that can be stolen by our enemies to use against the U.S. in future conflict.
64. Not very timely
65. Cost, risk of failure, maintenance costs
66. People overestimating the capabilities that 3D printing can bring while it's still an immature technology. If people assume a more robust capability than actually exists, it could lead to neglecting important planning for reliability of systems and logistics support to operational unit.
67. Maintaining machines, cost of doing so.
68. Price
69. Availability

2. USAF

1. Printing of contraband.
2. Cost and maintenance
3. Cost
4. It's expensive technology at this time. The benefits may not outweigh cost yet.
5. Costs and understanding of how to use it and maintenance
6. Not sure it can be used to produce military grade parts
7. Form, fit, function, reliability, utility, survivability, sustainability
8. Economic impacts of small batch production on large scale producers

3. USA

1. Time to print objects, ruggedness of the printers (don't think they are deployable and can stand up to a muddy/dusty/wet environment
2. The material being strong enough to stand up to demands and the time it takes to print something.
3. Training will take too long, cost vs benefit may not be good enough yet, abuse by service-members.
4. Today and fundamentally: costs versus other forms of manufacturing.
5. Tomorrow and ethically: ability to create weapons that are not controlled/regulated.

6. You can't print a market quality microchip in the field; even if you could, it would come out 'dumb' w/o necessary software for the application. I still have to haul the weight of the material of the thing I'd make. It also still takes so long to pump out a piece. I'm SURE it will be useful, at scale, in 5–10 years; but right now its a mild disruptor, not a war winner.
7. Quality control and failure of spare parts not manufactured to the original design.
8. Using the wrong type of material for creating parts or overestimating the strength/durability of printed parts. There are limitations for certain designs and the type of material used that can be easily overlooked by an average Soldier.
9. That many things that could be printed are made of a mix of materials, so how do you "print" it up with different materials in different locations?

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