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JOINT FORCES STAFF COLLEGE

JOINT ADVANCED WARFIGHTING SCHOOL



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Diplomatic Solutions to Additive Challenges

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A paper submitted to the Faculty of the Joint Advanced Warfighting School in partial satisfaction of the requirements of a Master of Science Degree in Joint Campaign Planning and Strategy. The contents of this paper reflect my own personal views and are not necessarily endorsed by the Joint Forces Staff College or the Department of Defense.

This paper is entirely my own work except as documented in footnotes.

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Abstract

Additive manufacturing (AM) technology, colloquially known as 3D printing,¹ will bring significant benefits to society, but also poses great risks from printed weapons proliferation. Working with other nations to resolve the appropriate balance between development and security, and to promote norms of acceptable behavior, is the task of the U.S. Department of State (DOS). The traditional tools of diplomacy, such as export controls and treaty regimes, are not sufficient to address the challenges presented by 3D printing technology. The DOS should evaluate and promote unconventional strategies to resolve the regulatory and monitoring gaps posed by AM. Suggestions proposed by DOD, industry, and academic experts include cyber bounties, weapons marking, nanocomposites to counter fake products, and outreach to the hacker and maker communities, as just a few of the ways to fill the regulatory gaps. The DOS should evaluate these proposals and begin to include many of them in Country Team programming. Current public diplomacy programs that expose future scientists and leaders to the benefits of the technology, while neglecting to discuss the risks, represent missed opportunities to expose young people to important policy issues that will soon affect their nations. Evaluation and adoption of the proposals in this thesis will require awareness raising within the diplomatic community, as well as high-level commitment to address them.

¹ AM is a process of printing in which materials are added layer by layer to produce a final product. It differs from traditional manufacturing in which materials are subtracted to form a final product, and often result in significant waste.

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Chapter 1: Introduction

Additive manufacturing (AM) technology, known colloquially as 3D printing, is advancing at a faster rate than industry experts first predicted, with the potential to revolutionize world economies and the way consumers and companies buy, produce, and transport goods. While the technology has the potential to improve life in many ways, it also poses challenges to U.S. security through proliferation and the printing of restricted arms and weapons. The Department of State (DOS), responsible for protecting U.S. interests, should employ and promote unconventional strategies, along with the traditional tools of export control and treaty, to resolve the regulatory and monitoring gaps posed by this technology. Suggestions proposed by the Department of Defense (DOD), industry, and academic experts include cyber bounties and outreach to the hacker and maker communities as just a few of the ways to fill the regulatory gaps. The DOS should evaluate these proposals and work with Country Teams to include many of them into overseas programming.

Industry expert David Bray observes that individuals can now easily produce in the home, products that were once only available to nation states or high-tech companies, and they can do so with little technical knowledge. He said, “In the future, bad actors could use the internet for distribution of digital designs to build explosive drones or other incendiary devices using 3D mass fabricators.”¹ The DOS can prepare for this future by employing the policies of effective export control and analyzing previous export control failures, some of which resulted, unfortunately, in increased proliferation. While the DOS’ traditional approach of enforcing dual use export controls has had some success,

¹ “David Bray, “Australia and the Internet of Everything,” *Fedscoop.com*, February 17, 2015, <https://www.fedscoop.com/australia-and-the-internet-of-everything/> (accessed November 4, 2017).

such as those regulating unmanned aerial vehicles, there have also been export control failures, such as the effort to control the 3D printed “Liberator” gun. Joelle Jenny explains that top down governance will not resolve the security issues posed by AM and is often counterproductive. She proposes a horizontal governance model to bring government together with industry, users, academia, and law enforcement.²

The effectiveness of previous approaches, or lack thereof, should be used as lessons learned when proposing new and unconventional strategies to share with other nations. The DOS should propose a combination of interagency collaboration, effective export controls, end-use monitoring, scientific countermeasures, and public diplomacy outreach to non-traditional communities, to address the potential security gaps posed by AM equipment and technology. The DOS will likely need to reinterpret existing policies that were designed to address the proliferation of goods from port to port, and not via the internet, and that may at times be at odds with commercial development interests.

The majority of scientific and academic analysis on the future of AM focuses on the boon of the technology to the DOD. There is little focus on the potential for the technology to destabilize world economies (including U.S. arms sales and defense trade), and the ability of the U.S. to win wars and fight terrorism. Working with private industry and academia, the DOS should initiate political and economic analysis of the potential ramifications of this technology, the potential for destabilization, and the security implications for the U.S. and overseas missions.

While existing arrangements, treaties, and controls may buy the U.S. some time and provide some protection right now, this technology could result in a shift in the

² Joelle Jenny, “Chapter 46 Title TBC,” email to author October 18, 2017, (unpublished manuscript, August 2017), 1.

balance of world power and pose threats both to U.S. citizens overseas and at home. Multilateral protection agreements are subject to the willing participation of the signatories, and to self-reporting. Non-signatory states, and non-state entities that are not party to these agreements, are in a position to evade sanction and export controls by simply obtaining the technology via the Internet, developing their own printers, or obtaining the technology by other means. Understanding how this technology could disrupt U.S. and world economies is crucial in determining the direction of DOS strategy. This strategy should aim to develop a holistic approach, which encourages innovative, new, and unconventional methods to address the challenge.

This thesis examines the most recent AM literature and uses interviews with DOD, academic, industry, and DOS experts to analyze the challenges and explain potential mitigation measures. Chapter Two examines the history of technology disruption and the current status of 3D printing in various sectors of the U.S. economy. Chapter Three looks at the current mechanisms used to protect the U.S. from some of the dangers of dual use items like AM, and examines their limitations. Chapter Four overviews two case studies of export control success and failure and discusses the elements for good export control policy. Chapter Five reviews the effect of AM on all aspects of a diplomatic mission and addresses how the Country Team can work with private industry and academia on these issues. Chapter Six introduces government, industry, and academic mitigation strategies which range from cyber privateering to using nano-composites in 3D printed products. The conclusion recommends adjustments in policy approaches to AM, and calls on the DOS to evaluate the aforementioned

mitigation strategies and promote the most feasible of them to allies and partners and in international fora.

Chapter 2: Technology Disruption and the Status of 3D Printing

Advanced technologies often have transformative and disruptive effects on societies and shift balances of power between nation states. Advances in cellular phone technology, the internet, the automotive industry, and advanced agricultural techniques, (just to name a few), resulted in significant worldwide social and economic changes. Some of these changes resulted in the decline of industries that were slow to respond, unemployment, crime, changes to legislation, and the mass migration of people. When affected by transformative technologies, governments around the world face the same predicament of needing to ensure that their societies reap the benefits of new technology, while also implementing safeguards to mitigate the risks.¹ Many technology authors warn about the challenge of trying to balance the security trade off with the technology benefits. Jenny warns that an imbalance toward security concerns can often suffocate innovation.²

The transformative power of AM derives from the unique nature of the manufacturing process. AM is a process of printing in which materials are added layer by layer to produce a final product. It differs from traditional manufacturing in which materials are subtracted to form a final product, and often result in significant waste. The U.S. is poised to significantly benefit from this technology as it revolutionizes the defense, health, manufacturing, and supply chain industries. Known variously as “over the horizon threats,” “Black swans,”³ “transformative/disruptive technologies,”⁴ or

¹ Jenny, 2.

² Jenny, 6.

³ U.S. Department of Homeland Security, *2014 Quadrennial Homeland Security Review*, DHS <https://www.dhs.gov/sites/default/files/publications/qhsr/2014-QHSR.pdf> (accessed November 4, 2017).

⁴ The United Nations describes AM as a “transformative technology.” Harvard Professor Clayton M. Christensen coined the term “disruptive technologies” which is generally applied to AM. Christensen’s definition describes a technology that creates a new market by disrupting an existing market. LTC Snow

“radical leveling technologies,” many technology experts point to AM’s ability to change the balance of power between nation states, or from nation states to non-state entities.⁵ A shift in the balance of power to non-state entities requires a review of DOS’ technology strategy. This review should analyze how dual use technologies like AM allow non-state entities to increase status and influence and whether current policies are appropriately positioned to address them.

Today, AM is revolutionizing the defense and health industries at an incredible rate. Several U.S. Navy authors note that AM is experiencing the kind of growth that is outpacing Moore’s law.⁶ In the AM context they explain that “If a 3D printed toy takes four hours to print today, it will take just seven minutes and thirty seconds to print by 2025.”⁷ A 2010 Gartner report⁸ noted that AM was in the “Technology Trigger” phase of the Hype cycle, which means the technology was 5-10 years from mass adoption.⁹ Part of this rapid growth is due to the expiration of patents and significantly decreased costs. The global AM industry is expected to be worth 10.8 billion USD by 2021. Many industry

defines radical leveling technologies as a technology anchored in the Internet whose employment results in a broad decentralization of power with a transformative and disruptive nature; Jennifer Snow, “Radical Leveling technologies: additive manufacturing and counter proliferation.” Naval Post Graduate School Defense Analysis Program, February 6, 2016); Abel O. Olorunnisola, “Revitalizing vocational & technical education to prepare the workforce for disruptive technologies: Nigeria as a case study,” *Department of Agriculture and Environmental Engineering*, University of Ibadan, http://unctad.org/meetings/en/Presentation/CSTD_2014_IPanel_ppt05_AbelOlajideOlorunnisola_en.pdf (accessed November 26, 2017).

⁵ U.S. Department of State, *Embassy Singapore finds value in use of interagency opportunity analysis to tackle complex issues*, MRN 15 Singapore 1298, U.S. Embassy Singapore, September 23, 2015.

⁶ Moore’s law explains that the number of transistors in an integrated circuit is expected to double approximately every two years.

⁷ Derek Lothringer et al. “Countering weapons of mass destruction: a preliminary field study in improving collaboration” (Naval Post Graduate School Defense Analysis Capstone Project, March 2016), 12, https://calhoun.nps.edu/bitstream/handle/10945/48551/16Mar_Lothringer_McGraw_Rautio_Thaxton.pdf?sequence=1 (accessed August 28, 2017).

⁸ Gartner is a research and advisory company.

⁹ Thomas Campbell et al. “Could 3D Printing change the world?” *Atlantic Council Strategic Foresight Report*, October 2011, 4, <http://www.atlanticcouncil.org/publications/reports/could-3d-printing-change-the-world> (accessed August 28, 2017).

experts expect the technology to grow 20 percent per year. While high quality printers that use metals and advanced polymers are currently hundreds of thousands of dollars, any hobbyist can send their designs to a large company to print.¹⁰

Most industry experts agree that AM has the potential for mass disruption, but disagree on when that could happen. Ian Gibson compares the future of AM to the way the internet changed retail business by creating new online markets. He predicts that 3D printing could have a similarly disruptive influence, just as the advent of ride share service technology disrupted local economies, caused violence, and resulted in changes to legislation.¹¹ Along with the disruptive economic risk is the ease with which individuals and entities can achieve their aims, for good or bad, without the need for any technical expertise.¹²

The current ability of the U.S. government to keep abreast and develop policy to keep pace with advances in AM is precarious. The authors of a U.S. Naval Postgraduate School study note that the government does not have the resources to maintain even a minimum level of awareness. They predict that U.S. adversaries may soon have the ability to print a nuclear weapon.¹³ Other authors agree that nuclear weapon component printing is a reality, but express more doubt about the feasibility of printing an entire nuclear weapon and state that it remains costly and difficult. What is more realistic, is that part of a damaged existing nuclear weapon could be combined with printed replacement parts. The Naval authors also lament that many other countries are outpacing

¹⁰ Jenzen Jones, N. R., "Small arms and additive manufacturing: an assessment of 3D printed firearms, components, and accessories," *Behind the Curve*. New technologies new control challenges. An occasional paper of the Small Arms Survey, Switzerland, (February, 2015): 45.

¹¹ Ian Gibson et al., *Additive Manufacturing technologies* (New York: Springer, 2010), 297.

¹² Jenny, 3.

¹³ Lothringer, 16.

U.S. investment in AM. They point to an imminent takeover of the industry by the UK, Germany, and Asia and note that Singapore is investing 400 million USD in a five-year project. They also highlight the Chinese government's 245 million USD pledge to take over AM leadership in the next seven years.¹⁴

In a recent analysis of the AM industry in Japan, U.S. Embassy Tokyo noted that Japanese companies are among the leaders in developing hybrid-manufacturing equipment that combines 3D printing with precise machine tools.¹⁵ A conglomerate of Japanese companies focused on AM technology is working on a 30 million USD research project to develop prototype machines for metal 3D printing. The machines are scheduled for commercial sale in 2018.¹⁶ One of Japan's printer companies, Mutoh, features a website disclaimer stating that its machines should not be used to build weapons. As the Embassy notes, "it is unlikely that Mutoh can limit the items produced by the end users of 3D printers sold."¹⁷ The disclaimer is a stark reminder of the risks posed by this rapidly advancing dual use technology and the need for strategies to address the regulation gap.

Today, the U.S. defense and health industries enjoy the most rapid advances in the use of 3D printing technology. These advancements save lives through the printing of organs and human tissue as well as making better and cheaper parts for military systems that contribute to U.S. security. But, they also highlight the tension between the need for R&D with the role of the DOS to mitigate the risks the technology poses. While some

¹⁴ Ibid., 12.

¹⁵ U.S. Department of State, *Cutting edge Japan- 3D Printing growing layer by layer*, MRN 16 Tokyo 790, U.S. Mission Japan, June 7, 2016.

¹⁵ Jenzen-Jones, 63.

¹⁶ U.S. Department of State, *Cutting edge Japan*, 2.

¹⁶ Jenzen-Jones, 63.

¹⁷ U.S. Department of State, *Cutting edge Japan*, 2.

government insiders propose restricting access to AM printers, certain materials, and digital Computer Aided Design (CAD) files, author Jenzen-Jones believes that kind of restriction would negatively affect development within the industry and would be difficult to enforce. He points to the failed attempts to regulate digital music piracy as evidence of the impossibility of controlling 3D files on the internet.¹⁸

While the potential for future restrictions are an unpopular industry topic, this has not deterred the U.S. Defense and Aerospace Industries from significant investment in 3D printing technology. Worldwide, multiple start-ups are in a race to build a more economical rocket. The founders of U.S. based company Relativity Launch aim to reduce the price of a rocket launch through 3D printing from 100 million USD to 10 million USD.¹⁹ NASA awarded a grant to a company that will make an AM facility for the International Space Station, allowing astronauts to make and replace parts.²⁰ Of particular interest to the Defense community, the company MITRE is developing a printing capability for the battlefield to negate the need for logistics in hostile terrain.²¹

In healthcare, medical tools and instruments, prosthetics, and biological matter such as skin tissue and organs can be 3D printed. This capability has a direct effect on national security as it has the potential to change the survival rate and treatment of battlefield injuries.²² According to Angela Daly, 3D printing prosthetics is a good example of the dilemma between increasing availability to poor communities by lowering

¹⁸ Jenzen-Jones, 63.

¹⁹ Ashlee Vance. "These giant printers are meant to make rockets." *Bloomberg News* (18 October 2017) <https://www.bloomberg.com/news/articles/2017-10-18/these-giant-printers-are-meant-to-make-rockets> (accessed October 23, 2017).

²⁰ Thomas Campbell and Ivanova, Olga. "Additive manufacturing as a disruptive technology: implications for three dimensional printing." *Technology and Innovation* Vol. 15 (2013): 74.

²¹ Campbell and Ivanova, "Additive manufacturing," 75.

²² Connor M McNulty, et al. "Toward the printed world: additive manufacturing and implications for national security." *Defense Horizons* no. 73 (September 2012): 9.

costs, but also needing regulation to ensure these products meet adequate standards.²³ Desktop printers reduced the price of prosthetics from 60,000 USD to 2,000 USD.²⁴ Ian Gibson predicts that AM for organ and limb replacement “is on the horizon.”²⁵ Home printing medications is also a future possibility.²⁶ In August 2016, the FDA approved the first use of a 3D printed drug to treat epilepsy.²⁷ In November 2015, A Russian company printed several thyroid glands, while U.S. company Organovo printed human blood vessels in 2010 and the first liver tissue in January 2014.²⁸

On the business side, AM printers will allow companies to customize products for consumers with rapidity.²⁹ This change will significantly affect the supply chain and has the potential for global disruption. A U.S. Army report noted that:

Virtually anyone in the world with access to a computer system and 3D printer will be able to “print” anything from drones to weapons. Encrypted blockchains will be massively disruptive to commerce functions. Together with robotics, autonomy, and AI they comprise a perfect storm for “blue collar” and “white collars” alike, causing vast economic displacement as formerly high-quality information technology and management jobs follow the previous path of agricultural and manufacturing labor. Militaries, paramilitaries, mercenary groups, criminal elements, and even extremist groups all will be able to take advantage of this potential pool of manpower.³⁰

²³ Angela Daly, *Socio Legal Aspects of the 3D Printing Revolution* (Hawthorne, Australia: Swinburne University of Technology, 2016), 50.

²⁴ Natasha Bajema, “3D printing: Enabler of mass destruction?” Natasha Bajema website (April 28, 2016), 4, <https://natashabajema.com/2016/04/28/3d-printing-enabler-of-mass-destruction/> (accessed August 28, 2017).

²⁵ Gibson, 298.

²⁶ Bajema, 8.

²⁷ U.S. Department of Commerce, *FDA’s perspective on 3D printing medical devices*, by Matthew Di Prima, National Institute of Standards and Technology, June 2016, https://www.nist.gov/sites/default/files/documents/mml/Session-1_1-DiPrima.pdf (accessed December 28, 2017).

²⁸ Christopher Barnatt, *3D Printing*, 3rd Ed. (Explaining the Future, 2016), 196.

²⁹ Charlene Rohr, et al, “Travel in Britain in 2035. Future scenarios and their implications for technology innovation,” Santa Monica: Rand Corporation, 2016: 13.

³⁰ U.S. Army Capabilities Integration Center, “The Operational environment and the changing character of future war,” 9, http://www.arcic.army.mil/App_Documents/The-Operational-Environment-and-the-Changing-Character-of-Future-Warfare.pdf (accessed December 29, 2017).

One of the most concerning aspects to this type of access is the ability to print weapons and other highly controlled materials. In 2013, U.S. company Solid Concepts printed a fully metal firearm, the 1911 DMLS. Other companies also 3D print AR-15 upper and lower receivers.³¹

The advent of 4D printing poses the same kind of challenges as 3D printing. 4D refers to the use of smart materials that can self-heal, as well as high performance polymers, and thermodynamically designed alloys that can adapt to environments, have low observability, improved strength, and speed. These 4D materials can change properties based on external pressure and reaction to the environment.³² Likewise, advances in artificial intelligence (AI), the internet of everything, big data analytics, and robotics are game changers in terms of the battlespace and potential shifts in balance of power to non-state entities. Developing policies today, that positively address and influence what this future looks like 100 years from now, may determine the success or failure of nation states. SpaceX founder Elon Musk believes the AI competition between nation states will be the most likely cause of the next world war, while others believe that it will fuel an arms race at a minimum.³³

The body of academic and scientific research to date suggests that AM will be significantly disruptive worldwide. The DOS already has many of the tools needed to mitigate some of these disruptive factors, but traditional tools have limitations as noted in

³¹ Jenzen-Jones, 46-47, 55.

³² Tate Nurkin, "Technological revolutions threaten nuclear security," *Jane's Intelligence Review*, (March 2016): 5.

³³ "Getting to grips with military robotics," *The Economist* (January 25, 2018), <https://www-economist-com.nduezproxy.idm.oclc.org/news/special-report/21735478-autonomous-robots-and-swarms-will-change-nature-warfare-getting-grips> (accessed February 17, 2018).

chapter 3, and additional tools such as those in chapter 6 should be evaluated and the most feasible promoted.

Chapter 3: The Limitations of Dual Use Protection Arrangements

The DOS has many traditional tools for mitigating some of the risks posed by dual use technologies. These tools include multilateral treaties and arrangements, export controls, and bilateral agreements. What these arrangements do not address is how AM can evade all of these tools through printing and sharing digital information over the internet.¹ David Bray believes treaties may be irrelevant today, “status quo treaties in a changing world are just quaint stalling tactics, though they may have some value if you’re using the time to get ready to play the game differently.”² Jennifer Snow concurs and notes that cyber-based transnational entities are non-responsive to regulations that were designed for state-to-state interactions.³ Further, members of the technology community share that policies promoted by The Australia Group and Wassenaar are essentially dead in the age of digital sharing over the internet. These community members advocate for “smart technology policy ...regulating those specific threat aspects without impacting the positive benefits of the technology for our nation.”⁴

Deciding how to regulate those parts of the technology that pose a threat is the challenge. Gustav Lindstrom notes that a complicating factor to this regulation is that to avoid detection, entities or individuals could simply print materials from a variety of different companies so that component part printing does not raise any alarms.⁵ Several industry authors, including Wassenaar participants, suggest training manufacturers to

¹ John P. Caves and W. Seth Carus, “The future of weapons of mass destruction: their nature and role in 2030. *National Defense University Press* (June 2014): 1-63.

² Dr. David Bray, Telephone Interview by Wendy Rejan, October 18, 2017.

³ Jennifer Snow, “Entering the matrix: the challenge of regulating radical leveling Technologies,” (Thesis, Naval Post Graduate School, December 2015), 36.

⁴ Jennifer Snow, Telephone Interview by Wendy Rejan, September 28, 2017.

⁵ Gustav Lindstrom, “Why should we care about 3D- printing and what are potential security implications,” *Geneva Center for Security Policy* (September 2014): 4.

recognize parts and component parts of concern. The DOS should explore this suggestion, for implementation and promotion by Country Teams. The DOS is unlikely to abandon its traditional treaty commitments in favor of solely unconventional tactics in the near term. So, a comprehensive review of the available traditional tools and their limitations follow.

U.S. Regulations

The International Traffic in Arms Regulation (ITAR), enacted in 1976, controls the import and export of military articles in the interest of national security and foreign policy. The items regulated are listed in the United States Munitions List, which include firearms, bombs, and directed energy weapons. The only 3D printed items specifically addressed in the Munitions List include 3 and 4D printed carbon billets (blocks of carbon) and weapons.⁶ Violations of the ITAR result in fines or imprisonment.⁷ The ITAR requires U.S. citizens to apply for a license if they want to train a foreign national or sell an item to a foreign national, which is on the Munitions List.⁸ After University of Texas law student, Cody Wilson, the DOS sent him a letter recommending that he remove them as he was likely violating the Arms Export Control Act (AECA) and its implementing regulation, the ITAR.”⁹ This case represents the only high-visibility action

⁶ U.S. Code of Federal Regulations, “The United States Munitions List,” 22 CFR Chapter 1 (4-1-13 edition) https://www.pmddtc.state.gov/regulations_laws/documents/official_itar/ITAR_Part_121.pdf (accessed November 15, 2017).

⁷ U.S. Department of State, “The International Traffic in Arms Regulations.” Department of State website https://www.pmddtc.state.gov/regulations_laws/itar.html, (accessed November 15, 2017); U.S. Department of State, “International Traffic in Arms Regulations” Bureau of Political Military Affairs Office of Defense Trade Controls (June 1996), 127, <http://www.dtic.mil/dtic/tr/fulltext/u2/a312382.pdf> (accessed November 15, 2017).

⁸ U.S. Department of Justice, “International Traffic in Arms Regulations” U.S. Department of Justice <https://www.justice.gov/usam/criminal-resource-manual-18-international-traffic-arms-regulations> (accessed November 15, 2017).

⁹ Jenzen-Jones, 61.

taken by the DOS in regards to AM printing to date. The DOS' actions did not result in the intended outcome expected, which would have been the removal of the file and preventing access to the file. Instead, the media attention resulting from the DOS action caused further proliferation of the files, after Mr. Wilson removed them. The unintended consequences of this action are further discussed in chapter 4.

The Undetectable Firearms Act of 1988 makes it illegal to manufacture, sell, export, or import any firearm that is undetectable by a metal detector.¹⁰ The International Small Arms Survey group suggests that all governments need to prepare for the day when 3D printed firearms can be easily and economically produced in large quantities.¹¹ Because 3D printed firearms are composed mostly of polymers, they are undetectable by metal detectors. Polymer guns require a metal block embedded in the frame of the weapon, but Jenzen-Jones notes that home fabricators can easily eliminate this step.¹² Mitigating strategies to handle this regulation gap should be addressed by Country Teams, and is discussed in chapter 5. Some nations do not require private individuals to mark firearms they personally produce. Jenzen-Jones points out the legal gap in the U.S. regarding AM as the U.S. does not require individuals to mark home produced firearms with serial numbers, provided they do not sell or transfer ownership of the weapon.¹³ Further, he notes that in countries that regulate only particular parts of firearms, AM may be used to avoid registration requirements or to produce components that are restricted, such as muzzle attachments and sound suppressors.¹⁴

¹⁰ U.S. Code, "Title 18 - crimes and criminal procedure part I - crimes Chapter 44 – Firearms," 18 USC Sec. 922 (May, 1, 2005), <http://trac.syr.edu/laws/18/18USC00922.html> (accessed December 17, 2017).

¹¹ Jenzen-Jones, 12.

¹² Ibid., 50.

¹³ Ibid., 60.

¹⁴ Ibid., 62.

The U.S. Department of Commerce (DOC) administers the Export Administration Regulations (EAR), which regulate the export of many dual-use items. These items include goods and related technology designed for commercial purposes, but which could have military applications, such as computers, aircraft, and pathogens.¹⁵ The U.S. administration is considering moving the regulation of other dual use items as well as small arms from the DOS to the DOC. This move is likely to result in increased small arms sales overseas due to DOC's sometimes more lenient and less restrictive controls, and perceived greater focus on facilitating trade. This change could also include the export of 3D printed arms. According to Robert Monjay it is very likely to do so, "under the DOC regulations, the EAR, individuals may post controlled information to the internet without a license in most cases, so long as it is freely available to everyone who wants to visit that website per 15 CFR 734.7(a)(4)."¹⁶ The DOS and DOC should adopt and enforce marking recommendations made by the UN for AM manufactured weapons, and evaluate the feasibility of requiring contrast agents for these weapons, as discussed in chapter 6.

Multilateral Treaties and Arrangements

Over 190 countries joined the Treaty on the Non-proliferation of Nuclear

¹⁵ U.S. Department of Commerce, "The Export Administration Regulations" U.S. Department of Commerce, <https://www.bis.doc.gov/index.php/regulations/export-administration-regulations-ear> (accessed 17 December 2017); Massachusetts Institute of Technology, "The Export Administration Regulations" MIT, <https://osp.mit.edu/compliance/export-control/guidance-documents/export-control-regulations/export-administration> (accessed 17 December 2017).

¹⁶ Mike Stone and Matt Spetalnick, "Exclusive: Trump administration prepares to ease export rules for U.S. guns" *Reuters* (September 19, 2017), <https://www.reuters.com/article/us-usa-trump-weapons-exclusive/exclusive-trump-administration-prepares-to-ease-export-rules-for-u-s-guns-idUSKCN1BU2N8> (accessed December 28, 2017); Robert Monjay, e-mail message to author, April 6, 2018.

Weapons since 1968. The treaty's principle aim is to prevent the spread of nuclear weapons. A recent counter WMD study predicted that:

Within 5 to 10 years, the advancement in metal 3D printing, when combined with high speed computing, will lower the threshold barrier for fabrication of nuclear weapons and enrichment technology available to threat actors...The nuclear fuel cycle has traditionally proven to be resource intensive and requires a significant production footprint, but advancements like additive manufacturing...offer alternative methods that can be diffused to a broader range of adversaries and can create critical components for boutique nuclear programs.”¹⁷

The ease with which non-state entities can obtain controlled dual use items leads Jenny to conclude that new mechanisms are needed to limit access to these technologies.

Traditional treaty regimes are not protection enough and she warns, “technological developments are driving change at a pace that exceeds the agility of government regulation.”¹⁸

The Wassenaar Arrangement was the international community's attempt to deal with the changes brought about by rapidly advancing technology. Signed in 1994, in Wassenaar, Austria, the 41 nations of the Wassenaar Arrangement pledged to regulate and control particular dual use technologies through national legislation. The states participating agree to control all goods in a dual use list to prevent terrorism and promote transparency.¹⁹ The dual use list specifically includes two references to additive manufacturing technology: single-crystal additive-manufacturing, and 3D viscous software validated with wind tunnel or flight test data required for detailed engine flow

¹⁷ Lothringer et al, 3, 12.

¹⁸ Jenny, 4, 7.

¹⁹ The Wassenaar Arrangement, “About us.” The Wassenaar Arrangement website. <http://www.wassenaar.org/about-us/> (accessed December 17, 2017).

modeling. The agreement includes technology transfer and so applies to the transfer of digital 3D blueprints for weapons.²⁰

The Wassenaar members signaled an interest in developing strong controls for only the most sensitive 3D applications. In Tokyo, in February 2017, Wassenaar announced that based on national proposals, experts would continue core work in addressing technologies of concern which included 3D printing.²¹ Wassenaar participants note the challenge of risk mitigation and not hindering the development of industry expertise.²² One limitation of the Wassenaar Arrangement is that it is dependent on self-reporting by the signatories and their national manufacturing entities and legislators.

The Arms Trade Treaty regulates the international trade in finished parts, specifically conventional arms, and entered into force in 2014 with participation from 130 signatory states.²³ The treaty applies equally to 3D printed weapons, however it does not cover technology transfer and therefore does not cover blueprints for 3D weapons.²⁴ The aim of the treaty is to establish norms for arms trading and thereby reduce conflict, increase stability, and reduce human rights violations. Article 2 addresses the kinds of arms regulated by the treaty which include battle tanks, armored combat vehicles, large-caliber artillery systems, combat aircraft, attack helicopters, warships, missiles and

²⁰ Gerald Walther, "Printing Insecurity? The security implications of 3D-Printing of weapons." *Scientific Engineering Ethics* (2015): 1439.

²¹ The Wassenaar Arrangement, *The Wassenaar Arrangement: Recent Developments*, by Ambassador Philip Griffiths, 24th Asian Export Control Seminar Tokyo (21-23 February 2017). <http://www.wassenaar.org/wp-content/uploads/2015/06/24th-ASIAN-EXPORT-CONTROL-SEMINAR.pdf> (accessed October 21, 2017).

²² The Wassenaar Arrangement, Ambassador H.E. Jean Louis Falconi and Ambassador H.E. Philip Griffiths, Interview by Rainer Himmelfreundpointner. CD Cercle Diplomatique (January 2017) http://www.wassenaar.org/wp-content/uploads/2017/03/CD_012017_Interview.pdf (accessed October 20, 2017).

²³ The United Nations, *The Arms Trade Treaty*, Office for Disarmament Affairs <https://www.un.org/disarmament/convarms/att/> (accessed October 21, 2017).

²⁴ Walther, 1439.

missile launchers, and small arms and light weapons. Each signatory is required to keep records detailing the transfer of any of the covered arms and to enact its own national enforcement measures.²⁵ The limitation of this treaty is that its only as good as individual states commitment to enforce it, and some do better than others.²⁶

AM is not currently controlled by the Missile Technology Control Regime (MTCR). AM can be used to manufacture missile components, and evaluating options to prevent this reality is a key topic in MTCR literature. The regime formed in 1987 and the 35 participating states agree to limit the proliferation of missiles and missile technology. The regime addresses the proliferation of missile delivery systems for nuclear, chemical, and biological weapons. There are no legally binding obligations on participants. The regime focuses on rockets and UAVs “delivering a payload of at least 500 kg to a range of at least 300 km and on equipment, software, and technology for such systems.”²⁷ The MTCR creates norms for appropriate non-proliferation behavior and participants enact guidelines in accordance with national legislation. Common understanding is promoted through bilateral and multilateral consultation.²⁸ The MTCR should be amended to include AM, just as AM is included in other multilateral agreements to promote norms of acceptable behavior.

The 2001 United Nations Small Arms Programme of Action (POA) applies to 3D printed weapons and requires states to control the production of small arms and light

²⁵ The United Nations, *The Arms Trade Treaty*, Office of Disarmament Affairs, <https://unoda-web.s3-accelerate.amazonaws.com/wp-content/uploads/2013/06/English7.pdf> (accessed October 30, 2017).

²⁶ Matthew Bolton and Wim Zwijnenburg, “Futureproofing is never complete: Ensuring the Arms Trade Treaty keeps pace with new weapons technology,” *International Committee for Robot Arms Control* (October 2013): 1. <https://icrac.net/2013/10/futureproofing-is-never-complete-ensuring-the-arms-trade-treaty-keeps-pace-with-new-weapons-technology/> (accessed August 28, 2017).

²⁷ U.S. Department of State, “Missile Control Technology Regime (MCTR) FAQs,” Department of State website <https://www.state.gov/t/isn/rls/fs/2017/266847.htm> (accessed November 12, 2017).

²⁸ Ibid.

weapons and to prevent illegal manufacture, trafficking, and transfer. Paragraph 3 requires states to make the illegal manufacture of small arms and light weapons a criminal offence, while paragraph 6 requires states to take steps to identify and take action against those engaged in the illegal manufacture of small arms and light weapons. A Small Arms Survey report detailed some of the possible mitigating strategies to combat weapons proliferation through printing. The report points to new or underutilized technologies to mark, record-keep, trace, and strengthen stockpile security. The 2005 UN International Tracing Instrument (ITI) requires states to ensure that weapons are properly marked and records retained. The Small Arms Survey authors note that “new marking technologies, such as data matrix codes and microstamping, coupled with improvements to associated scanning technology, could allow users to instantly capture, store, retrieve, and exchange information about a given weapon.”²⁹

The 2008 EU Common Position on Arms Exports and the corollary EU Common Military List includes technology required for the development and production of arms. An export license permit is required for anyone wanting to disseminate blueprints for a 3D printed gun.³⁰ This requirement is consistent with current U.S. policy on disseminating blueprints, however chapter 4 notes the U.S. policy resulted in increased proliferation in one particular case.

There are various other international fora in which 3D printing policy is discussed, including The Nuclear Suppliers Group Technical Experts Group and the UN

²⁹ “One meeting after another. UN Process update.” Small Arms Survey Issue Brief No. 12 (February 2015) <http://www.smallarmssurvey.org/fileadmin/docs/G-Issue-briefs/SAS-IB12-UN-Process-Update.pdf> (accessed November 5, 2017).

³⁰ Walther, 1439.

Commission on Science and Technology for Development (CSTD).³¹ The CSTD identifies AM as a high priority theme as an economic change agent.³² While it appears that AM is discussed in many different fora, the corresponding national strategies and amendments/adaptations to current regulation have not followed.

Enforcement limitations

While a plethora of U.S. and International laws and agreements provide a solid framework for sharing norms and self-policing, as one DOS Official noted, these agreements rely and depend upon the willing cooperation of the participants. Violations of the mechanisms often rely on industry self-reporting and information from informers. Traditional export control and treaty mechanisms should not be abandoned as they are effective tools between like-minded states and states wanting to join the international community. However, new and unconventional strategies are needed to address the challenge with entities that do not share the norms of the international community, and who fall into regulatory gaps. Jenny concludes that:

In and by themselves, export control regimes and the whole law enforcement ecosystem that surrounds them, will not deliver the kind of adaptive and resilient safety and security culture needed in the digital age. The proliferation of radical leveling technologies calls for new forms of “horizontal” or “hybrid” governance: agile arrangements open to policy-makers, the private sector, communities of users, scientists and security experts, with a three-fold mandate: to track rapidly evolving dual-use technologies and their security implications; to mutually educate one another about the risks and most adequate approaches to mitigate them; and to enhance societies’ resilience to the inevitable disruptions that occur when malevolent actors leverage RLTs to pursue hostile, criminal or terrorist ends.³³

³¹ U.S. Department of State, *Report of the 41st Nuclear Suppliers Group (NSG) Consultative Group (CG) Meeting and 4th Technical Experts Group (TEG) Meeting in Vienna, Austria, April 4-7, 2017*, MRN 17 State 52406, U.S. Department of State (May 24, 2017).

³² U.S. Department of State, *Demarche Request: Increasing participation at the UN Commission on Science and technology for Development*, MRN 16 State 24314, U.S. Department of State (March 8, 2016).

³³ Jenny, 11.

Chapter 4: Dual-Use Export Control Success and Failure

The DOS enjoys recent mixed success in the employment of export controls used to regulate dual use technologies. While export controls on advanced UAV systems prevent the sale of these systems outside the country to non-allies and nefarious entities, other large manufacturing countries unencumbered by such controls, step in to fill the sales void.¹ These sales highlight a key complaint from U.S. industry, that existing regulations stifle trade, make the world no safer, and inhibit development and innovation. The DOS' action regarding the Liberator gun also indirectly resulted in the further proliferation of the digital files by drawing significant attention and concern among maker and online communities who were already wary of government regulation. This chapter examines a case study in export control success and failure and compares each to the suggested elements for effective export control policy.

While the DOS focuses on the legal principles and international norms that make for effective export control policy, the Institute for Science and International Security promotes several specific objectives. It states that effective export control policy: delays and increases cost, serves as a deterrent, aids in detection and prevention, aids in intelligence gathering, builds confidence in the international community, and triggers safeguards.² Industry awareness and compliance are the keys to export control success.

¹ Jeremy Page and Paul Sonne, "Unable to buy U.S. military drones, allies place orders with China," *Wall Street Journal* (July 17, 2017), <https://www.wsj.com/articles/unable-to-buy-u-s-military-drones-allies-place-orders-with-china-1500301716> (accessed February 17, 2018).

² Institute for Science and International Security, "Key elements of an effective export control system." Institute for Science and International Security, http://exportcontrols.info/key_elements.htm (accessed December 28, 2017); U.S. Department of State, "Essential elements of an effective export control system," in *Overview of U.S. Export Control System*, Department of State website, <https://www.state.gov/strategictrade/overview/> (accessed February 18, 2018).

One element not mentioned but that should be added, is that good export control should make the world safer, or at least avoid making the world more dangerous.

Liberator Gun case study

In 2013, the company Stratysys rented a 3D printer to Cody Wilson, a University of Texas law student. The company recalled the system soon after, over concerns that Wilson was using the system to print a polymer gun.³ Wilson uploaded the digital files for this gun, named “The Liberator,” to the internet. Printing of the gun required no technical or engineering skill, only a basic understanding of IT and 3D printing.⁴ The upload of the Liberator files to the internet violated the Arms Export Control Act and the International Traffic in Arms Regulations. Over 100,000 people downloaded the Liberator design files in two days before the DOS advised Cody’s company, *Defense Distributed* of an ITAR violation.⁵ Some private, public, and international sites voluntarily took the files down but the files continue to proliferate on the dark web. Wilson’s attorneys argued that the requirement to seek an export license prior to posting the files constituted a restraint on free speech.⁶ While the DOS plays a role both in harm reduction and the promotion and protection of free speech, the courts agreed that posting of the files online violated the ITAR.

According to RLT expert Jennifer Snow, asking Mr. Wilson to remove the digital files had some unanticipated consequences:

As soon as Cody Wilson was asked to remove his Liberator gun design and the State Department announced their intention to regulate all digital weapon designs, the 3D printed weapons community rapidly moved from open discussions on regulation and areas of concern to closed forums. At

³ Daly, 51.

⁴ Jenzen-Jones, 51.

⁵ Ibid., 63.

⁶ Daly, 54-55.

this point these groups stopped talking to the government altogether, creating a potentially dangerous blind spot for nefarious actors to operate in.⁷

Jenny concurs that the U.S. government's attempt at preventing the proliferation of printed guns actually accelerated its development, "as communities of users went underground and redoubled their research efforts, in explicit defiance of government controls."⁸ Snow describes this kind of enforcement action as "compliance without effect."⁹ She points to the "Streisand effect"¹⁰ of attracting unwanted additional attention to an issue which results in the opposite effect of that intended.¹¹ Promoting strategies and policies that account for the Streisand effect should be a focus of DOS efforts when sharing best practices with allies and partners.

When reviewing the elements of effective export control, the response to the 3D printed gun files met most of the DOS' legal principles, which focus on regulation and enforcement, but failed in several key areas identified by the Institute for Science and International Security. The action of the DOS did not delay the acquisition of the digital files but sped up the acquisition among non-state and nefarious entities. It also decreased costs as many organizations with anti-government regulation agendas began investing in the technology in opposition to the DOS action. The action did not serve as a deterrent but turned Mr. Wilson into a cult hero and drove the practice onto the dark web. The actions of the DOS did not aid in intelligence gathering, did not make the world safer, and did not set an example of a best practice for the international community. The

⁷ Jennifer Snow, Telephone Interview by Wendy Rejan, September 28, 2017.

⁸ Jenny, 2.

⁹ Jennifer Snow, *Entering the Matrix*, 57.

¹⁰ Barbara Streisand complained that pictures of her beach house were posted online, attracting additional unwanted attention and an explosion in the proliferation of the photos.

¹¹ Jennifer Snow, "Radical Leveling technologies: additive manufacturing and counter proliferation." Naval Post Graduate School Defense Analysis Program, (February 6, 2016).

alternative is not to allow the practice to go unchecked, but to explore unconventional mitigation strategies first, starting with direct engagement through hacker and maker communities to influence behavior. In the case of Mr. Wilson, an avowed anarchist, this may not have resulted in the desired outcome, but was at least worth a good faith attempt.

UAV Case Study

The U.S. currently employs strict controls on UAVs that are capable of carrying weapons. Policy changes enacted in 2015 did allow for the sale of some of these platforms to allied and partner nations with end-use monitoring and an agreement to terms of use. While U.S. manufacturers consistently voice concerns over competition from Israel and China, these export controls are still in place.¹² These controls also apply to 3D printed UAVs, which the DOD now uses across all services.¹³ The U.S. controls all UAVs that can carry a payload of 500 kilograms for more than 300 kilometers. Bajema notes that a small facility with ten 3D printers could print 1,000 UAVs a day that could be weaponized.¹⁴ So, while U.S. UAV export controls are currently effective for this technology, AM poses the same regulatory and monitoring gap for UAVs as it does for other weapons.

When reviewing the elements of effective export control suggested by the Institute for Science and International Security, the export control enforcement of weaponized UAVs forced other nations and non-state entities to delay acquisition or to

¹² Aaron Mehta and Paul McLeary, “New Armed UAV Export Rules Help US Firms,” *Defense News* (February 21, 2015), <https://www.defensenews.com/air/2015/02/21/new-armed-uav-export-rules-help-us-firms/> (accessed September 15, 2017).

¹³ Meaghan Doherty Myers, “Drones on Demand: additive manufacturing and the future battlefield,” *Avascent White Paper* (July 2017), <http://www.avascent.com/2017/07/drones-on-demand-additive-manufacturing-and-the-future-battlefield/> (accessed September 9, 2017).

¹⁴ Bajema, 2.

obtain these platforms from countries with inferior technology and logistical support. In some cases, it increased costs as sales from other countries often do not include the level of maintenance support provided by the U.S. Strict U.S. export controls of weaponized UAVs also encourages norming behavior and contributes to confidence building in the international community. However, AM could one day change the effectiveness of UAV policy.

Chapter 5: 3D Printing and Strategy for the Diplomatic Mission

AM technology touches all aspects of the DOS' mission overseas and has foreign policy implications and relevance that should be addressed with a sense of urgency. While obvious political and economic concerns are the most significant, taking advantage of the technology and mitigating the risks apply equally to the interagency members, public diplomacy section, consular, management, and diplomatic security, all stakeholders on the Country Team. A DOD-led study conducted at Embassy Singapore, to analyze interagency response to a hypothetical AM proliferation scenario, confirmed "the value of diplomatic and law enforcement agencies having the lead on such issues, to promote awareness, conduct industry and private sector outreach, establish norms, and facilitate capacity building."¹

DOS should develop a strategy to connect law enforcement, other government agencies, private industry, and academic sectors in the U.S. who work on AM issues to the Country Team at diplomatic missions overseas. Since this effort would be too cumbersome on a case by case basis, the AM interagency working group could form a team of experts to travel to each hemisphere and conduct on-site training and programming with Country Teams.

Economics: Commerce, Academia, & the Country Team

Several authors note the potential for AM technology to have a destabilizing effect on world economies and to potentially cause the decline of large manufacturing states like China, Germany, and Japan. The UN Trade and Development board issued a

¹ U.S. Department of State, *Embassy Singapore finds value*.

report citing the possibility of much more diverse economies, while the UN Commission on Science and Technology observed that radical changes in the economy are not a forgone conclusion as AM could remain in the realm of hobbyists and a niche market.² The fact that AM is outpacing Moore's law and the Gartner report predicted imminent mass adoption, makes it unlikely that AM remains in the realm of hobbyists. Worldwide, the technology experts expect AM revenues to reach 21 billion USD by 2020. In India, the AM printing economy is expected to reach 79 million USD by 2021.³ Developing countries could become less dependent on the U.S. and International community if they can cheaply print resources, drugs, and infrastructure, reducing reliance on foreign imports.

An Economic analysis of the potential destabilizing effect of the technology and the effect on the U.S. economy requires assessment. Could AM technology change the international balance of power and have a democratizing effect on the world? Working with the DOC, and U.S. and local academic experts, Economic and Foreign Commercial Service (FCS) Officers should focus on the current level of adoption in their host countries to predict effects on labor, industry, and trade. Economic and FCS Officers should prepare to engage with their host country counterparts on related policy and legislation issues that are of mutual bilateral interest. Robert Monjay, in the Department of State Office for Defense Trade and Controls, suggests the Department could evaluate proposing an international system of import certificates for advanced 3D printers, just as

² The United Nations, *Science technology and innovation as catalysts for the Sustainable Development Goals*. Geneva: Trade and Development Board, (September 25, 2017), 4, http://unctad.org/meetings/en/SessionalDocuments/ciid36_EN.pdf (accessed September 15, 2017); The United Nations, *Issue paper on foresight for digital development*, Advanced unedited draft. UNCTAD Secretariat. Inter sessional panel 2015-2016, Budapest, Hungary (January 11-13, 2016), 22, 29-30.

³ The United Nations, *Issue paper on foresight*, 24.

import certificates have been used for rocket launchers.⁴ DOS should closely coordinate with DOC to evaluate this proposal.

Protecting U.S. intellectual property rights and U.S. businesses from counterfeiting, especially the dangers of medical drug counterfeiting, should be a central focus of the Country Team. Counterfeit goods are a 650 USD billion industry. Low cost laser scanners can now scan any 3D product and reproduce it. This will increase challenges in patent enforcement, and affect health and safety from fake products. Campbell and Ivanova note that there are currently no anti-counterfeit devices for 3D printed objects.⁵ Country Teams should work closely with U.S. and local private industry to monitor advances in counterfeit devices for AM.

Economic and FCS Officers should report on those sectors of the economy in which the U.S. can expect to see a reduction in the demand for traditionally manufactured U.S. goods, and the Department of Labor (DOL) should engage with these industries in preparation. The U.S. may also see reduced demand for medical tourism visas as health sectors overseas embrace AM technology. While the U.S. economy may lose in health tourism, developing countries may be able to improve their level of health care self-reliance, and lessen dependence on the international community and the U.S.

One of the important benefits of AM is reducing the carbon footprint of manufacturing, both in raw material and transportation costs. An increased investment in AM technology could boost the U.S. commitment to combat climate change and negate some of the effect of the U.S. withdrawal from the Paris climate accord. Campbell et al. predict the technology will result in a reduced demand for rare earth metals as AM can

⁴ Robert Monjay, Telephone Interview by Wendy Rejan, August 18, 2017.

⁵ Campbell and Ivanova, "Additive manufacturing," 76.

obtain more product out of the same quantity of a non-renewable resource.⁶ Economic and FCS Officers should provide analysis on how this change could affect economic relationships with countries on which the U.S. currently depends for these metals. The UN Commission on Science and Technology notes while AM will reduce carbon emissions, it also has the potential to consume more electrical energy and contribute to unhealthy air emissions and increase the reliance on plastics.⁷ Resolving these concerns will require focused effort, but the majority of industry experts agree that AM will improve environmental stewardship. Christopher Barnatt believes that AM will allow people to live more sustainably and reduce consumption of natural resources. He also notes that it could increase recycling and repair, and change the way people transport and store goods.⁸

U.S. leaders, including former President Barrack Obama, predicted that AM technology will lure jobs back from China, India, and other developing nations. Barnatt agrees, but argues that this will be driven by resource shortages and rising energy prices, not from the technology itself.⁹ Noting the U.S. lag in AM investment, the authors of the NPS counter WMD study propose that the U.S. needs to reevaluate AM investment if it wants to be economically competitive.¹⁰ Russian Deputy Prime Minister Dmitry Rogozin called AM “a sixth industrial revolution” and noted Russia’s significant interest in advancing the technology to compete with the U.S.¹¹ Industry observers agree the technology represents another industrial revolution and the potential “re-shoring of

⁶ Thomas Campbell et al., “Could 3D Printing change the world?” 11.

⁷ United Nations, *Issue paper on foresight for digital development*, 26, 28.

⁸ Barnatt, 222.

⁹ *Ibid.*, 248.

¹⁰ Lothringer, 12.

¹¹ U.S. Department of State, *Embassy Moscow ESTH Weekly for March 14, 2014*, MRN 14 FTR 5994, U.S. Mission Russia (March 17, 2014).

manufacturing to wealthy countries, and the diffusion of production away from centralized factories to local businesses, shops, and homes.”¹² Country Teams can play a key role in capitalizing on this opportunity by working closely with industry partners.

Politics: Multilateral Organizations & the Country Team

Country Teams should be attuned to the potential for AM technology to undermine U.S. sanction and treaty regimes in their host countries, and create political instability due to the reduced need for labor. AM technology has the potential to change the way the U.S. conducts diplomacy and removes one of the strongest and most effective tools of last resort in the diplomatic tool kit: isolation through sanctions. David Bray recently consulted on the issue for Australia and Taiwan and he believes the technology disrupts the concept of the Westphalian nation state and the notion of physical borders.

The speed of information sharing and decision-making on the Internet may disrupt the democratic multi-party system for nations that historically relied on tension between different parties to provide checks-and-balances in making decisions... 3D mass fabricators challenge the central tenets of multi-party democracies to adapt both to a changing global, technological environment and also provide stability and security to its people... When does the speed of the public sector relative to such global, technological change disrupt the successful model of a Westphalian nation-state?¹³

Nations, such as Iran and North Korea, can easily circumvent treaty and export controls through 3D printing. Lothringer et al. predict that AM will open new markets for proliferation and lower the barriers to obtaining WMD, especially for those entities “for whom ideology sometimes run deeper than rational deterrence can reach.”¹⁴ The Country

¹² Andrew Sissons and Spencer Thompson, “Three Dimensional Policy: Why Britain needs a framework for 3D printing,” The Big Innovation Centre (October 2012) http://www.nibec.ulster.ac.uk/uploads/documents/3d_printing_paper_final_15_oct.pdf (accessed August 28, 2017); Rohr, 13; Campbell et al “Could 3D Printing change the world?”

¹³ David Bray, “Australia and the Internet of Everything,” *Fedscoop.com* (February 17, 2015) <https://www.fedscoop.com/australia-and-the-internet-of-everything/> (accessed October 31, 2017).

¹⁴ Lothringer et al., 13.

Team should engage host country interlocutors as well as explore unconventional methods to address this future reality.

Visas & U.S. Citizens: Private Industry & the Country Team

Visa officers are the first line of defense in preventing internal physical intellectual property theft and industrial espionage through effective use of the Technology Alert List (TAL) in visa interviewing. Working with private industry, Consular Affairs and Country Teams could improve the use of the TAL by reinforcing comprehensive training to ensure Officers have strong skills and ready access to the resources they need to make good decisions. Although it would be impossible to have a complete understanding of all technologies on the TAL, engaging with private industry and scientists, to explain the general terms and concepts to adjudicators and to the Country Team, would be helpful. Developing TAL expert adjudicators would also strengthen this line of defense.

A significant part of most consular sections is American Citizen Services. Walther notes that an increase in gun ownership due to 3D printing may pose a particular threat to women. Injuries to women, and U.S. citizen women, from 3D printed weapons may increase in countries with lax or little public awareness or regulation of these materials.¹⁵ Through coordination with host country contacts, Country Teams should report on injuries and homicides involving 3D printed weapons as an early indicator of mass adoption of the technology.

¹⁵ Walther, 1440.

Security: Law Enforcement & the Country Team

3D printed weapons can be untraceable and undetectable by common screening devices. Diplomatic Security will need to adapt methods and technology used to provide for Embassy and Consulate security. The Country Team should begin working with U.S. based law enforcement experts on the latest methods for detecting polymer weapons. While the bullet and firing pin on 3D printed guns are still made from metal, Walther predicts that in the future it will be possible to print both from plastic.¹⁶ Backscatter X-ray body scanners can identify polymer weapons and Jenzen-Jones suggests “the addition of contrast agents to certain high-strength polymers may help to make them more readily detectable by X-ray machines.”¹⁷ Adding this contrast agent during weapons manufacturing is a topic that should be addressed by the Country Team with allies and partners and in the context of Wassenaar and other multilateral fora.

Polymer guns pose a further law enforcement challenge in that they are considered disposable and could be easily destroyed. Jenzen-Jones describes the lack of rifling on some AM firearms, which could hamper ballistic forensics techniques. He recommends the training and education of law-enforcement personnel on this topic, “Otherwise, law enforcement efforts risk being ineffective and prone to error.”¹⁸ The Law Enforcement Working Group at posts should begin to explore training with host country interlocutors on this topic and promote contrast agents in the manufacture of 3D printed weapons.

¹⁶ Ibid., 1437.

¹⁷ Jenzen-Jones, 64; Barnatt, 242.

¹⁸ Jenzen-Jones, 64-65.

Logistics: Private Industry & the Country Team

The Country Team and the Office of Overseas Building Operations should begin exploring how Embassies and Consulates could use AM printers to save time and resources on everything from motor pool parts to infrastructure. The cost to purchase an AM printer and the requisite powders should be analyzed against the current requisition process. Private industry could provide the needed analysis on the feasibility of in house printing for the multitude of items contained in a post's integrated logistics management system.

The Message: Public Diplomacy & the Country Team

The DOS sponsors numerous public diplomacy programs that address various aspects of AM, including intellectual property protection, promoting women in STEM, and exposing young people to 3D printing. The Office of American Spaces funds 3D printing workshops and “maker spaces.”¹⁹ Mission Spain recently promoted workshops advocating the use of free maker spaces to support entrepreneurship and skills development. It hosted hands-on AM workshops in Madrid, Barcelona, and Cuenca in 2017 to introduce students and teachers to the technology and its application in different industries.²⁰ Public diplomacy programs like this one need to include policy discussions with students who will be the future leaders and scientists in those countries. Introducing the technology and discussing the benefits, without discussing responsible use and challenges, is a missed opportunity to shape global norms and increase U.S. national security. Mission Thailand's events for World IP Day represents a good model for

¹⁹ U.S. Department of State, American Center Jerusalem promotes STEM for women with the Shecodes Hackathon, MRN 17 Tel Aviv 1618, U.S. Embassy Tel Aviv (May 26, 2017).

²⁰ U.S. Department of State, *Spain: U.S. Maker spaces bring American Innovation to Spanish Audiences*, MRN 17 Barcelona 36, U.S. Mission Spain (April 11, 2017).

including important policy issues into the AM conversation.²¹ Embassy Bangkok noted that many small foreign companies “are not aware of IP protection concerns in the early stages when their product values are typically low. Investors, however, are reluctant to fund growth when a company is unable to protect against copycat works.” The Embassy invited various speakers from U.S. private industry as well as the UN to address best practices for protecting IP such as protecting websites, strong cyber security, educating employees, and fostering a culture of creative input.²² Embassy Bangkok’s event should be used as a model for encouraging digital security conversations about AM challenges. Country Teams should be attuned to the perpetual need to shape the public diplomacy message on AM in terms of policy benefit and risk.

Innovative Development & the Country Team

USAID uses foresight analysis to plan for shifting development efforts and future trends. Instead of expanding and growing current industries, investment in AM may provide longer-term dividends for a local community. According to Linton Wells, “This will have implications for development planners as urbanization, smart cities, innovation hubs and new infrastructure become even hotter topics in development thinking and program implementation.”²³ Through its Global Development lab, USAID should analyze the extent to which AM and 4D printing should be promoted to address issues

²¹ U.S. Department of State, *Thailand: Digital Creativity events in Bangkok and Chiang Mai celebrate world IP day*, MRN 16 Bangkok 898, U.S. Mission Thailand (May16, 2016).

²² U.S. Department of State, *Thailand: Digital Creativity events in Bangkok and Chiang Mai celebrate world IP day*, MRN 16 Bangkok 898, U.S. Mission Thailand, (May16, 2016).

²³ U.S. Agency for International Development, “Technological Change and Sustainable Development” in *The Future Can’t Wait. Over the Horizon Views on Development*, by Linton Wells, National Defense University Woodrow Wilson International Center for Scholars, (September 2013) <https://www.usaid.gov/sites/default/files/documents/15396/TheFutureCantWait.pdf> (accessed November 26, 2017).

such as food security, economic growth, and global health, consulting with the Country Team, on areas where this might be most appropriate.²⁴

²⁴ U.S. Agency for International Development, “About the U.S. Global Development lab,” USAID website <https://www.usaid.gov/GlobalDevLab/about> (accessed December 29, 2017).

Chapter 6: Mitigating Strategies: From Marking Weapons to Collaborating with Non-Traditional Communities

The risks posed by AM in the form of 3D printed rockets, UAVs, IEDs, and parts to nuclear weapons will often require policies and initiatives that exist outside the DOS' traditional export control and treaty regimes. Easy access to this technology by state and non-state entities, through the evasion of sanctions and export controls, is a future reality. This threat does not just exist overseas but also at home, as Daly observes that "the possibilities of 3D printed weapons have piqued the interest of white supremacist groups."¹ While the ease of obtaining conventional weapons for terrorist groups may remain the case right now, the potential to cause significantly more damage through AM is the future. There is no treaty that can control the transfer of data and technology over the Internet, nor is there ever likely to be such an arrangement. For the moment, very high-end AM systems are likely to remain out of reach for most groups with limited budgets, and therefore easier for law-enforcement and intelligence agencies to monitor. This will not always be the case and there are currently thousands of printers worldwide that allow anyone to send a file for printing from anywhere in the world.²

Remote printing poses risks from entities that choose to use different companies to print various parts, none of which by themselves would raise suspicion, as well as entities with the technology to disguise their products. Snow discussed a program called *Disarming Corruptor* that can disguise a file to look like something it is not. For example, an M-16 CAD file can be disguised to look like a file to print Mickey Mouse,

¹ Daly, 52.

² Jenzen-Jones, 56.

and without the key, all anyone will print is Mickey Mouse.³ Some of the solutions proposed by defense experts include the use of cyber bounties, cyber privateering, and collaborative teaming. Economist Sheila Ronis proposes the idea of an interagency Center for Strategic Analysis and Assessment, which would provide a mechanism to conduct “foresight studies.”⁴ Many government agencies and private industry already do this but they do it in silos, without coming together to compare how their findings affect each other and could be used in a whole of government focused effort. Continuing to promote international norms of accepted behavior and non-traditional partnerships will be central to engaging with U.S. allies and interested states to mitigate the risks of AM.

David Bray suggests that the correct mitigation strategy is one that is not draconian, “we can’t line up like the ‘Red Coats’ did in 1781... in a world that is changing rapidly and providing asymmetric benefits as well as vulnerabilities.” He emphasized the need to think creatively, to possibly introduce defects for protection, to protect IP but allow for reproduction and become experts in servicing the parts, “we need to change the game,” he concluded.⁵ In an article for *Fedscoop* Bray reiterates the need for global collaboration, “It could be a combination of public empowerment and bottoms-up, public-private hybrids that might offer solutions for our changing world ahead.”⁶

The UN Industrial Development Organization proposes the following approach in response to what its Director of Policy and Research terms a Fourth Industrial Revolution which includes AM. The approach includes: forum activities, research, capacity building,

³ Jennifer Snow, Telephone Interview by Wendy Rejan, September 28, 2017.

⁴ Sheila Ronis, *Economic Security. Neglected Dimension of National Security?* (Washington D.C. National Defense University Press, 2011), vii.

⁵ David Bray, Telephone Interview by Wendy Rejan, October 18, 2017.

⁶ Ibid.

policy development, normative standard setting, technological cooperation, and partnerships with academic, government, and the private sector.⁷ The UN Office for Disarmament Affairs proposes a sanctions, capacity building, and export control approach to countering some of the dangers of proliferation through printing.⁸ The DOS should form a working group to evaluate these proposals for promotion with allies and partners, as well as closely review the following specific suggestions.

Marking & Tracing Weapons

The DOS, through multilateral fora and direct bilateral engagement, should encourage host governments to develop solutions in marking and tracing polymer weapons. Arms analysts note the difficulty of proposals to place controls on printers, materials used in printers, and digital files when the same materials and equipment are used to produce other dual use products.⁹ Marking and tracing weapons, however, is something most nations already enforce, to various degrees, for traditionally made weapons. The Small Arms Survey noted that “criminals and non-state armed groups may find 3D-printed guns attractive since, when unmarked, they are untraceable, and because many security screening devices have difficulty detecting firearms made largely of polymer.”¹⁰ The Small Arms Survey Issue Brief suggests policy responses to include a control identification component for 3D printed small arms, new marking methods for

⁷ The United Nations, *Manufacturing the future: the 4th Industrial revolution and the 2030 development agenda*, by Ludovico Alcorta, Industrial Development Organization, Geneva (January 25, 2017), http://unctad.org/meetings/es/Presentation/cstd2016_p23_Alcorta_en.pdf (accessed November 26, 2017).

⁸ The United Nations, Won-soo Kim, “Opening remarks,” 3.

⁹ “One meeting after another. UN Process update,” *Small Arms Survey Issue Brief No. 12* (February 2015), 12, <http://www.smallarmssurvey.org/fileadmin/docs/G-Issue-briefs/SAS-IB12-UN-Process-Update.pdf> (accessed November 5, 2017); U.S. Department of State, *Wassenaar Arrangement: Side meetings address Russia-Ukraine and other export control priorities*, MRN 14 UNVIE Vienna 404, U.S Mission UNVIE (November 14, 2014).

¹⁰ “One Meeting after another,” 2.

polymer guns, as well as guidance on the depth and placement of the markings and tracing.¹¹

Interagency Collaboration

The benefits and risks of AM touch all government agencies, and therefore any strategy to address the challenges should apply a whole of government approach. An NPS study recently noted that: “The U.S. government does not currently have the agility to effectively address the speed of exponential technological advancements; it lacks the capacity and expertise to deeply analyze the diverse range of potential dangers...no single organization is given priority to lead until there is a crisis.”¹² The authors propose higher levels of proactive interagency collaboration and used collaboration models from the corporate world to explain how the interagency can overcome challenges to collaboration and build trust and interdependence.¹³

A DOS cable on the study noted that the collaboration model was useful in situations “where multiple agencies may have overlapping authorities and competing priorities.”¹⁴ Of the ideas generated to combat a hypothetical AM proliferation scenario, the majority had a diplomatic component, while the minority focused on a strictly law enforcement role.¹⁵ The study authors and Embassy participants recommended adding the collaboration model to the U.S. government training curriculums including at the Foreign Service Institute.¹⁶ The Embassy interagency working group proposed 6 key efforts to handle the theoretical AM crisis that involved North Korea printing nuclear fuel

¹¹ Ibid.

¹² Lothringer et al., 13.

¹³ Ibid., 5, 29.

¹⁴ U.S. Department of State, “Embassy Singapore finds value.”

¹⁵ Ibid.

¹⁶ Ibid.

cycle components inside Singapore. The six themes included: 1. increasing education to establish and maintain awareness, 2. conducting outreach, 3. building capacity, 4. shaping policy, 5. establishing norms, and 6. enforcing those norms. The study authors noted the importance of working with stakeholders before regulation was implemented to ensure the effect on global markets was considered.¹⁷ The DOS should discuss this exercise with ally and partner nations and encourage similar tabletop exercises within their host countries to identify areas of weakness.

Cyber Bounties

To bridge the gap between regulations that were designed for state-on-state relationships, and the reality of a digital environment un-influenced by traditional regulation, Snow proposes a cyber bounty approach to addressing the AM challenge. Snow believes web-advertised contracts offering a reward for specific information will contribute to proliferation deterrence. She notes that many private companies and some government agencies already offer cyber bounty rewards for helping to locate criminals and cyber bugs.¹⁸ The DOS should evaluate the risks and benefits of cyber bounties and compare data from agencies already employing this tactic, such as the Federal Bureau of Investigation. Public diplomacy programs that engage with the tech community overseas could offer this idea as a model for countries to secure their intellectual property and encourage norms and standards of behavior that comport with ethical practices.

¹⁷ Lothringer, 44-45.

¹⁸ Snow, *Entering the Matrix*, 83.

Cyber Privateering

Snow also suggests engaging the privateer clause in the U.S. Constitution, offering Individuals or teams contracts to locate machines, powders, digital files, or any other component along the AM spectrum. Privateers work for money, commission, or part of the materials recovered.¹⁹ Florian Egloff raises these concerns about the use of privateering: “increased risk of unnecessary escalation, the potential for reprisal, and the setting of an international norm that is, for the United States, strategically undesirable.” Egloff fears a lack of oversight of privateers could mean they are difficult to control.²⁰ DOS should consult the interagency AM working group to evaluate the benefits and risks of this approach, which may make sense for many countries that lack the internal government capacity for such efforts.

Outreach to Hackers and Makers

Encouraging U.S. and host government outreach to the hacker and maker community should be one of the first steps in enlisting private sector allies to address AM challenges. Through the Donovan Group, Snow interacts regularly with the hacker and maker communities who explain that current policies are not effective when addressing issues like AM risks. She said, “These communities are telling us that policy is lagging... We need industry experts to examine our policies and where they’re not effective. Our policies are often acting as a force for proliferation.” Snow discussed the Cody Wilson case and the “cultural misinterpretation” between the DOS’ actions and the interpretation that digital free speech was under attack:

¹⁹ Ibid., 83-84.

²⁰ Florian Egloff, “Cyber Privateering: A Risky Policy Choice for the United States,” *Lawfare Blog* <https://www.lawfareblog.com/topic/cybersecurity> (accessed December 21, 2017).

We didn't understand the culture or what was being said and this caused proliferation through downward directed policy. We need to get better at interacting with digital communities. What happened here was akin to trying to drive new policy in a foreign nation without first talking with the people who live there or understanding the culture. We need to start building our network of digital community partners the same way we build out our nation state and diplomatic relations.²¹

Snow laments that non-traditional communities claim they are trying to help but government is not listening, they complain they do not get feedback, their information and tips get classified, and that the government always wants them to come to it. She says there is currently no way for technology communities to anonymously report cyber-attacks or other threats. But she notes that nations like Germany, Israel, Estonia, Ukraine, and the Netherlands already have processes for anonymous tipping in these areas via "responsible disclosure" mechanisms that help to proactively identify digital and physical threats. She said, "we don't have to reinvent the wheel. USSOCOM is leading this space with a network of 630 ethical technology community members who just recently agreed to team up with DHS to make a responsible disclosure process in the U.S. a reality."²² Jenny also reinforces the need for collaborative government and private partnerships to develop mechanisms for distributive safety and security. She notes the reality that the online places where bad things happen are often inaccessible to government. She points to citizen assistance as the key to identifying threats and "breaking down silos between governments, scientists, and communities of users...incentivizing responsible individual and collective behaviors."²³

²¹ Jennifer Snow, Telephone Interview by Wendy Rejan, September 28, 2017.

²² Ibid.

²³ Jenny, 9.

The U.S. Special Operations Command (USSOCOM) conducts outreach to hackers and makers through its J5 Future Plans and Strategies cell, the Donovan Group. Its SOFWERX program enables the public and government to collaborate on problems and develop solutions to benefit national and international security. The Donovan Group developed relationships with more than 400 private citizens who “voluntarily identify innovations of interest, inform on smart technology policy and regulation, and collaborate to identify emerging threat technology reporting to pre-empt malicious or ignorant use that could lead to loss of life.”²⁴ Some countries are already using this type of partnership such as Denmark’s “Technology Ambassador” position and Germany’s Chaos Computer Club. These programs use hackers to advise government officials about advancements in the digital arena.²⁵

The DOS could explore similar Donovan Group endeavors with host country contacts overseas where they do not exist, and promote this model to other allies and partners. Promoting a closer relationship with private industry through models like Donovan, and harnessing their influence is one of the very first steps DOS should take in achieving a minimum level of technology awareness. These relationships can serve to shape and inform realistic deterrent analysis of technology policy.

Secure Transfer Technology

The protection of intellectual property is one of the key concerns of the AM industry and one of the DOS’ leading roles in protecting U.S. business interests overseas. Embassy Tallinn reported on an Estonian company that developed secure transfer technology for 3D printing, protecting files from copyright or patent infringement. As

²⁴ Jenny, 9.

²⁵ Ibid.

noted by the Embassy, design firms “face tremendous risk because of AM’s potential to enable massive intellectual property theft.” The Estonian technology promises to eliminate piracy and can also prevent the printing of weapons or other dangerous items. The Estonian company also expects to revolutionize supply chain management, “auto dealerships currently stock millions of dollars of spare parts. These inventories could be eliminated if the parts could be printed on site and only as needed.”²⁶ The DOS should pursue promoting this kind of technology through Wassenaar and international fora.

Enlisting Academia

The Department of State regularly partners with academic institutions to examine and inform all manner of foreign policy issues. One Stanford University program “Hacking for Diplomacy” partners international relations students with various DOS bureaus working on challenging issues of foreign policy.²⁷ In addition, the Bureau of Political and Military Affairs established a strategy lab to engage individuals inside and outside the government to use design theory to address challenging foreign policy issues.²⁸ The DOS should maintain and expand these partnerships with the academic community and encourage its allies and partners to do the same, sharing best practices from these programs and labs.

Software Controls in AM Machines

If AM machines could recognize weapons, and weapon parts, and prevent the

²⁶ U.S. Department of State, *Estonia’s Fabulonia: The world’s first 3D marketplace technology*, MRN 13 Tallinn 198, U.S. Embassy Tallinn (April 10, 2013).

²⁷ Jessica Floum, “In Stanford class, using tech to aid State Department,” *San Francisco Chronicle* (October 14, 2016), <http://www.sfchronicle.com/business/article/In-Stanford-class-using-tech-to-aid-State-9972485.php> (accessed December 21, 2017). The Department of Defense sponsors a similar program known as “Hacking for Defense.”

²⁸ Carten Cordell, “Private-sector strategies fuel State Department innovation lab,” *Federal Times* (November 25, 2015), <https://www.federaltimes.com/management/2015/11/25/private-sector-strategies-fuel-state-department-innovation-lab/> (accessed December 21, 2017).

machines from printing them, this would resolve some of the concerns about non-state and nefarious entities printing potentially harmful materials. Walther points out a few of the impracticalities of this idea such as not being able to print out toy guns and having to constantly update software to recognize new weapon designs. The software could also be hacked.²⁹ Still, DOS should explore the feasibility of installing these types of controls on machines that non-state entities are likely to be able to afford. The DOS would always support the security need of protecting U.S. interests over an individual's desire to print a toy.

Nano-composites to Combat Counterfeiting

Part of IP protection involves anti-fraud measures against counterfeit materials. The DOS defends the IP rights of U.S. companies and can also encourage host governments to introduce technology that will allow for the protection of their own businesses. Campbell and Ivanova suggest the introduction of nano-composites to AM materials as a way to combat counterfeit products. Physically embedding nano-composites for cryptography and security would allow a user or buyer to compare the pattern with the original record from the manufacturer.³⁰ This technology may prove especially important in the global health arena to address counterfeit 3D printed drugs.

Industry & End Use Monitoring

Robert Kelley proposes several aspects to monitoring advances in the field of AM. First, he says the suppliers of AM machines should monitor requests and sales for any unusual safety requirements, high vacuum, and remote handling capabilities. He

²⁹ Walther, 1443.

³⁰ Campbell and Ivanova, "Additive Manufacturing," 76.

suggests manufacturers should also be aware of the dimensions and general characteristics of centrifuges and weapons. This level of awareness would require active government partnership with industry to train printing professionals in weapons identification. This kind of training and partnership is what the Institute for Science and International Security refers to as a good example of export control through government-private collaboration.

Second, Kelley says the government should closely monitor advances in printing explosives and highly toxic materials. And third, monitoring the export of beryllium, nickel-based alloy, and beryllium-aluminum powder transactions is key to proliferation monitoring.³¹ Kelley emphasized that states need to put just as much emphasis on controlling raw materials as they do on finished parts.³² DHS, through the interagency AM working group, should address and assign roles for this kind of monitoring. DOS should promote a similar mechanism overseas with host country officials and through multilateral fora.

Revising Existing Policy

The normative models of treaty and export control regimes are only as good as a state's and individual's recognition, interpretation, and active adherence to those mechanisms. The UN High Representative for Disarmament Affairs, Won-soo Kim notes that when it comes to additive manufacturing there is a "normative gap" among nation states.³³ The DOS will likely need to reinterpret existing policies that were designed to address the proliferation of goods from port to port, and not via the internet, and that may

³¹ Kelley, 10.

³² Kelley, 9.

³³ The United Nations, Won-soo Kim, "Scientific and technical program opening session," 3.

at times be at odds with commercial development interests. The DOS should work closely with the DOC to address the points of incompatibility.

Snow recommends focused policy development and international jurisdictional authorities to deal with the transnational nature of radical leveling technologies.³⁴ She states that current reactive policies have a short term and chilling effect on community engagement and lead to anonymizing technologies such as the *Disarming Corruptor*. The tech community proposed developing a team to work on the legal aspects of technology regulation to create a fair and balanced approach, in a neutral space (not on government property).³⁵ DOS should evaluate the potential for success of this model and determine whether to promote it overseas with host country interlocutors.

Addressing the R&D - Security Dilemma

Any regulation of a dual use technology runs the risk of potentially hampering innovation and investment in research and development. All host governments are likely to raise concerns about any DOS promoted strategy which proposes a particular balance of reward and risk. Jenny addresses the need to develop laws and norms of responsible behavior while also being sensitive to the perception from the private sector that regulations could hamper their ability to gain competitive advantages through the development of these technologies. Further she cautions about the “high probability of enacting measures that are outright counterproductive, either because they are designed to respond to perceptions of threats rather than actual facts, or because of their unintended

³⁴ Jennifer Snow, “Radical Leveling technologies: additive manufacturing and counter proliferation.” Naval Post Graduate School Defense Analysis Program, (February 6, 2016).

³⁵ Jennifer Snow, “D.C.’s disengagement problem: rebuilding relationships with the tech community to improve national security.” Naval Post Graduate School Defense Analysis Department, (May 15, 2016).

negative consequences”³⁶ Brooks Tigner raises the question of whether the international community should only regulate products that could be used as WMD and comments on the difficulty of striking a balance between security and the competitive health of one’s economy.³⁷ In promoting norms of acceptable behavior with other countries, the key negotiation point will be finding the balance between R&D and security. Incentivizing nations who are reluctant to achieve a balance may become a primary driver of advanced technology policy for the DOS and DOC. The risk of not doing so, according to the UN Economic and Social Council, is significant disruption and transformation of “existing social, political, and economic norms.”³⁸

³⁶ Jenny, 4.

³⁷ Brooks Tigner, “Striking a balance: Reforming the EU’s export control regime,” *Jane’s Defense Weekly* (9 July 2013): 1-2.

³⁸ The United Nations, *Issue paper on foresight for digital development*, Advanced unedited draft, UNCTAD Secretariat. Inter sessional panel 2015-2016. (Budapest, Hungary, 11-13 January 2016), 2.

Chapter 7: Conclusion

The future of additive manufacturing presents enormous benefits as well as great risks for the U.S. The DOS should lead the way in developing AM strategy and determining the balance between the need for innovation and risk mitigation. Promoting normative behavior and outreach to non-traditional communities should be among the first approaches implemented. County Teams worldwide should engage on best practices, and encourage collaboration with non-traditional communities. Multilateral treaties and arrangements that do not include or address AM, such as the MTCR, should be amended.

All public diplomacy programs aimed at introducing young people to 3D printing skills should include policy discussions about the benefits and risks the technology poses to their nations. It is important to have these conversations with youth early as they will one day write and influence the policy of their countries. Outreach to hacker and maker communities should also be a central pillar of public diplomacy programming. Country Teams can use the elements of good export control to begin these conversations with their host country interlocutors. Country Team members should openly learn from and share the U.S.' successes and failures with these controls. Just as the U.S. will likely need to adapt and reinterpret some of its policies, many other nations with port-to-port control policies will also need to reevaluate the effectiveness of their programs.

Country Teams should be attuned to the levels of AM mass adoption in their host countries by maintaining close relationships with private industry and also by monitoring the number of injuries and deaths caused by 3D weapons. This close monitoring will allow the Country Team to analyze the potential for economic destabilization in its host country and allow it to inform U.S counterparts of areas of expected increased or

decreased trade. In countries with effective mass adoption of AM, the Country Team can alert the DOL to areas of industry that it needs to prepare for a reduction in exports. An increased U.S. investment in AM could potentially mitigate some of the negative trade impact that a reduction in demand for traditionally manufactured goods will create.

Employing and encouraging scientific countermeasures is an important component to mitigating many of the risks posed by AM weapons. Additive manufacturers should be trained on specifications and designs that are red flags, and trained to be attuned to component parts that, when part of a whole, could be of concern. The DOS should evaluate requiring import certificates for advanced printers, along with end-use monitoring, as well as tightly controlling the printer feedstock such as beryllium-aluminum powder that can be used to make harmful weapons. Country Teams and multilateral organizations should encourage the use of contrast agents in AM weapons manufacturing as well as micro stamping to mark the weapons.

The AM Interagency Working Group should continue to monitor advances in AM, especially advances in counterfeit devices to detect fake AM products. These devices will be especially important to overseas missions who may one day rely on parts and medicines solely produced by printing. The interagency working group should encourage the use of nano-composites as a way to counter fake products. In addition, the Interagency Working Group should also explore the feasibility of software controls that could allow machines to recognize prohibited items and refuse to print them.

Interagency collaboration through the working group should continue and should be expanded to train Country Teams. The Working group should evaluate the feasibility of using cyber bounties and cyber privateers and deliver a recommendation to DOS to

share with allies and partners. Secure transfer technology will be key to protecting intellectual property and ensuring blueprints for weapons do not fall into the wrong hands. In addition, both multilateral efforts and improved TAL training can strengthen the protection of U.S. IP by visa adjudicators.

While it may be impossible to completely future proof the U.S. from the inherent risks of this technology, early and unconventional approaches will complement the traditional treaty and export control regimes already in place. Increasing awareness in the diplomatic community about the benefits and risks of this technology will be an essential component to evaluating and adopting the proposals presented in this thesis. Likewise, a high-level commitment from the DOS geographical and functional bureaus will support efforts to share best practices and promote norms with allies and partners.

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