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Why should we care about 3D-printing and what are potential security implications?

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Key Points

- *3D-printing is likely to have a substantial impact on manufacturing processes and society at large over the coming decades. According to a 2013 McKinsey study, 3D-printing could generate an economic impact of $230 to $550 billion per year by 2025.*
- *Advantages offered by 3D-printing include opportunities for rapid prototyping, product customization, and a more efficient use of input materials. In addition, 3D-printing can be applied to a range of sectors, spanning healthcare to defense.*
- *3D-printing gives rise to at least four security implications. These are: 1) Printers can be used to print hard-to-trace non-metallic weapons and weapons components; 2) Groups with malicious intent may rely on 3D-printers to print customized platforms, such as unmanned aerial vehicles; 3) Countries of concern may rely on 3D-printers or associated commercial services to by-pass international sanctions; and 4) 3D-printing may give rise to several unintended consequences, for example unauthorised access to sensitive design and modeling software.*
- *Given its wide ranging potential, policymakers delving with security and defence issues should begin to gauge the potential security implications of 3D-printing.*

Additive manufacturing, also known as 3 dimensional printing, is not a new technology.[1] The first 3D-printer was unveiled in 1984 by 3D Systems Corporation – some thirty years ago. Some might even argue that the origins of 3D-printing were foreshadowed in the early 1900s through the automated pointing machine used by German sculptor Max Kruse. However, it was only around 2010 that a growing number of businesses and households began to explore its potential, largely due to the introduction of less expensive models. From 2007-2011, sales of 3D- printers grew 200-400 percent every year.[2]

While mainstream awareness of 3D-printers remains limited today, this partially changed in May 2013 when the world's first fully 3D-printed gun was unveiled and tested – resulting in substantial

1 3D-printing or additive manufacturing builds objects layer by layer as opposed to traditional molding or "subtracting" production techniques. A variety of 3D-printing techniques currently exists; please see Table 1 for examples.

2 "Disruptive technologies: Advances that will transform life, business, and the global economy, McKinsey Global Institute, May 2013.

media attention. Since then, a growing number of policymakers and analysts are trying to gauge the security ramifications of 3D-printing. This policy paper aims to contribute to that discussion, offering thoughts on why we should care about 3D-printing as well as potential security implications.

Table 1: Examples of Additive Manufacturing Techniques

Technique	Example of application areas
Selective laser sintering	Production of complex parts, including prototypes
Direct metal laser sintering	Rapid tooling development, medical implants, aerospace parts
Fused deposition modelling	Single- and multipart prototyping
Stereolithography	Rapid prototyping, intricate shapes with high-quality finish (e.g. jewellery)
Laminated object manufacturing	Form/fit testing, rapid tooling patterns
Inkjet-bioprinting	Facilitate cell growth

Source: "Disruptive technologies: Advances that will transform life, business, and the global economy, McKinsey Global Institute, May 2013; http://www.3dprinter.net/reference/what-is-3d-printing.

Why Should we Care about 3D Printing?

There are at least five reasons why we should care about 3D-printing. First, as the technology matures it is likely to impact a wider range of manufacturing processes – opening the door to enhanced productivity and economic growth. Already today, some argue that 3D-printing is the closest we may get to a new industrial revolution.[3] Early adopters of the technology span a variety of industries, including jewellery, architecture, engineering, and science. These sectors are still finding new ways to leverage 3D-printing. For example, the automotive and aerospace industries are increasingly relying on 3D-printing to make complex geometric forms, build prototypes, or produce actual components. At Boeing, 3D-printers are used to print approximately 200 different parts for ten aircraft models.[4]

Second, 3D-printing enables a more efficient use of materials. Through additive manufacturing, in which layers of material are fused on top of each other, the amount of surplus material remaining post-production is minimised. In contrast, traditional production procedures (sometimes known as subtractive manufacturing) tend to generate surplus material in the cutting, grinding, and polishing stages – some of which may not be recyclable. Moreover, since 3D-printers can work with lighter materials in comparison to traditional manufacturing methods, it can further magnify efficiency gains. To illustrate, some 3D-printed aircraft components are up to 65 percent lighter than, but as strong as, traditional manufactured components. This contributes to an overall lower aircraft weight that decreases fuel consumption and carbon emissions.[5]

Third, 3D-printing can contribute to a reduction of transportation and logistical costs. With 3D-printing becoming more prevalent, producers might consider production hubs in multiple locations. Rather than transport final or semi-finished products, some of which may be fragile or cumbersome to move, producers could print finished products in or near target locations. And although input materials would still need to be shipped to printer locations, it would probably be less costly since some input materials might be available locally, e.g. plastic, ceramics, glass, paper. Other input materials could be shipped in block form in standard containers.

Fourth, 3D-printing holds promise across a variety of sectors that are still in the very early stages of developing applications and services. Two examples include:

Medical sector: Among applications receiving attention are possibilities to print replacement organs and custom medical devices. Concerning organ printing, scientists already use 3D-printers to produce strips of organ tissue.[6] In a few decades, 3D-printers may be able to produce organs such as kidneys or livers. In case this becomes a reality, it would impact other medical sectors such as transplant services and regenerative medicine. With respect to custom medical devices, 3D-printing is increasingly used to produce exoskeletons. For example, the world's first 3D-printed Ekso-Suit was customised to a patient in February 2014.[7] Advantages associated with 3D-printing of exoskeletons include their faster production time

3 P. Jensen-Haxel, "3D Printers and Firearms", *Golden Gate University Law Review*, Vol. 42, Issue 3, Berkeley Electronic Press, 2012.

4 L. Willcocks, W. Venters, and E. Whitley, *Moving to the Cloud Corporation*, Palgrave Macmillan, 2014.

5 C. Jewell, "3-D printing and the future of stuff", WIPO Magazine, April 2013.

6 B. Griggs, "The Next Frontier in 3-D Printing: Human Organs", CNN.com, 3 April 2014.

7 M.A. Russon, "Paralyzed Woman Walks with 3D Printed Exoskeleton, *Robotics Trends*, 21 February 2014.

compared to traditional assembly methods as well as the possibility to customise individual pieces.

Food sector: While the production of an artificial hamburger using muscle fibres grown from stem cells made the headlines in 2013, much less is known about the potential of 3D-printed food. For example, a market is slowly developing to serve the needs of people suffering from dysphalgia. According to a report, one in five individuals over 50 suffer from dysphalgia which is characterised by an inability of the "larynx to close properly while swallowing".[8] In such cases, food may be redirected to the lungs, resulting in potential health problems like renal failure. To date, liquefied foods are used to address this challenge. While satisfactory, it takes out the enjoyment of eating food for many people. 3D-food printers are starting to print gelatinous food in the shape of traditional food objects. As this sector develops, it is possible that uses and applications are broadened, for example to address food shortages in post disaster or conflict areas.

Lastly, 3D-printing presents applications in the security and defence domain, some of which may result in unintended security implications. These are covered in greater detail in the next section.

What are potential security implications of 3D-Printing?

Looking ahead, 3D-printing is likely to have significant applications in the security and defence field. Within the military domain, armed forces across the globe will be eager to integrate cutting-edge opportunities offered by 3D-printing. These may include enhanced abilities to prototype future weapons systems or platforms (such as aircraft) in a shorter timeframe, the production of exoskeletons to boost the strength and stamina of military personnel, opportunities to treat wounded soldiers, and the deployment of more efficient military supply/spare parts chains (e.g. using an aircraft carrier as a mobile manufacturing base; printing food).[9] As 3D-printers become more advanced, there may also be opportunities to incorporate strong yet light-weight materials such as titanium in the production of specific military assets.

However, applying 3D-printing to this sector will give rise to at least four security implications. First, and as has already been demonstrated, 3D-printers can print weapons and weapons components – including a complete functioning gun. While the process of printing weapons components for semi-automatic rifles or guns takes considerable time and effort, they effectively allow anyone to access such components (this open accessibility dimension is frequently referred to as "democratised manufacturing" in the literature). According to Defense Distributed, the blueprints for the Liberator plastic gun were downloaded over 100,000 times within two days of being uploaded.[10] Even after the website hosting the information was blocked, enough individuals had downloaded the blueprints to facilitate sharing across other websites.

While it could be argued that in many corners of the world it is currently easier to purchase an existing weapon rather than printing one, the availability of increasingly sophisticated blueprints and multiple-material printing devices is likely to enhance the attractiveness of 3D-printing. Why? Beyond faster 3D-printing processes in the future, there is the possibility to avoid monitoring or regulatory checks – something that may be particularly attractive to criminal groups and terrorist organisations. Another attraction may be the ability to use different materials. In an age of ubiquitous scanners, individuals or groups with malicious intent may be particularly drawn by the possibility to print "metal-free" weapons that are more difficult to detect with present-day scanning technology.

Second, and related to the point above, 3D-printing may be employed to print more advanced types of platforms that can be used for warfare, reconnaissance, or scouting purposes. An area with great potential is small scale drones, including micro air vehicles (MAVs). Individuals have already shown it is feasible to print unmanned aerial vehicles (UAVs). In April 2014, engineers at the University of Sheffield's Advanced Manufacturing Research Center printed and flew an UAV within 24 hours.[11] As 3D-printers become more advanced, they may facilitate the transition towards customised MAVs – which presently are trademarked by their design variability (some are shaped like birds, similar developments are underway with autonomous underwater vehicles).[12] As this technology matures, it is likely to draw interest from both criminal and terrorist groups interested in

8 M. Molitch-Hou, "The Elderly Get the First Taste of 3D Printed Future Food", 3D Printing Industry.com, 14 April 2014.

9 For more on opportunities within the naval sector, see M. Llenza, "Print when ready, Gridley", *Armed Forces Journal,* 1 May 2013. For printed rations see http://www.dailymail.co.uk/news/article-2716368/US-army-use-3D-print-technology-make-meals-battle-weary-soldiers.html

10 A. Holpuch, E. MacAskill, and C. Arthur, "State Department Orders Firm to Remove 3D-Printed Guns Web Blueprints", *The Guardian*, 10 May 2013.

11 B. Coxworth, "3D-printed UAV can go from not existing to flying within 24 hours", Gizmag, 2 April 2014. Available at http://www.gizmag.com/3d-printed-uav-airframe/31473/

12 For an example of such projects, see http://www.geek.com/news/silent-running-uav-looks-like-a-bird-capable-of-invisible-surveillance-1552049/

new means to maximize their impact. It is also plausible that countries of international concern "leap-frog" to take advantage of 3D-printing opportunities. Further ahead, some may look into the promises of 4D-printing which aims to work with materials that can change their attributes/characteristics over time. Known as smart materials, these may include materials that "self-heal" in case they are damaged.

A third security implication is that some countries or organisations may use 3D-printing technology to bypass international restrictions or sanctions. To illustrate, a country facing long-time sanctions, leading to a shortage of spare parts for certain military equipment such as aircraft, might be able address this by relying on a 3D-printer for replacement parts or missing components. While gaining access to a cutting-edge industrial 3D-printer and the digital blueprints necessary to print such components is not straightforward, it provides options – especially should commercial 3D-printing services become more widespread (examples of existing services include Cubify, iMaterialise, and Shapeways). To minimise risk of detection, stakeholders could use an array of printing companies to produce different components.

Lastly, there are a host of unintended consequences that may arise over time. These include:

Access to sensitive design and modelling software: "Sensitive" 3D-printing software, such as that used for security or defence related products, may at some point fall in the wrong hands. This could occur through a variety of means, ranging from cyber espionage to open source developed code for dual use technologies. Negative unintended consequences could arise should such information reach malicious groups.

Loss of sensitive intellectual property rights: The evolution of 3D-printing technology and related software may impact existing export control regimes and national regulations such as the U.S. International Traffic in Arms Regulation. Developments in 3D-printing may affect trademarks, copyrights, and patents for sensitive technologies, including those with defence applications.

Conclusion and the Way Ahead

While not yet a widely known or ubiquitous technology, 3D printing will have a substantial impact on manufacturing processes and society at large over the coming decades. Its applicability across civilian and military sectors, while in its infancy, foreshadows tremendous potential. Spin-off products and services are likely to mushroom as the technology matures – including in the areas of commercial printing services and software development. According to a 2013 McKinsey study, 3D-printing could generate an economic impact of $230 to $550 billion per year by 2025.[13]

Given its wide ranging potential, policymakers delving with security and defence issues should begin to gauge the potential security implications of 3D-printing. The goal of such reflection should not be focus on ways to stem or direct its evolution, e.g. via regulatory means. On the contrary, the objective should be to raise awareness of the technology and objectively analyse its potential security benefits and risks. Doing so in a systematic fashion will facilitate the identification of appropriate solutions and workarounds once security challenges begin to loom in the horizon.

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13 "Disruptive technologies: Advances that will transform life, business, and the global economy, McKinsey Global Institute, May 2013.

NB: The views expressed in this policy paper are those of the author and do not necessarily reflect the views of the GCSP.

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