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BACKGROUND PAPER

3D Printing & Biotechnology: Possible Security Implications for NATO, Its Partners, and Beyond

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EXECUTIVE SUMMARY

Developments in 3D Printing and Biotechnology may appear to be quite unrelated; in fact they share commonalities. Both have the potential to greatly benefit the societies we live in - from developing new industrial processes through to enabling treatments for diseases and improvements in healthcare unimaginable just a few years ago.

Indeed, developments in 3D Printing mean new techniques can be used positively in Biotechnology, prosthetics, and medical devices. A 3D 'bioprinter' can even be used to produce 'bioprinted' human organs. At the same time, 3D 'bioprinting' could also be used by those who wish to inflict great harm on our societies. Both 3D printing and biotech are apt to simultaneously empower many - who would not otherwise have the means - to acquire dual-use technology and their means of production. Such capabilities are likely to be used by states, terrorists and criminal actors, creating new security challenges.

Background: What is 3D Printing? What is Biotechnology?

3D Printing is an additive manufacturing process for making three-dimensional objects. While it is not a new technology – it is several decades old – improvements have increased dramatically in recent years as capacities and prices have gone down. The ability to print with different materials has likewise enhanced the versatility of 3D printing. A printing process may consist of having layers of material successively added in a computer-controlled process to make a final object. Depending on the process, materials can include plastics, metals, polymers, ceramics and even cellular tissue. ASTM International defines 3D Printing as "the fabrication of objects through the deposition of a material using a print head, nozzle, or another printer technology."[1]

The definition of biotechnology, according to the UN Convention on Biological Diversity[2] is "any technological application that uses biological systems, living organisms or derivatives thereof, to make or modify products or processes for specific use". In other words, biotechnology refers to the use of living systems and organisms to make things. Recent advances in biotechnology include developments in the areas of synthetic biology and gain of function.

[1] *According to ASTM International Committee F42 on Additive Manufacturing Technologies, http://www.astm.org/COMMITTEE/F42.htm*
[2] *Article 2 of the UN Convention on Biological Diversity. See: www.cbd.int/doc/legal/cbd-en.pdf*

Characteristics of 3D Printing and Biotech

3D Printing is part of developing 'cyber-physical systems.' It is considered as a fundamental part of 'Industry 4.0' (sometimes called the Fourth Industrial Revolution' following-on from the digital revolution, the mass production and electrical revolution, and the steam power revolution). 3D Printing clearly has great potential benefits for our societies. It can be used to enable 'platform' industrial manufacturing. A platform enables the cost advantages of mass production, combined with the individualization of a product. For example, hip joints can be mass-produced from a computer program while at the same time individualized for a single consumer.

3D Printing may also endow anyone the ability to create products at low cost that would otherwise be impossible without access to vast capital and other resources. Additionally, 3D Printing may enable companies and individuals to move from in-house rapid prototyping to custom one-off or mass production in short time frames. There are a vast range of portals with highly reliable drawing and instructions and video tutorials helping anyone to capture the technology. It is becoming an 'open' mass movement technology that challenges the notion that years of training and professional development are needed to develop manufacturing expertise.

Indeed, 3D Printing is set to play a key role in the interdisciplinary development of cyber-physical systems and likewise the life sciences are increasingly drawing on engineering, mathematics, computer science, chemistry, and materials science. While 3D Printing may be central to the Industry 4.0 there is a similar 'industrial revolution' occurring in biotechnology. This developing form of biotechnology is sometimes described as 'synthetic biology'. The British Royal Academy of Engineering's defined the concept as “Synthetic biology aims to design and engineer biologically based parts, novel devices and systems as well as redesigning existing, natural biological systems.” This is an interdisciplinary branch of biology, combining subjects such as evolutionary biology, molecular biology, systems biology, biophysics, genetic engineering, and materials science.

Biotechnology may allow vast developments in healthcare, agriculture, and industry. In health it may enable the treatment and prevention of chronic illnesses including heart attacks, strokes, multiple sclerosis, breast cancer, cystic fibrosis, leukemia, diabetes, hepatitis and other rare or infectious diseases. It is already enabling the development of 'personalized medicine' where a single patient’s problems are individually identified and treated to better adapt the healthcare solutions to suit their specific needs. In industry, biotech can use enzymes and microorganisms to make products that can clean the environment and enable the production of paper and pulp, food, clothing, chemicals and indeed bioenergy. Agricultural biotechnology can reduce the cost of food production using less land, energy, and water.

So, both 3D Printing and Biotechnology enable great strides in human progress. But what of the security concerns?

Use For Harm - 3D Printing as an 'Enabler'

3D Printing may provide the 'missing-link' that enables terrorists, lone-wolf actors and other with nefarious aims to engage in new, high technology threats and actions. Moreover, it may allow for the creation of new weapons and tools for novel crimes.

Curiously, printing guns – one of the most prominent dangers of 3D Printing highlighted in various news stories over the last year – may be the least of our concerns. The guns made so far with 3D printing were of generally poor quality. Indeed there are legitimate questions as to why someone would print a gun, as vast numbers of industrial-grade, high quality guns are already available to be purchased, either legitimately or on the black market. Therefore the simple ability to 3D print a gun does not significantly add to our security worries. However the ability to *print parts* that might enable more complex devices or sections of systems which may not be purchased commercially so easily is a growing and real area of concern. Moreover, while producing a 'standard' gun with a 3D printer would be of little interest to a terrorist, the types of complex or advanced weaponry that may be produced could well be enhanced by 3D Printing. This includes the ability to produce complex mechanisms from metals or plastics, embed discrete components during a build process, print

Improvised Explosive Devices (IEDs), as well as Unmanned Ground and Unmanned Ariel Vehicle system components. In addition, 3D Printing may enable the manufacture of new types of small arms that are harder to detect and trace.

But it is not 3D Printing's use for violence alone that concerns security analysts. US President Barack Obama has repeatedly noted that intellectual property theft is a direct national security concern. With that in mind, 3D Printing depends on computer files that may enable those who wish to steal intellectual property a greater ability to do so and increased capacity to manufacture items based on stolen intellectual property. Indeed, one of the challenges that intellectual property criminals have is producing something from their stolen data and information in an accurate way. 3D Printing may enable such criminals to successfully overcome this hurdle. Intellectual property underpins the research, innovation and development that is the foundation of our economies; as such, IP theft is a direct security concern and a clear emerging security challenge.

Additionally, 3D Printers themselves are vulnerable to hacking and security exploitations. This could be a serious concern if companies such as Pratt & Whitney or Rolls Royce are printing complex components for their engines and a process becomes vulnerable. It can also be a concern when they are used in the development of biotechnology products.

Bio Technology – Concerns and Caveats

One of the main concerns in biotechnology is the development of new pathogens. Since studies were undertaken to improve the transmissibility of the H1N1 virus, a vigorous debate has been taking place inside scientific, research, publishing and policy circles on the range of Gain of Function studies[3]. While at present, the technologies and knowledge necessary to improve the lethality or transmissibility of organisms appears beyond the capacity of most amateur scientists, rapid technical change and sharing of knowledge is the norm. While there is comprehensive international law prohibiting the development of bioweapons, especially the 1972 Biological and Toxin Weapons Convention via its general purpose criterion, scientific research equipment and know-how is available at decreasing prices and reduced complexity.

Additionally, new biology concerns data - indeed it is data, held on systems, often in the 'cloud' that is the knowledge basis for biotechnology research. This data can be hacked by the breaking into laboratory computers and databases by criminals and others with harmful intent. Moreover, hobbyists or 'bio-hackers' can work from home using DNA sequencers bought off the Internet and adjust DNA using synthetic biology. One ESC WG expert suggested that this hobby is "harmless" but conceded that that there is no clear oversight of its development. Potential danger in biotech is more likely to arise from state-sponsored terrorists and criminal entities, not necessarily 'lone wolves.' Indeed states may wish to develop biological weapons in violation of agreements and may choose new pathways. What could enable such actors, now and in the future to use biotech as a weapon? There are four main factors:

- The requisite science and technology base is now in place
- Complexity is being reduced
- The production capacity is now available
- A new confluence of trends in science and technology is underway

These factors produce three major areas of concern, however each come with major caveats as shown in Table 1.

3 See http://www.nature.com/nrmicro/journal/v13/n1/full/nrmicro3405.html

Table 1: Overview of Synthetic Biology Challenges and Caveats

Concern	Caveat
Concern 1: Synthetic biology is making it easier for non-experts to manipulate dangerous pathogens[4] and therefore, making it easier for terrorists to concoct bioweapons.	**Caveat 1:** At present, even the most sophisticated experts have major challenges and difficulty enhancing a disease pathogen.
Concern 2: Synthetic biology has led to the growth of a 'Do-It-Yourself' biology community that could offer dual use knowledge and equipment to terrorists seeking to do harm.	**Caveat 2:** This form of 'DIY Biology' is not particularly sophisticated. A high level of advancement would be needed in order to enable bioterrorists using DIY biology.
Concern 3: DNA synthesis has become cheaper and can be outsourced, making it easier for terrorists to obtain the basic materials to create biological threat agents.	**Caveat 3:** Building such a dangerous virus from scratch is a very hard thing to do; it is not something that can simply be outsourced.

4 A pathogen is the agent that causes an infectious disease.

Potential Security Implications - Outside the control of governments

A highly significant overlapping factor of 3D Printing and biotechnology is that both developments shift control from central administrations to individuals or small groups of non-state actors and reduce barriers to make use of such technologies for the production of weaponry, explosives or other dangerous goods. Governments of NATO and Partner Nations may quickly be losing what little control they have of these technologies. Like the Internet, 3D Printing is an example of a technology over which governments have little control. Indeed, it could be argued that governments and even international organizations are playing 'catch-up' as the technology steams ahead of them. Less control is available vis-a-vis software code for printing different objects (e.g. Stereolithography files). To illustrate, the software design for the Liberator gun was downloaded over 100,000 times in one day. Biotech developments are enabling not just a rise in international research collaboration, but indeed an "increasing ability to carry out life sciences research outside traditional, institutional, settings". One therefore might describe 3D Printing and biotechnology as 'disruptive technologies,' which governments and nationally based administrations are poorly equipped to either utilize for good or to prevent harm from occurring.

In summary, both in 3D Printing and in biotechnology there are potential dangers and risks. In 3D Printing those risks are real but very hard to monitor and control; indeed there is no legislation to even attempt to do this at present, and such legislation that might be proposed would be unlikely to handle globalized technology. In biotech the risks, at present, may be inflated; nonetheless, rapid developments in the field mean that these risks are unknown to some degree and so must be monitored closely.

In terms of law, the major difference between the two is that very comprehensive international legislation governs many aspects of biotech, which it does not in any way for 3D Printing. Most importantly, both 3D Printing and biotechnology shift control from states that are to be held accountable to democratic control, towards non-state or illegitimate state-sponsored actors, who are not.

Policy Considerations

With this background in mind, several policy considerations arise. Among the most prominent are:

1. Advances in 3D Printing and biotechnology empower non-state actors by reducing complexity and barriers to entry for the production of formerly complex creations that may challenge the security of our countries.

2. 3D printed guns are not the problem at present, but intelligence and law enforcement must become aware of new developments in IEDs and other illegal weapons and tools, which may arise out of 3D printing technology.

3. In biosciences, while beyond the skill of most hobbyist or DIY researchers at present, governments must pay close attention to “gain of function” experiments that increase the pathogenicity of infectious agents.

4. Public accountability of scientific research in biosciences needs to be secured, as secrecy will only increase confusion over what needs to be controlled and by whom.

5. While threats run the gamut from rogue individuals to coordinated non-state actors, with bioweapons and 3D printing challenges states may be apt to use non-state actors as proxies.

6. As intellectual property for 3D Printing and biotech is apt to become a high value target, governments should enhance their efforts to improve security in cyberspace.

7. 3D Printing and biotech underscore the need to be much more international, collaborative, flexible, and proactive in our approaches to new security challenges.

Both 3D Printing and biotechnology are examples of 'uncertain' emerging security challenges. Indeed, *how* they will manifest themselves as security challenges is largely unpredictable – especially concerning implications for national security. Therefore proactive policy planning needs to be included while considerations of reactive, post-event responses remain important. .

How do we engage such issues and manage them across the Alliance? Indeed, do we try to manage them, should we or must we take a laissez faire approach and allow these developments to occur without interference? Or is that path simply too dangerous as it enables those with nefarious aims to take advantage of these technologies? Perhaps there is a 'third way' where governments attempt to enhance and enable the development of 3D Printing and biotech to benefit society but simultaneously attempt to prevent their use for harmful purposes via targeted measures that do not result in burdensome regulation. Non-state actors are now developing power that someday soon might rival that of states, so at present the main policy challenge is how to increase international awareness and monitoring of the rapid advancement of these technologies.

This background paper was prepared by Dr. Dinos Kerigan-Kyrou, Mr. Sean Costigan and the Co-Chairs of the ESCWG based on recent meetings of the PfP Consortium's Emerging Security Challenges Working Group.

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