RELATO DE EXPERIÊNCIA

3D PRINTING AND NEW SECURITY THREATS

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ABSTRACT: The present study is a horizon scanning report based on the British model Sigma Scan. It explores possible future issues and trends in 3D printing and its potential impact on society, particularly with regard to new security threats that its spread is expected to cause. This exercise allows for an examination based on the best predictions of how the future of this disruptive and, at the same time, enabling technology is likely to be, in order to better understand the uncertainties that its development will bring. This report addresses the potential implications of the development of 3D printing, in particular for crimes, the likely early indicators of the development of this technology, the simultaneous developments that can serve as inhibitors and drivers, the potential crime preventers and promoters, and the evidence that indicates the possibility of the predicted events.

Keywords: 3D printing. Additive manufacturing. Disruptive technology. Enabling technology. Security risks.

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1. INTRODUCTION

Horizon scanning is a technique that explores possible future issues and trends in a wide range of categories such as politics, economics, socioculture, technology, law, and environment, based in research that involves a wide variety of sources. By systematically investigating and examining potential opportunities, threats, risks, emerging issues, and evidence about future trends using scientific journals, government agency studies, interview with specialists, etc, horizon scanning helps to detect early signs of important phenomena, providing the background for implementing strategies to anticipate future developments.

The study in hand is a horizon scanning report based on the British model Sigma Scan used by the United Kingdom Government Office for Science, thus following its structure which is particularly different from a traditional scientific paper. It was originally developed as a research assignment for the Horizon Scanning and the Changing Nature of Crime module in the master's degree in Policing from the University College London. It explores possible future issues and trends in 3D printing and its potential impact on society, particularly with regard to new security threats and the plausible impacts on crime that its spread is expected to cause.

Figure 1: Criteria on the potential of 3D printing to create pervasive and serious change

Impact	★★★★☆	Likelihood	★★★☆☆	Controversy	★★☆☆☆
Where	Globally	When	11/20 years	How Fast	Years

Source: Author's own development based on United Kingdom (2017) as an assessment of all references used in this report, providing a visual snapshot about the trend.

2. SUMMARY OF 3D PRINTING

3D printing is how additive manufacturing (AM) is popularly known, the technology that combined with automation and artificial intelligence (AI) will enable the next industrial revolution. By adding 'layer by layer', AM turns a digital model into a physical object covering a vast array of sectors, materials and processes (CAMPBELL *et al.*, 2011; JOHNSTON *et al.*, 2018; NGO *et al.*, 2018).

One of the most AM game-changing solutions that has become a catchphrase is that 'additive manufacturing offers complexity for free'. This means that while in traditional manufacturing the cost and time of production is directly related to the complexity of the object's shape, AM allows the creation of elaborate products practically by the same cost of simple ones; the focus of production is shifted to the creation of the digital design (CAMPBELL *et al.*, 2011; COTTELEER, 2014; JOHNSTON *et al.*, 2018).

Given its 'layer by layer' way of printing, 3D printed objects are created as single pieces and hence the necessity for multiple subcomponents is reduced; this contrasts with 'subtractive manufacturing' which demands the assembly of multiple parts. As a result, AM has made the fabrication of elaborate items easier, cheaper and faster, allowing the development of even more elaborate geometries without increasing the cost or time of fabrication, and also the making of products that could not be fabricated by traditional methods, which demonstrates that the importance of AM is increasing rapidly, representing a major advancement in the way items are designed, manufactured, sold and fixed (BERMAN, 2012; CAMPBELL *et al.*, 2011; JOHNSTON *et al.*, 2018; SCHULZ *et al.*, 2017).

Whereas additive manufacturing improves time, quality and costs of production, industries worldwide are increasingly adopting this technology as a form of just-in-time and large-scale manufacturing; for customising products while reducing design and assembly complexity; simplifying supply chains, reducing logistics and warehousing costs by producing locally; and increasing efficiency. In addition, the simplicity of the process, the decreasing cost of printers and the increase in the variety of usable materials in the process make 3D printers a viable solution not only for big companies, but also for designers, engineers, architects, artisans, and even hobbyists. However, experts' opinions diverge in this matter, particularly regarding if the day will come when 3D printers will become a household appliance just as ink-jet printers are nowadays enabling the manufacture of many objects at home (BERMAN, 2012; CAMPBELL *et al.*, 2011; JIANG *et al.*, 2017; JOHNSTON *et al.*, 2018).

With its initial development dating back the 1980s, AM has become in the last decade a highly interesting and viable solution to optimise the production of a vast variety of sectors. Small and large-scale construction, medical technology, automobile, aircraft, clothing, food and medicine industry are some application examples that suggest that there is no limitation to what this technology can achieve besides availability of base materials, human imagination and inventiveness. Whether by material extrusion, material jetting, powder bed fusion, among other process, its possibilities are numerous. Examples of materials that are being used in 3D printing are: thermoplastic, polymers, photopolymers, resins, ceramics, melted plastic filaments, concrete, biological cells, liquid and metal powders, carbon fibre, titanium, wood filament, edibles, etc (JOHNSTON *et al.*, 2018; LEE *et al.*, 2017; NGO *et al.*, 2018; POTTER, 2017; YAMPOLSKIY *et al.*, 2015).

All this versatility offers a huge scope of potential creations. The first 3D vascularised engineered heart has just been printed in April 2019 out of the patient's own cells and biological materials. Examples of 3D printed items are: organs, jaw-bones, skull protective plates, biodegradable materials, household goods, buildings, bridges, clothes, aircrafts and vehicles parts, electronics, custom pharmacology, stretchable electronics, nanoscale objects, piezoelectric materials, robots, printable solar cells, etc (CUI, 2019; LEE *et al.*, 2017; NGO *et al.*, 2018; NOOR *et al.*, 2019; SCHULZ *et al.*, 2017; YU *et al.*, 2017).

3. GENERAL IMPLICATIONS OF 3D PRINTING

With what seems to be endless possibilities, it is not hard to overestimate the impact of additive manufacturing on different areas as politics, ethics, economic, technology, law, environment, business and society in general. There still is a high level of uncertainty; most experts agree that, although since the introduction of AM in the early 1980s 3D printing has developed very quickly, its biggest changes and implications are yet to come bringing simultaneously benefits and risks (CAMPBELL *et al.*, 2011; JIANG *et al.*, 2017; JOHNSTON *et al.*, 2018; NEELY, 2016).

At the same time AM is a powerful enabler which will make manufacturing widespread, it is a disruptive technology for some industries. Automotive, aviation, transportation, aerospace, logistic and traditional manufacturing are areas where experts consider the disruptive effects of AM will be most felt. The effects in sectors as health, food production, entertainment are more controversial. Finally, service industries would be more resistant to the changes to be introduced by AM (CAMPBELL *et al.*, 2011; JIANG *et al.*, 2017; JOHNSTON *et al.*, 2018).

AM promises manufacture decentralisation by enabling local production. This would disrupt the supply chains worldwide, cross-border trade and the labor market, causing economic dislocation, changing the balance of power between nations, and even compromising effectiveness of economic sanctions and embargoes. This will cause a drastic disruption to the global economy causing the loss of millions of jobs, what can be even more disruptive depending on the development of automation and AI (BERMAN, 2012; CANN, 2016; JIANG *et al.*, 2017; JOHNSTON *et al.*, 2018; LEERING, 2017).

AM will also present new challenges to intellectual property laws, changing the very notion of what is creativity. Because AM enables the creation of any product in a fully personalised manner and the manufacture of items at home, new safety regulations will be needed. It will be difficult to ensure safety and assign legal liability; this consequently raises concerns about the reliability of manufactured products. The development of an in-space 3D printing technology will affect space missions (KURFESS & CASS, 2014; NEELY, 2016; PIERRAKAKIS *et al.*, 2014; SCHOLES, 2015).

As an impressive technological change that will revolutionise manufacturing, change business and transform lives, affecting a huge range of areas - some research already discuss the development of an in-space 3D printing technology that will affect space missions - 3D printing will also support and challenge criminal investigations by providing new ways to fight crime and unleashing new kinds of security threats (BAIER *et al.*, 2018; BAYENS *et al.*, 2017; CHASE & LAPORTE, 2018; MCGUIRE *et al.*, 2016; NEELY, 2016; SCHOLES, 2015; TIRONE & GILLEY, 2015; WALTHER, 2015; YAMPOLSKIY *et al.*, 2015; ZELTMANN *et al.*, 2016).

4. IMPLICATIONS OF 3D PRINTING FOR CRIME

4.1 SUPPORTING CRIMINAL INVESTIGATIONS

AM can support criminal investigations and police operations by allowing, e.g., the printing of a building's model for training and tactical entrance decision-making; the replication of crime scene evidence; an accident, facial, or body reconstruction that could be used for court demonstrations. The application of AM, scientific methods, and analysis techniques to the reconstruction of criminal events will play a significant role in the investigation of crime, provision of justice and crime deterrence. It will aid the detection and identification of offenders and victims increasing the risks of committing an illegal act, and will have a direct effect on the tertiary level of crime prevention, helping preventing recidivism, for example (BAIER *et al.*, 2018; BRANTINGHAM & FAUST, 1976; CHASE & LAPORTE, 2018; CLARKE, 1983; 1995).

4.2 UNLEASHING NEW KINDS OF SECURITY THREATS

The offender is a rational decision-maker. Therefore, criminal behaviour will occur when the perceived benefits outweigh perceived costs. AM will change the benefits/costs relation for existing crimes and will unleash new kinds of security threats (CORNISH & CLARKE, 2016).

There are numerous ways in which offenders can exploit AM technology to commit crimes or to challenge criminal investigations. Some of these possibilities are summarised below.

- Cyber sabotage in the physical world: 3D printers can be compromised by undetectable and dangerous defects cyber-introduced in the manufacturing process causing real-world damage with disastrous results (BAYENS *et al.*, 2017; BELIKOVETSKY *et al.*, 2016; IRVING, 2018; STURM *et al.*, 2017; WALTHER, 2015; YAMPOLSKIY *et al.*, 2015; ZELTMANN *et al.*, 2016).
- The physical object will no longer be the product, but its graphic file containing the instructions to print it: 3D printing presents comparable threats to author rights and intellectual property laws as the illegal file sharing of movies, books and music. In the specific case of AM, it is also possible to photograph or to scan an item and

print unauthorised copies, which poses an even larger-scale threat (JIANG *et al.*, 2017; KURFESS & CASS, 2014; NEELY, 2016; SCHOLES, 2015).

- 3D printed weapons and explosives: They could be undetectable. The development of 3D printers using metal and alloys will enable the production of even more deadly and prohibited kind of weapons. Onsite manufacturing: Attackers could command a printer inside a sensitive location and build a weapon or explosive behind the security perimeter. Forensics and investigations difficulties: difficulties for tracing the origin of production. The possibility to create unique products can impose problems for forensic identification and explosives disarmament. The threat of homemade untraceable firearms is real (BAIER *et al.*, 2018; CHASE & LAPORTE, 2018; IRVING, 2018; SCHOLES, 2015; TIRONE & GILLEY, 2015; WALTHER, 2015; YAMPOLSKIY *et al.*, 2015).
- 3D printed handcuff and prison keys: Having access to a picture of a key on the social media will allow anyone to 3D print it (CHASE & LAPORTE, 2018; SCHOLES, 2015; YAMPOLSKIY *et al.*, 2015).
- 3D printing ATM skimming devices: allowing criminals to steal sensitive information (BIGGS, 2011; Sorrel, 2011).
- New manufacturing capabilities will endanger jobs imposing a series of challenges: job scarcity could push people into engaging in criminal activities or towards mass migration; the latter could threaten international relations (BERMAN, 2012; CANN, 2016; IRVING, 2018; JIANG *et al.*, 2017; JOHNSTON *et al.*, 2018; LEERING, 2017).
- Trade embargoes and economic sanctions will lose effectiveness: Nations will print what they need without much difficulty. International affairs rules will need to changed leading to new conflicts (CAMPBELL *et al.*, 2011; JOHNSTON *et al.*, 2018; LEERING, 2017).
- Advancements in healthcare derived from bio-printed structures would increase population: Food scarcity and pressure for natural resources will lead to conflicts (CAMPBELL *et al.*, 2011; JOHNSTON *et al.*, 2018; NOOR *et al.*, 2019).
- Threat to privacy: Miniaturised 3D printed cameras installed in surveillance 3D printed micro-drones will captures images with a high central acuity recording sensitive locations without being noticed (MCGUIRE *et al.*, 2016; THIELE *et al.*, 2017).
- 'Interactive Robogami': The possibility to design, 3D print and assemble a robot in four hours could be leveraged by terrorists printing these devices to deliver explosives (SCHULZ *et al.*, 2017).
- Manufacture counterfeit parts: These parts could be used for fraudulent purposes (CHASE & LAPORTE, 2018; Scholes, 2015).
- 3D printed fingerprint, handprint, and pattern of blood vessels in the eye: Offenders could use these devices to bypass biometric security measures (CHASE & LAPORTE, 2018; ENGELSMA *et al.*, 2018).
- Illicit drugs: While AM promises to revolutionise pharmaceutical industry by allowing the printing of medicines at home, chemical 3D printers will provide the tools to print illicit drugs and even chemical weapons and explosives (JOHNSTON *et al.*, 2018; NGO *et al.*, 2018; SCHOLES, 2015).

5. EARLY INDICATORS

- AM is an emerging technology. Nowadays 3D printers capable to use metals and alloys as raw material are very expensive and available mostly for industrial usage. It is likely that within 10 years AM with metals and alloys will be accessible for personal use, raising concern about the possibility of 3D printing weapons, ammunition, explosives and security keys made from these materials that are more reliable and deadly than plastic (JIANG *et al.*, 2017; YAMPOLSKIY *et al.*, 2015).

- The development of AM coupled with the advancements in automation and AI will lead to a loss of at least 10 million jobs around the world in the next 20 years. AM itself, by allowing local production, will wipe out 25% of world trade in the next 30 years causing drastic disruption in the global economy (BERMAN, 2012; CANN, 2016; JIANG *et al.*, 2017; LEERING, 2017).
- Within 10 years, the possibility to 3D print fingerprints and handprints at home will make current biometric security measures obsoletes (CHASE & LAPORTE, 2018; ENGELSMA *et al.*, 2018).
- The development of chemical 3D printers will make it possible homemade illicit drugs within 15 years. This advancement coupled with the development of 3D printed weapons will enable the production of chemical weapons (JOHNSTON *et al.*, 2018; NGO *et al.*, 2018; SCHOLES, 2015).
- Within 20 years, space-based 3D printing facilities will allow the maintenance of space aircrafts and the construction of buildings allowing longer missions, better space exploration, and enabling homeland security mission by printing in-space small satellites that will be used in a variety of intelligence missions (MCGUIRE *et al.*, 2016).
- Manufacture industries such as toys, decorative objects and cutlery production will be strongly disrupted in the next 20 years. The development of AM will move the trade of this objects to the trade of their design that will be printed locally (CAMPBELL *et al.*, 2011; JIANG *et al.*, 2017; JOHNSTON *et al.*, 2018; NEELY, 2016; SCHOLES, 2015).

6. DRIVERS AND INHIBITORS

6.1 DRIVERS

The development of nanotechnology will enhance 3D printing by allowing the use of new materials and new printing process, consequently bringing advantages to nanofabrication, which is important for objects that require fine details, e.g., human organs. The development of medical technology will also drive advancements in 3D printing (JIANG *et al.*, 2017; JOHNSTON *et al.*, 2018; LEERING, 2017).

The increasing demand for cheaper and eco-friendly products will benefit the development of 3D printing because AM simplifies supply chains and reduces labour, human error, warehousing, prototyping and transportation costs, and the consumption of raw materials (JIANG *et al.*, 2017; JOHNSTON *et al.*, 2018; LEERING, 2017).

Industries, world-class leading universities, and researchers are pushing AM technology to new levels, presenting constant advancements and new applications (JIANG *et al.*, 2017; LEERING, 2017).

6.2 INHIBITORS

Raw materials used in 3D printing are still part of a controlled market with few suppliers; this increases costs. Besides, the controlled access to certain substances and base materials imposed by governments and suppliers' monopoly, and the limitation of computer design methods plus the limited number of printing processes can hold back AM development. The control over raw materials can be leveraged as a situational crime prevention strategy restricting the access to certain substances (CLARKE, 1983; 1995; LEERING, 2017; NGO *et al.*, 2018).

Stringent regulatory laws regarding the possession and use of 3D printers may make it difficult or even impossible to obtain a 3D printer. This example of a situational crime prevention strategy can be the result of government concerns about the possibility of 3D printing weapons and explosives, liability and unclear intellectual property rights (CLARKE, 1983; 1995; JIANG *et al.*, 2017; KURFESS & CASS, 2014; LEERING, 2017; NEELY, 2016; PIERRAKAKIS *et al.*, 2014).

Industries worldwide may not want to construct new plants and make the current ones obsolete. Governments and international institutions may be concerned about the risk of mass job losses mainly in industrialised countries and the disruption to the global trade and its effects on global economy, inhibiting the development of AM (BERMAN, 2012; CAMPBELL *et al.*, 2011; CANN, 2016; JIANG *et al.*, 2017; JOHNSTON *et al.*, 2018; LEERING, 2017).

7. POTENTIAL CRIME PREVENTERS AND PROMOTERS

Crime is a complex phenomenon that requires a multilateral effort to be prevented. State, citizens and stakeholders should be involved in decision-making processes aimed at controlling crime. Identifying the potential crime preventers and promoters regarding the use of AM is important to identify who owns the responsibility to set situational crime prevention strategies (CLARKE, 1983; 1995; SCOTT, 2005).

7.1 PREVENTERS

- Industry and business: Protect their files and devices against cyberattack.
- Designers and engineers: Safe proof their products' design so it cannot be used for criminal purposes.
- 3D printer manufactures: Only produce printers with 'fingerprints'. This will help to identify the machine that produced the 3D printed object (NEALON, 2018).
- Place managers: With 3D printers accessible in the local commerce, they should be responsible to prohibit printing of illegal items.
- International organisations and government agencies: United Nations, International Labour Organisation, World Trade Organisation, Ministry of Labour, Ministry of Science, and Ministry of Economy should be responsible for tracking the evolution of AM technology and its implications in job losses and for global trade.

Figure 2: The relation between preventers and the situational crime prevention outcomes of their actions

Preventers	Increase the effort	Increase the risk	Reduce the rewards	Reduce provocations	Remove excuses
Industry and business	✓	✓	✓	⛔	✓
Designers and engineers	✓	✓	✓	⛔	⛔
3D printer manufacturers	✓	✓	✓	⛔	⛔
Place managers	✓	✓	✓	⛔	✓
International organisations and government agencies	⛔	⛔	⛔	✓	✓
Law makers	✓	✓	⛔	⛔	✓
Policing	✓	✓	⛔	⛔	⛔

Source: Author

- Law makers: The Congress and international organisations with power to create international laws should regulate the use and access to some types of 3D printers and raw materials.
- Policing: Police forces and forensics departments should be aware of 3D printing's crime implications and how to identify the future threats it will impose.

7.2 PROMOTERS

- Hackers: Will be able to cyberattack files and devices to interfere in the AM process for many reasons, as such industrial espionage, sabotage, terrorist attack. Their motivation can be political, religious, economic, etc.
- Terrorist groups: May have access to weapons and explosives that otherwise they would not.
- Lone wolves: Will be able to produce their own weapons.
- Fraudsters: AM will facilitate and enable news ways to create counterfeit products.
- Industries, universities, researchers, designers: When developing new 3D printing processes and new material applications they can, either purposely or inadvertently, be contributing to new ways of committing crimes.

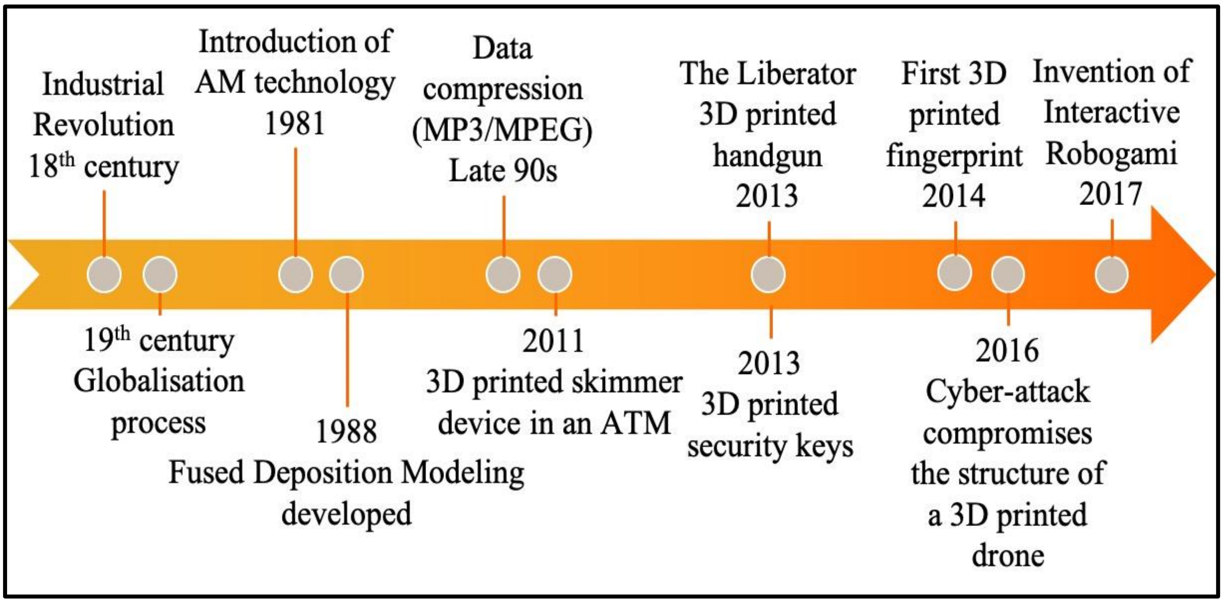
8. PARALLELS AND PRECEDENTS

- The Industrial Revolution that started in the late 18th century created industrial and urban centres, disrupted craftsman activities and the manufacture at home, developing the mass production. AM promises to produce locally, even homely, enabling the mass customisation (BERMAN, 2012; CANN, 2016; COTTELEER, 2014; KALDOR, 1977; LEERING, 2017).
- The globalisation process that took place in the early 19th century imposed a new world economic order in which items are produced globally and the trade of raw material and goods between nations is an important aspect of global relations. 3D printing is a threat to global trade (CANN, 2016; LEERING, 2017; O'ROURKE & WILLIAMSON, 2020).
- The introduction of AM technology happened in 1981 and the development of Fused Deposition Modelling (FDM) happened in 1988. In 2013 the world's first 3D printed weapon known as 'The Liberator' was printed by Cody Wilson using ABS (Acrylonitrile Butadiene Styrene) plastic (CHASE & LAPORTE, 2018; IRVING, 2018; MCGUIRE *et al.*, 2016; NEELY, 2016; SCHOLES, 2015; TIRONE & GILLEY, 2015; WALTHER, 2015).
- The development of data compression technologies for audio and video like MP3 and MPGE in the late 90s enabled mass illegal file sharing of music and video that threatened author rights and intellectual property laws (KURFESS & CASS, 2014; NEELY, 2016; OBERHOLZER-GEE & STRUMPF, 2010; SCHOLES, 2015).
- In 2011 realistic 3D printed skimmer device was found in an ATM in California - Unites States. This kind of device is used to get the credit card information. In 2010 3D printing company I.Materialise informed that they had received an order for a device which is inserted in an ATM machine (BIGGS, 2011; Sorrel, 2011).
- In 2013 MIT students released program to 3D print high security keys used in prisons cell locks (GREENBERG, 2013)
- In 2014 a team of researchers from the University of Michigan developed the first 3D printed fingerprint. In 2016 the Michigan Police Department 3D printed a murder victim's fingerprint and used it to unlock his mobile phone in order to get access to evidences that could help to identify the murderer (ARORA *et al.*, 2014; BRANDOM, 2016; ENGELSMA *et al.*, 2018).

- In 2016 researchers developed a full chain of cyber-attack to compromise the structure of a 3D printed drone's propeller that resulted in its physical destruction (BAYENS *et al.*, 2017; BELIKOVETSKY *et al.*, 2016; IRVING, 2018; STURM *et al.*, 2017; ZELTMANN *et al.*, 2016).

- The development of the 'Interactive Robogami' in 2017 enabled the 3D printing of small robots in minutes (SCHULZ *et al.*, 2017).

Figure 3: Timeline of parallels & precedents



Fonte: Author's own development

CONCLUSION

This study is a horizon scanning report based on the British model Sigma Scan. It addressed the potential implications of the development of 3D printing, particularly for crimes, exploring what the future of this technology might look like to help better understand its uncertainties. By exploring the general implications of 3D printing, and its possible impact upon crime, this report can be useful for a variety of stakeholders to analyse whether they are adequately prepared for the potential opportunities and threats presented, helping to ensure that strategies and policies are resilient to different future environments

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RELATO DE EXPERIÊNCIA

IMPRESSÃO 3D E NOVAS AMEAÇAS À SEGURANÇA

RESUMO: O presente estudo é uma análise de horizonte baseada no modelo britânico *Sigma Scan*. Ele explora possíveis questões e tendências futuras da impressão 3D e seu impacto potencial na sociedade, principalmente quanto às novas ameaças à segurança que sua disseminação deve provocar. Este exercício permite o exame baseado nas melhores previsões de como o futuro dessa tecnologia disruptiva e, ao mesmo tempo, capacitadora provavelmente será, visando compreender melhor as incertezas que o seu desenvolvimento trará. Neste relatório são abordadas as potenciais implicações do desenvolvimento da impressão 3D, em especial para a prática de crimes, os prováveis indicadores precoces de desenvolvimento dessa tecnologia, os desdobramentos simultâneos que podem servir de inibidores e de impulsionadores, os potenciais atores da prevenção e da promoção criminal, e as evidências que indicam a possibilidade dos acontecimentos previstos.

Palavras-chaves: Impressão 3D. Fabricação aditiva. Tecnologia disruptiva. Tecnologia capacitadora. Riscos à segurança.