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3D PRINTING: SOLVING SUSTAINMENT CHALLENGES IN THE CANADIAN ARMY

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AIM

1. The aim of this service paper is to analyze the benefits and limitations of 3D printing for use in the Canadian Army (CA) to alleviate immediate maintenance and resupply needs at the tactical level and in austere locations. Additive Manufacturing (AM) is a process that consists of manufacturing a required three-dimensional object by layers using a digital plan or design. The process requires a printing machine, computer-aided design (CAD) files for the required object, and the material needed to create the specific object. The term '3D printing' refers to the act of printing the objects, whereas Additive Manufacturing refers to a larger manufacturing process.[1] This paper will examine the various scenarios in the CA where 3D printing could play a vital role in tactical sustainment, look at how the benefits and challenges might influence where the CA could best employ 3D printing and make recommendations to alleviate supply chain challenges during deployed operations.

INTRODUCTION

2. In Canada's Defence Policy: *Strong, Secure, Engaged,* much of the future of CA involves adapting and evolving capabilities to ensure "maintaining the proper mix of combat capabilities, the ability to operate jointly with the rest of the Canadian military and in concert with key allies and partners".[2] *Strong, Secure, Engaged* highlights communication, C2, intelligence, surveillance, mobility, firepower and sustainment as the keys to ensuring the CA remains agile and adaptable to the "changing security environment".[3] Arguably, the SUSTAIN function is one of the most important army functions related to meeting this intent, and having a tactical ability to manufacture parts needed for maintenance or repair 'on-the-spot' can assist in relieving some of the supply chain challenges front line troops often face.

3. 3D printing traces its roots back to the 1980's, when the earliest versions of 3D printers called 'stereo-lithography machines' melted plastic into shapes[4]. An extremely expensive process, the concept of 3D printing evolved slowly over the years, until in 2005, an open source desktop version of earlier printers was introduced at a price-point which would allow consumers to own their own printers[5]. Once 3D printers were available to the public, and the open source project allowed designers to develop improvements, the AM and 3D printing technology began to advance much quicker.

4. Despite recent advancements, AM and 3D printing remains in its early stages of infancy. High-end 3D printers are not yet affordable to the general public, and machines are limited to the specific type of building materials required. In Canada, 3D printers are being used by the Federal

[1] Peter Zelinski, "Additive Manufacturing and 3D Printing Are Two Different Things," *Additive Manufacturing,* 2017, 6.

[2] Dept. of National Defence, *Strong, Secure, Engaged: Canada's Defence Policy.* Ottawa, Ont.: National Defence, 2017, 36.

[3] Ibid, 36.

[4] Elizabeth Matias and Bharat Rao, "3D Printing: On its Historical Evolution and the Implications for Business." Portland International Conference on Management, 2015, 551.

[5] Ibid, 551.

Government for basic projects. In January of this year the Royal Canadian Mounted Police in British Columbia issued a tender for one printer to recreate models of vehicle accidents for use in courts of law,[6] and since 2015 the CA at Canadian Forces Base Gagetown has been using 3D printers to create models for training and tactical planning.[7] As early as 2007, the Royal Military College of Canada has been using 3D printers in its Engineering programs to bring students' designs to life.[8]

DISCUSSION

5. 3D printing in the CA has practical applications at the tactical level. The ability to produce required parts and supplies immediately and on-site can ease complex lines of communication in the battlefield; on peace support operations; or in remote areas. This capability will allow the CA to maintain a high level of readiness and effectiveness without having to rely solely on the supply chain and without having to contract supplies locally. It is important however, to stress that 3D printing capability should be integrated into the sustainment plan for CA operations, not replace it.

Maintenance

6. Vehicle maintenance is among the most important sustainment responsibilities for the CA at the tactical level: without mobility, the army cannot function. Domestic or Expeditionary first or second line maintenance could benefit from the application of 3D printing in that it could allow technicians to print missing or needed parts for multiple different vehicles with different requirements, ensuring they are returned to service quickly.[9] Some vehicles or equipment also have obsolete parts that are no longer available through the supply chain. Having the ability to recreate these parts can result in extended life for the CA's transportation fleet.

Parts and Supplies

7. When it comes to supply stock in deployed or austere locations, the possibilities are endless. Uniform parts, protective plates and clothing, camouflage, weapon accessories, buckles and fasteners are just a few of the options for 3D printing in the front lines. In deployed situations, the ability to print small replacement items in theatre has the potential to make room within a costly and complex supply network for other required stores.

8. Another consideration for the application of 3D printing especially in conflict zones is the possibility to use 3D printing capability for ammunition. The ability to create bullets on-site

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[6] Maura Forrest, "'A Natural Step': RCMP Looks to 3D Printing as Part of New Wave of Crime-Solving Technology." *National Post (Online)*, 2018.

[7] Margot Macpherson Brewer, "Make me a tank: 3D printing and computer animation leading the way in training the future Canadian Army." *Canadian Armed Forces (Online)*, 2015.

[8] Lt (N) Stephane Lachance, "Royal Military College engages its future engineers with 3D printer." *e-Veritas (Online)*, 2010.

[9] Sean R. Walsh, "3D printing: Enhancing Expeditionary Logistics" *Marine Corps Gazette*, 2015, 68.

delivers the potential to replenish ammunition in location, but also allows for customization and innovation[10]

Medical

9. The use of 3D printing for medical applications in a Canadian Armed Forces (CAF) Role 1 or Role 2 facility yields promise for the future. The ability to print specialty medical equipment or parts to keep a field hospital running smoothly means increased capability for the hospital and faster recovery for wounded soldiers. Alternatively, the ability to print skin tissue or even organs is quickly gaining the attention of many in the medical industry, including within the Canadian Armed Forces.[11]

Structures

10. Lastly, one of the most recent applications of 3D printing being tested is much larger than front line parts or supplies. Christopher Bayley and Michael Kopac suggest that AM is "equally capable of constructing infrastructure, including the building of base camps, and humanitarian efforts, or enclosing contaminated areas with limited exposure to personnel."[12] They suggest that the cost to construct a shelter using 3D printing technology is equivalent to the costs to build shelters using manual labour and traditional materials and they argue that the 3D option could be a stronger option with a longer life.[13]

11. In August of this year, a team at the Marine Corps Systems Command and I Marine Expeditionary Force used a 3D printer to build a concrete shelter. The construction took less than 40 hours. Project officer Captain Matthew Friedell notes that a structure hadn't been built continuously using a 3D printer before, and that the ability to construct shelters while freeing service members to focus on other tasks is the ultimate goal.[14]

Benefits

12. There are a number of obvious benefits to integrating 3D printing capabilities to the front lines of CA missions. Those include reduction of storage requirements; supply chain savings; reduced turnaround time; customization; innovation; and less environmental impact.

a. <u>Reduction of storage requirements and supply chain savings.</u> Having the ability to 'print' items as they are needed means that storage space is freed up by not needing to store items that can be printed on-demand as required. As well, reducing the requirement

[10] Tabitha Jean Naylor, "5 Ways U.S. Army Uses 3D Printing." *Benzinga Newswires*, 2014, 1.

[11] Christopher Bayley and Michael Kopac. "The Implications of Additive Manufacturing on Canadian Armed Forces Operational Functions." *Canadian Military Journal*, 2018, 49.

[12] Ibid, 48.

[13] Ibid, 49.

[14] Kaitlin Kelly, "MCSC Teams with Marines to Build World's First Continuous 3D-Printed Concrete Barracks." *U.S. Department of Defense Information*, 2018.

for storage reduces the transportation expenses related to resupplying these parts that are no longer required.[15]

b. Reduced turn-around time. Especially with regards to vehicles and equipment, reducing the amount of time it takes to get a piece of equipment back up and running. In their *Canadian Military Journal* article, Christopher Bayley and Michael Kopac note that the "use of AM to either shorten or simplify the logistics tail is one of the most prevalent applications for AM. This is particularly pertinent for ageing platforms in which there is no longer the availability of Original Equipment Manufactured parts"[16]

c. Innovation and customization. Given the endless possibilities regarding design and 3D printing, innovative soldiers have the potential to push the boundaries of innovation in the field. Soldiers can come up with their own designs or make slight changes to existing designs that may improve the CA's effectiveness in the field.

d. Environmental Impact. When discussing AM deployment in remote or austere environments, Meisel et al note that some material required for 3D printing such as plastic or metal powder is recyclable.[17] This means that printing parts on location can produce much less waste than through traditional manufacturing processes.

Challenges

13. Despite the obvious benefits to using 3D printing in a military construct, there remain challenges to successful integration of printing capabilities to the front lines of the CA. These challenges include high start-up costs; lack of technical expertise and experience; intellectual property rights; printer operating and storage requirements; and supply chain challenges.

a. Initial printer start-up costs. Depending on the 'print' capacity and the needed building material, a single AM machine can range between $10,000 and $1,000,000 USD.[18] These costs along with the expenses to ensure operators are trained and qualified on the equipment can be quite high at the beginning; however the savings over the long run could outweigh the start-up costs.

b. Technical expertise and experience. 3D printing is not a plug-and-play process. The ability to manipulate designs, operate and repair the machinery and execute the printing process requires intensive technical training. The CA would have to ensure that soldiers operating the equipment in remote locations have the expertise and experience to ensure no disruption to the supply chain.

c. Intellectual Property Rights. Intellectual property rights might arguably be the most challenging aspect of 3D printing. Aside from the concern over CA proprietary or classified parts, many of the CA's supplies and parts come from specific manufacturers

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[15] Nicholas Meisel, Christopher B. Williams, Kimberly P. Ellis, and Don Taylor. "Decision Support for Additive Manufacturing Deployment in Remote or Austere Environments." *Journal of Manufacturing Technology Management* 27, 2016, 899.

[16] Bayley and Kopac, "Implications of Additive Manufacturing", 48.

[17] Meisel et al, "Decision Support for additive manufacturing deployment", 906.

[18] Ibid, 904.

under legal contracts to provide these parts. In order to print these parts in the front lines, manufacturers would be required to share their designs and allow the CA to print them. This presents challenges to the manufacturers who would no longer profit the same from an agreed-upon service. In his *Marine Corps Gazette* article, Major Sean Walsh suggests that the United States Department of Defense should "enter into legal arrangements with commercial manufacturers to "pay per download" of each part."[19] This option would ensure that the contracts with the CA are upheld, and that the manufacturers can still profit from their designs that are being printed in location. This would also ensure that the designs for the parts being printed would be legitimate designs, and not copies or fakes.

d. Printer operating and storage environment. Although 3D printing has many applications in a deployed environment, there are power and environmental factors that could severely affect a CA team from realizing the full benefits of this technology. Many 3D printers need "230/240V AC 3-phase power"[20] 3D printers also benefit from a constant temperature, balanced by heating and air conditioning systems which can sometimes be complicated to ensure[21]. The storage requirements also depend on the type of material being used: temperature and humidity levels must be carefully controlled for some types of raw material.[22] Finally, some printing materials such as concrete need large amounts of water to turn the dry ingredients into a solid construction.

e. Supply Chain Challenges. Despite the supply chain savings anticipated through 3D printing capabilities, there is still a supply chain challenge that can't be overlooked. According to Meisel, Williams, Ellis and Taylor, most manufacturers maintain their own "proprietary raw material"[23], meaning that the military's lines of communication can still be impacted.

CONCLUSION

14. CA personnel - especially logisticians – continually face the challenge of providing quick sustainment and maintenance on the front lines of an operation. In times of fiscal restraint, any initiatives would be welcomed that can increase turn-around time on parts and equipment and ensure vehicles are returned to service within minimal timeframes, while saving the Government of Canada money.[24]

15. This paper has examined the various applications of 3D printing for use in deployed or austere locations, and has identified how 3D printing could be used for maintenance; parts; medical supplies and structures. Some of these applications such as for parts and maintenance are achievable today at the tactical while advancements are still needed to make others affordable and feasible.

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[19] Walsh, "3D printing", 68.
[20] Meisel et al, "*Decision Support for additive manufacturing deployment*", 904.
[21] Ibid, 904.
[22] Ibid, 905.
[23] Ibid, 907.
[24] Walsh, "3D printing", 68.

16. Having the ability to print small parts and stores in the front lines for replacement and maintenance means increased storage space for other supplies; supply chain cost savings; reduced turn-around time for vehicle and equipment repairs; the ability to create new and innovative parts; the ability to customize on the spot; and environmental benefits. That said, 3D printers are expensive to acquire; they require specific training and technical expertise to operate them; there is a concern over design proprietary rights; printers and raw materials require specific storage conditions; and the raw materials required to create items using a 3D printer still need to come from somewhere.

RECOMMENDATION

17. Advances in 3D printing paints a bright future for CA sustainment. As the industry continues to test innovative developments such as skin tissue and concrete, this is just the beginning. Some companies are testing the inclusion of "stress sensors"[25] in metal creations, allowing users to know ahead of time when a metal part might deteriorate.

18. Despite these advancements, AM and 3D printing are still young technologies. As such, manufacturers of printing machines, and suppliers of materials still have not matured enough to provide a competitive and consistent market for the CA to truly capitalize. In North America, there are only a few companies that can supply the CA with a reliable service.[26] In Canada, the Quality Engineering Test Establishment (QETE) notes that even today, the Department of National Defence (DND) and the civilian market is not yet capable of integrating AM into the CAF sustainment network at the operational level.[27]

19. If the CA wishes to integrate 3D printing into its deployed capability, it is recommended to first determine what types of objects are to be built at the tactical level and procure machines and material that will meet those requirements. [28] At this time, the capability to build concrete structures, in remote locations is difficult due to machinery and raw material environmental requirements; however, there is a case to be made for smaller plastic or metal parts needed for resupply or maintenance. Having the ability to print these parts "on-demand" will result in increased savings and quicker turn-around on repairs.

[25] Xu et al 2017 "The Boom in 3D-Printed Sensor Technology, 2.

[26] Helen Rogers, Norbert Baricz, and Kulwant S. Pawar. "3D Printing Services: Classification, Supply Chain Implications and Research Agenda." *International Journal of Physical Distribution & Logistics Management,* 2016, 888.

[27] Bayley and Kopac, "Implications of Additive Manufacturing", 53.

[28] Meisel et al, *Decision Support for additive manufacturing deployment", 905.*

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