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THREE DIMENSIONAL PRINTING AND SUSTAINMENT: AN ARMY SOLUTION?

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AIM

1. The aim of this service paper is to examine the potential of three dimensional (3D) printing technologies for use by the Canadian Army (CA) in both domestic and expeditionary sustainment operations. The future of land capabilities requires a sustainment process that is flexible and responsive to user requirements. This service paper will examine whether 3D printing is a viable option to improve upon the responsiveness and flexibility of the current sustainment system.

INTRODUCTION

2. The Canadian Armed Forces (CAF) faces many challenges concerning procurement and maintenance of equipment. Long product development, testing and contracting timelines mean that new equipment can be obsolete before it ever reaches the end user. Additionally, original cost estimates are based on information available at the commencement of a project but after substantial time spent researching and managing a specific requirement the price of a project invariably increases. This leads to additional time spent gaining approvals and in some cases, such as the F35 project, delays and/or cancellations follow.

3. According to an Evaluation of Land Force Readiness and Training conducted by the Chief of Review Services in March 2011, there is a shortage of key occupations in the Maintenance Companies and “the priority for spare parts has naturally been to Afghanistan, but both the pooled training fleet of vehicles and equipment, and the

domestic fleets have had usage rates in the past four years that far exceed the original Life Cycle Materiel Management planning estimates".[1] In short, the Army's equipment is old and overused and there are not enough people employed in key jobs to maintain it. This is but one example of the challenges facing the entire sustainment system within the army as resources dwindle and equipment ages.

4. As well, recent deployments have illustrated that the resources available to sustain troops are often limited, whether related to finance, transport, personnel or materiel. The use of 3D printing technology is currently being reviewed and researched by many public and private organizations in Canada and elsewhere. The potential usefulness of 3D printing, specifically to assist in sustainment of the army, will be reviewed in this paper.

DISCUSSION

5. 3D printing technology was first invented more than 30 years ago in 1983 by Charles Hull.[2] At the time when Hull was creating this technology it was referred to as Rapid Prototyping (RP) based on its utility for producing prototypes quickly. Now referred to as additive manufacturing (AM) the technology has evolved significantly over time. Initially, the technology was used almost exclusively for prototyping but recent

[1]Department of National Defence, *Evaluation of Land Force Readiness and Training* (Ottawa: DND Canada, 2011), 36. http://www.crs-csex.forces.gc.ca/reports-rapports/2011/167P0861-eng.aspx

[2] "3D Printing History: The Free Beginner's Guide," *3D Printing Industry*, Date accessed 02 Feb. 2016. http://3dprintingindustry.com/3d-printing-basics-free-beginners-guide/history/

advances in research and development now see 3D printing being developed for printing everything from organs to automotive parts to weapons.[3]

6. The United States Navy (USN) currently uses 3D technology printing onboard the United States Ship (USS) Essex for printing a number of items including medical syringes[4] and drones[5]. The United States Army Research Laboratory recently signed a contract with a leading AM company to conduct research into "in-field manufacturing, and depot-level maintenance and repair, both of which are aimed and [sic] reducing the Army's overall logistics burden".[6] Based on these examples it would appear that the United States has recognized the importance of 3D printing and is committed to its use and development as a viable option for future sustainment operations.

Cost

7. One advantage of using AM technologies for sustainment is the relatively low cost associated with it. The type of object to be created will dictate the materials used in the printing process and thereby the price of the printer but there are numerous printers on the market that cost less than $50,000 with many costing less than $10,000.[7] These printers would be more than adequate to produce low cost or disposable items, especially

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[3] Amit Chowdhry, "What Can 3D Printing Do? Here Are 6 Creative Examples." *Forbes Magazine*, 08 Oct. 2013, Date accessed 02 Feb. 2016. http://www.forbes.com/sites/amitchowdhry/2013/10/08/what-can-3d-printing-do-here-are-6-creative-examples/#2eba522761b0

[4] Sydney J Freedberg, "Navy Warship Is Taking 3D Printer to Sea; Don't Expect A Revolution," *Breaking Defense*. Breaking Media, 22 Apr. 2014. Date accessed 02 Feb. 2016. http://breakingdefense.com/2014/04/navy-carrier-is-taking-3d-printer-to-sea-dont-expect-a-revolution/

[5] Martyn Williams, "The US Navy Is 3D-printing Custom Drones on Its Ships," *PCWorld*, 29 July 2015, Date accessed 02 Feb. 2016. http://www.pcworld.com/article/2954732/the-us-navy-is-3dprinting-custom-drones-on-its-ships.html

[6] Kira Charron, "3D Systems Partners with U.S. Army to Develop 3D Printing Lab," *3ders.org*, 30 Oct. 2015, Date accessed 04 Feb. 2016. http://www.3ders.org/articles/20151030-3d-systems-partners-with-us-army-to-develop-3d-printing-lab.html

[7] "Price Compare- 3D Printers," *3ders.org*, Date accessed 03 Feb 2016. http://www.3ders.org/pricecompare/3dprinters/

on operations where regular resupply is not always available or even possible due to high threat levels. While there would admittedly be an initial cost to purchase the printing equipment the cost savings to be achieved in terms of expedited shipping requirements or new parts could be substantial.

Time

8. Additionally, using a 3D printer domestically could reduce cost not only financially but in terms of time. The lengthy process involved in defining requirements, confirming suitability, and redefining requirements if applicable can take years depending on the complexity of the project. By using AM to build low cost prototypes rather than sending the specifications to companies to build, the risk of wasting time modifying and adjusting plans is significantly lowered. If the first prototype is flawed in some way, simply adjust the design and reprint. The control that the Department of National Defence (DND) would then have over its own projects would increase substantially, decreasing reliance on other government departments and privately owned businesses.

9. The current materiel sustainment system in place in the Canadian Army uses a system of first, second, third and fourth line facilities in order to provide and maintain equipment for the end-user. While serving at home bases or on domestic operations units request items from local or national warehouses and, depending on availability and how critical the requirement is, wait anywhere from 1-14 days to receive the item. If the part is customer off the shelf (COTS) then there are a number of factors that determine how the item is acquired, including cost and contracting restraints. It is clear that for time

sensitive repairs and requirements, waiting 14 days for an item to arrive from a warehouse thousands of kilometres away can have a serious impact on training and operations. An example of this impact can be seen during the Army high readiness confirmation exercises in Wainwright, Alberta. The exercises normally take place over 6 weeks with the primary training audience portions taking place during the middle 4 weeks. Often, if a critical part breaks or is unavailable in the first week of the main exercise that piece of equipment is non-serviceable (NS) for the remainder of the exercise. The waste of time and training opportunities is significant. If units or even support bases were equipped with AM technology the wait time could be significantly reduced and the impact on operations would be lessened.

Personnel

10. An additional benefit of 3D printing is perhaps one of the most obvious. Apart from time and cost, the use of AM technologies could prove to be a significant force multiplier on expeditionary operations. By locating a printer forward of a main operating base, units would have the capability to print parts without having to wait on the next scheduled resupply. Instead of a heavy reliance on resupply convoys, the supply technician could instead upload the specifications for the required item and then print it onsite. This would be extremely useful for those "one of" items that would not be held in a first or second line units' holdings. When operating in an asymmetric and unpredictable environment the flexibility provided by this technology is without question beneficial. A follow on advantage is the fact that fewer troops would be required on the roads in order to conduct combat logistics patrols (CLPs). During Operation ATHENA Rotation 2 in Kandahar the National Support Element (NSE) was often sending out more than 2 CLPs

daily in order to conduct routine replenishment. The number of personnel required to conduct these replenishment runs was substantial. Aside from the obvious high operational tempo for these soldiers, their lives were at risk every time they undertook a convoy. Additionally, there is a force protection element required for each convoy. Due to limited resources, this ability is not integral within the NSE and supported units simply do not have the manpower available to regularly provide escorts. Therefore, by relying on AM technology for various items at forward operating bases (FOB), the number of personnel at risk each day is diminished as is the extremely high tempo.

Arctic

11. On the domestic front, the Arctic continues to prove to be a sustainment challenge in and of itself. The limited infrastructure in the North requires logistics planning to be more flexible, more adaptable and to be done well in advance of actual requirements. With the focus on the Arctic continuing to increase it is only logical that sustainment planners begin to plan for increased deployments and activities in the region. It is here where the CA domestic sustainment process could benefit most from 3D printing.

12. Sustainment in the North is heavily reliant on the weather and when bad weather makes sustainment flights impossible or the change in seasons makes overland travel unmanageable AM technology could provide the key to ensuring the Army remains operational in the region. Printing an urgently needed part or simply reducing the amount of supplies actually transported would save substantial resources. Additionally, as AM technology improves medical sustainment will also have the capacity to improve in a vast area that lacks advanced medical facilities as seen in the rest of Canada.

Training

13. Obviously there will be a training requirement in order to properly use this technology to its full capability. However, a quick internet search indicates that there are a number of companies that offer both courses and certification with the option to take the course and exam online or in person. As the technology advances additional courses can be taken to upgrade the member's knowledge and qualifications. Depending on the complexities of the machine and the item to be created, the training bill to utilize this technology appears to be relatively small when compared to the potential benefits.

Current Use

14. There are some Canadian military organizations that have already incorporated the use of AM technology into their day to day operations. The Royal Canadian Navy (RCN) in consult with the National Research Council (NRC) has begun using it to manufacture obsolete parts, exactly how it could be used by the CA maintenance program. At the Fleet Maintenance Facility (FMF) Cape Scott in Halifax they have the "first laser additive manufacturing system in a production facility in Canada"[8]. Most recently the team there used alloy steel to repair a part on the ship that is usually made of carbon steel. This will "increase its corrosion resistance and wear resistance, giving the part longer service life".[9] The fact that the RCN has actively pursued and instituted the use of this technology should act as a stimulus for the CA to so the same. The NRC, in a presentation made available online, lists a number of potential impacts to the capabilities of the Canadian military including the ability to make parts onsite, reducing and/or

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[8] "3D Printing Transforms the RCN", *The Maple Leaf*, January 2016, Volume 19, number 1.
[9] Ibid.

replacing physical inventories with digital inventories, and enabling a "revolutionized design approach to fabricate parts that would not be feasible through conventional manufacturing".[10] Seeing the success story of FMF Cape Scott and learning from its experience could enable a swift institution of AM technology for the CA should it desire to do so.

15. It is not only the RCN who has taken this technology onboard. The Royal Military College of Canada (RMCC) has a 3D printer in its engineering department[11] so that students can design and produce ship's hull prototypes and desk organizers. While not focused on sustainment issues, the carryover of the knowledge and technology would be simple. And finally, the Army itself has begun to use 3D printing at the Army Learning Support Centre in Gagetown. However, its use there is restricted to the production of small replicas of vehicles and firearms to be used as part of cloth model exercises.[12]

CONCLUSION

16. Without question, the use of technology to assist in training the future leaders of the Army is important business but using 3D printing to make replicas of buildings and vehicles cannot be the most valuable use of this exciting technology. The benefits that AM technology could bring to the CA's sustainment dilemmas are too numerous to ignore. Given the increasing diversity of operational theatres and the requirement to

[10] Lijue Xue, "Laser Consolidation and Additive Manufacturing Technologies for Military Applications", *National Research Council Canada*, 24 October 2014, Date accessed, 03 Feb 2016.

[11] "Royal Military College- Canadian Military College Engages Its Future Engineers with 3D Printer," *Aerospace Engineering Program Builds Aircraft Models*, Aug. 2013, Date accessed, 02 Feb 2016. http://www.stratasys.com/resources/case-studies/education/royal-military-college

[12] Margaret MacPherson Brewer, "Make Me a Tank: 3D Printing and Computer Animation Leading the Way in Training the Future Canadian Army." *Army News*. Government of Canada, 06 July 2015. Date accessed 04 Feb 2016. http://www.army-armee.forces.gc.ca/en/news-publications/national-news-details-no-menu.page?doc=make-me-a-tank-3d-printing-and-computer-animation-leading-the-way-in-training-the-future-canadian-army%2Fib6au7mx

operate in harsh environments, enabling Army sustainers with additional tools to conduct accurate sustainment planning would be an insightful decision with significant impact. The time saved in project management, the ability to manufacture obsolete parts for equipment used long past lifecycle estimates, the lives saved by reducing traffic on high risk routes; all of these examples serve to illustrate the usefulness of 3D printing for sustainment planners. Why then is the RCN the only service in the Canadian military to institute its use for that purpose? With the recent speculation in the media that the military will soon be entering another "decade of darkness"[13] it is critical that army sustainers focus again on the principles of sustainment, principles like flexibility, economy and most of all, foresight. While other militaries and even our own RCN are focused on overcoming the challenges of sustainment in the future the CA lags behind and needs to begin examining and trialing this technology in earnest.

RECOMMENDATIONS

17. Based on the information presented during this service paper, the following are recommendations concerning the implementation and use of 3D printing for sustainment in the CA.

a) Certain detailed information such as serviceability rates and resource shortages was not readily available to the author of this service paper which would have assisted the reader in making a fully informed decision concerning the use of 3D printing within the CA sustainment system. As such, a working group (WG) should be established or additional research conducted in order to provide more

[13]Evan Solomon, "Why Canada's Military Risks Returning to a Decade of Darkness," *Macleans.ca*, Rogers Digital Media, 03 Feb. 2016. http://www.macleans.ca/politics/ottawa/why-canadas-military-risks-returning-to-a-decade-of-darkness/

fidelity on specific requirements and a detailed cost benefit analysis of 3D printing and sustainment. The WG should also examine how other militaries are using AM technology and sustainment.

b) The Army G4 should look closely at how the RCN and the NRC worked together in order to bring 3D printing to FMF Cape Scott. By reviewing the process that was undertaken by the RCN, the CA may be able to institute a similar plan at select bases across the country.

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