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UNTAPPED POTENTIAL: HOW THE USE OF ADDITIVE MANUFACTURING COULD DRAMATICALLY IMPROVE THE CAF MILITARY DEPLOYMENT SUPPLY CHAIN

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AIM

1. The aim of this service paper is to examine how the Canadian Armed Forces (CAF) could be impacted by the implementation of additive manufacturing (AM). It will specifically explore how this technology could be used to positively influence the current CAF joint supply chain, and supply chain management in general. It will also suggest how AM can reduce shortfalls and reduce operational stockpiling requirements along with providing some recommendations on how the CAF could manage this technology.

INTRODUCTION

2. The CAF relies on a traditional supply chain to move its kit and equipment between bases across the country and around the world. At its most simplistic, this method of goods distribution involves warehousing goods, transporting goods, and an information technology (IT) system that provides asset visibility of goods. The CAF supply chain is limited by the distance from its warehouses to its final destinations (domestically and internationally), the amount of transportation available to move goods to their destinations, and the IT systems the CAF uses to track the location of these goods. The realities of Canada's vast geography, the diverse locations of its military bases and deployment locations, as well as the limitations of the transportation assets available, suggest that an alternate method of sourcing required goods could dramatically improve the efficiency of the supply chain.

3. AM as a goods production method has found early adopters in multiple industries, including aerospace, automotive, electronics, and medical.[1] AM can be defined as "the process of joining materials to make objects from three-dimensional (3D) models layer by layer as opposed to subtractive methods that remove material."[2] It has a variety of synonyms, including "3D printing, additive fabrication, additive process, additive techniques, additive layer manufacturing, layer manufacturing, and freeform fabrication."[3] This paper will explore how AM could affect the joint supply chain and supply chain management. It will propose that significant gains in efficiency could be achieved within all levels of the CAF through increased use of AM. It will also articulate a number of ways to effectively manage this technology. It will conclude by providing a variety of recommendations that would allow the positive impacts of AM to be implemented across the CAF.

DISCUSSION

How will AM technology affect the joint supply chain and supply chain management?

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[1] Thomas, Douglas, "Costs, benefits, and adoption of additive manufacturing: a supply chain perspective", *International Journal of Advanced Manufacturing Technology*, (July 2016): 1858.
[2] Ibid, 1857.
[3] Calignano, Flaviana, et al. "Overview on Additive Manufacturing Technologies." Proceedings of the IEEE, (April 2017), 593.

4. To explore how Additive Manufacturing could affect the joint supply chain and supply chain management, it is important to consider how advancements in AM might impact supply chains in general, and then focus on its effects on the CAF specifically. Additive manufacturing is a technique that many industries are considering implementing to address the problem of spare parts required in multiple locations simultaneously without redundant stockpiling.[4] It is also being used in the production of complex parts that cannot easily be created by traditional manufacturing techniques.[5] AM has likewise demonstrably reduced the number of pieces that need to be created in multiple industries.[6] While the technology has not yet advanced to have a significant impact on the global supply chain, its potential to revolutionize the industry is widely acknowledged.[7]

5. The aerospace industry is a prime example of how AM could be implemented to reduce redundant stockpiling; "It is estimated that there is about $200,000 in spare parts in stock for every aircraft flying today."[8] In order to reduce the requirement for warehousing, the aerospace industry is looking at the development of AM centres that could produce parts to order, rather than simply warehousing required parts. These centres would be conveniently located close to aircraft repair centres, and would create far less of a footprint than traditional warehousing. Many leading experts in the aerospace industry believe that rather than centralized mass production plants, with warehouses close to aircraft repair centres, the future lies in locally or regionally produced parts.[9] One of the drawbacks of this technology is the speed with which the parts are printed; however, the time for production (2-3 hours for simple parts, considerably longer for more complicated pieces) will decrease as the technology improves. As more companies adopt this technique, the higher the priority becomes for faster and more cost effective technology; in 2018, cost reduction was rated the top priority trend, with printing speed ranked fourth.[10]

6. This reduction in the requirement for warehousing along with the shortening of supply lines could positively affect the way the CAF provides spare parts across the globe. With AM capabilities available on bases, ships, and in deployed settings, parts could be produced on demand and reduce not only warehousing requirements, but also transportation time. The Royal Canadian Navy (RCN) has begun using low cost plastic 3D printers to replace antiquated parts that are no longer available in the system.[11] Currently the practise is only in use for non-essential parts; however, if this technology were implemented at a higher level, with the creation of a

[4] Mohr, Sebastian and Khan, Omera, "3D Printing and Its Disruptive Impacts on Supply Chains of the Future", *Technology Innovation Management Review*, (November 2015), 22, http://timreview.ca/article/942; Calignano, Flaviana, et al. "Overview on Additive Manufacturing …, 594.
[5] Thomas, Douglas, "Costs, benefits, and adoption …, 1872.
[6] Wagner, S.M. & Walton, R.O., "Additive manufacturing's impact and future in the aviation industry", *Production Planning & Control*, (June 2016), 1125, http://dx.doi.org/10.1080/09537287.2016.1199824.
[7] Thomas, Douglas, "Costs, benefits, and adoption …, 1858; Chen, Zhen, "Research on the Impact of 3D Printing on the International Supply Chain", *Advances in Materials Science and Engineering*, (April 2016), 2, http://dx.doi.org/10.1155/2016/4173873; Wagner, S.M. & Walton, R.O., "Additive manufacturing's …, 1128.
[8] Wagner, S.M. & Walton, R.O., "Additive manufacturing's …, 1126.
[9] Ibid, 1128.
[10] Sculpteo, *The state of 3D printing.* Business Report, (San Francisco: 2018), 16, https://www.sculpteo.com/media/ebook/State_of_3DP_2018.pdf
[11] Anecdotal example mentioned during JCSP 45 Syndicate 10 discussion on the Maritime Functions and Capabilities, 28 Sep 2018

database for spare parts across all elements, the reliance on frequently-tasked transportation assets to deliver these items could decrease. If AM was deployed to an operational hub, with the ability to produce a variety of commonly required parts, there would be reduced requirement to rely on stockpiling, sustainment flights, or local purchase orders (LPO). The technology to deploy AM with a small footprint could even be used during a Theatre Activation (TA) or Disaster Assistance Relief Team (DART) deployment to produce unexpected but high priority requirements. Portable, desktop sized technology exists that could be used to manufacture required goods using engineering grade polymer, with only a small generator and computer required to run it, which would be ideal for deployed environments.[12]

7. An illustration on how complex parts could be created with AM has been demonstrated in the field of satellite development. In an industry where reduced weight and increased durability is critical, AM has already been used to produce parts that are challenging to create through traditional manufacturing methods. In the development of the Eurostar E3000 (a telecommunications satellite), Airbus Defence and Space was able to reduce the weight of a structural bracket by 35% and increase the stiffness by 40%, by using laser melting AM.[13] There are also multiple cases of AM being used to produce unique parts through the use of a computer assisted design (CAD) system. By combining 3D scanning technology with a CAD system, AM has managed to replicate objects without the necessity of manufacturing from scratch, as used in traditional methods.[14]

8. AM's ability to create unique and complex parts is relevant to the CAF in that it provides a solution to the frequent problem of parts replacement of older equipment. Many platforms across the CAF use older technology that has undergone life extension, whose initial producer may no longer have the required spares, or may even be out of business. The replication of older parts with traditional subtractive manufacturing can be extremely expensive or even impossible, while the replication of such a part with AM is both possible and practical.[15] It allows for customization and the flexibility to produce parts no longer available elsewhere.

9. In addition to the creation of unique parts, there exist many instances where the use of AM has reduced the overall number of parts required for multiple industries. A decrease in the number of parts and the requirement to assemble those parts could lead to a reduction in complexity, and part acquisition time. The bracket created by Airbus Defence and Space mentioned in paragraph seven once consisted of four parts and 44 rivets, but with the use of AM that same bracket was created in a single piece.[16] GE Aviation's AM branch was able to reduce the parts requirements for the production of fuel nozzles for jet engines from 20 separately cast parts to one, cutting the manufacturing cost by 75%.[17] As more companies adopt the cost savings and practicality of AM, market saturation in products and platforms using AM is highly likely.

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[12] Tatham, Peter, Jennifer Loy, and Umberto Peretti. "3D Printing (3DP): A humanitarian logistic game changer?" 12th ANZAM OM/SC Conference . (Auckland: Griffith University, 2014), 1-10.
[13] Calignano, Flaviana, et al. "Overview on Additive Manufacturing …, 606.
[14] Thomas, Douglas, "Costs, benefits, and adoption …, 1858.
[15] Ibid.
[16] Thomas, Douglas, "Costs, benefits, and adoption …, 1858.
[17] Wagner, S.M. & Walton, R.O., "Additive manufacturing's …, 1125.

10. With multiple industries taking advantage of this technology, it is increasingly likely that platforms procured by the CAF in the future will be built using AM technology. This opens up opportunities to benefit from the flexibility that AM offers, by including the concept of AM spare parts in future CAF planning. When procuring an aircraft, rather than simply acquiring the standard In-Service Support (ISS), with a set timeframe to deliver parts, the CAF could instead include the rights to the CAD specifications for any AM parts, and produce those internally. If only for deployed missions, when the timelines for ISS are generally longer, the inclusion of AM capability to provide critical spares would be incredibly advantageous.

How and at what level can this technology be leveraged to reduce reach-back and stockholding requirements in theater?

11. Additive manufacturing is not technology that can simply be purchased and then used at the tactical level with the expectation that the benefits will be strategic. While the RCN is currently using this technology at the tactical level, it has only resulted in small convenience fixes, with limited implications in the broader CAF context. For bases and deployed hubs to be able to use AM effectively at all levels, equipment, training, and costly raw materials would be required. The coordination of those elements would necessitate implementation authority and sourcing at the strategic level. To provide the AM baseline from which the CAF could build on, high level direction would be needed to produce far reaching and lasting effects. In this way, reach back and stockholding requirements in theatre could be reduced.

12. A variety of system wide changes would be required to implement an AM spare parts network. A database with common parts across all elements, or access to such a database of CADs from the Defence Wide Area Network (DWAN), would be necessary. Common AM equipment would be required across the forces to include AM equipment on bases, as well as smaller-scale deployable kit that could be used on operations, limiting the requirement for reach back and deployed stockpiling. There would be a heavy training requirement to ensure that personnel tasked with the creation of these AM parts would be well–versed in the techniques, and have a working knowledge of the customization potential of the equipment. Sourcing raw materials for AM equipment would also be necessary, and given that the material would be specialized, sufficient quantities would need to be available for AM equipment domestically as well as on deployment.

13. With the implementation of an equipment procurement program, the securing of a raw material source, and the development of a training program, the CAF could use AM both domestically and internationally. This would broaden the level of its use from solely at the tactical to all levels across the CAF; it would reduce the requirement for forces deployed globally to reach back to Canada for high priority requests, to stockpile in location, or to rely heavily on LPOs.

How should this technology be managed?

14. AM technology would need to be implemented and managed from the highest level. If AM was implemented across the CAF, with AM centres on bases along with deployed AM nodes, standardization across all locations would be essential. A unified standard to ensure

quality production, a common method of stocktaking for these created parts, and a strategy to account for the legalities involved in multiple copies of intellectual property (IP) being manufactured, would be necessary.

15. Standardization across different AM locations would be essential to ensure the quality of parts was kept to a high standard throughout the CAF, particularly with respect to aircraft parts. The requirement for testing in line with manufacturer specifications would also be necessary to ensure safety standards were met, and any defects associated with manufacturer error were tracked. Certain AM technologies have limitations in durability or strength (plastics versus metallics), so conformity of AM parts for higher safety standard equipment, such as aircraft parts, would need to be tracked closely. Other lower risk parts could be produced with an acknowledged shorter lifespan, and replaced more frequently. Industries already using AM have experimented with different techniques to ensure high quality standard, so any CAF implementation would need to determine which techniques would word best for the parts required.

16. In addition to tracking parts for quality standards, the requirement to track for stock purposes would also be necessary. While the reduction of parts requiring warehousing would also mean a reduction in NATO Stock Numbers (NSNs) needing to be tracked in the Defence Resource Management Information System (DRMIS), a tracking system for created parts could not be avoided. As parts would be created for specific platforms, the process could be simplified – the manufactured part would be linked with the platform it was created for, rather than being a free-agent part tracked for stocktaking purposes alone.

17. Tracking would also be required to remain in line with the legalities associated with IPs. While there would likely be a variety of AM parts that could be created at will without dealing with IP laws, such as parts no longer in stock elsewhere, there would likely be many that would require careful managing. For parts already created by AM by the manufacturer, the CAD could be included as part of the ISS of any new platform. If the company was unwilling to allow the CAF to have the design for use domestically, the option to secure the right to create the AM part while on deployment could be an acceptable secondary course of action.

CONCLUSION

18. This paper’s aim was to examine the effect of additive manufacturing technology implementation within the CAF. The manifold ways AM could benefit the CAF makes early implementation of this technology exceptionally beneficial. With the rapid development of this technology, the use of AM at all levels of the CAF has the potential to improve the parts delivery timeframe, reduce stockpiling and warehousing requirements, and improve deployment flexibility across the globe. AM has already been embraced by many industries with which the CAF does business, it seems clear the CAF could benefit were it to do the same.

RECOMMENDATIONS

19. In order to benefit from the advances in additive manufacturing technology, the CAF would need to implement a variety of measures, including the following:

a. Implementation. In order to ensure maximum benefit from the use of AM, top down implementation would be essential. CDS level authority would be necessary to start the process; otherwise the funding and buy-in at lower levels would be less widespread.

b. Appropriate AM Equipment. The appropriate technology to suit current and future CAF requirements would be essential. The multitude of different options would have to be explored, and standardization across bases and deployed locations would be required to reduce the possibility of error and wastage.

c. AM Database. A database that included CAD information on all useful products and spare parts would be essential; it would need to be accessible across the CAF. In addition, any local innovations would need to be added that would benefit other locations.

d. AM Innovation and Technology Tracking. The AM field remains a new one, with developments and innovations occurring frequently on a yearly basis. A centralized organization would be necessary to disseminate new updates and techniques to all CAF AM centres domestically and internationally.

e. AM Training. Training to ensure there were sufficient people across the CAF to use this technology would be essential as well – without the skills to create complicated and technical parts, the equipment could not be used safely.

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