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ADDITIVE MANUFACTURING: A CASE FOR SUPPLY CHAIN INTEGRATION AND ENHANCING NAVAL LOGISTICS READINESS

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ADDITIVE MANUFACTURING: A CASE FOR SUPPLY CHAIN INTEGRATION AND ENHANCING NAVAL LOGISTICS READINESS

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AIM

1. The aim of this service paper is to discuss additive manufacturing (AM) and its potential to enhance naval logistics readiness. AM as a disruptive technology has gained in popularity throughout industry and its potential is widely recognized and used not only in the private sector, but also by modern military forces such as the United States. The Department of National Defence (DND) and the Canadian Armed Forces (DND/CAF) have already recognized that AM is valuable for operational readiness. The Royal Canadian Navy (RCN) is a prime example as it currently possesses an AM capability resident within Fleet Maintenance Facility Cape Breton (FMF CB). However, the capability's scope and use are currently limited to building, repairing or refurbishing parts for ship's fitted equipment. But most importantly, the capability is not integrated into the supply chain. As it will be demonstrated, the integration of AM into the naval supply chain needs to be examined as it carries the potential to revolutionize logistics and, therefore, enhance the RCN's overall materiel readiness now and into the future.

INTRODUCTION

2. The RCN is currently in the midst of a major recapitalization of its fleet. The Halifax-class frigates recently completed a midlife refit to modernize most of its combat systems and sensors to extend their service until 2040. In addition, the RCN will soon see the Harry DeWolf-class arctic patrol vessels enter operational service while the next generation of Canadian Surface Combatant (CSC) is being designed, built and set to join the Fleet in the next decade. Maintaining and sustaining a fleet comprised of a blend of legacy and new platforms requires a robust integrated supply chain that is both responsive and innovative. In *Leadmark 2050: Canada in a New Maritime World*, the RCN already recognized the need to innovate in the technological and naval sustainment realms.[1] In line with this endeavour, this paper will provide an overview of AM as a disruptive technology, its current use within the RCN, as well as outline areas where there is potential to substantially enhance naval logistics through supply chain integration based on readily available information in the literature.

DISCUSSION

3. The concept of disruptive technology is not new. In fact, the term was first coined by Clayton M. Christensen in 1997 in the first release of his book: *The Innovator's Dilemma: When New Technologies Cause Great Firms to Fail*. Christensen described a disruptive technology as one "bring[ing] to a market a very different value proposition than had been available previously."[2] Another key aspect of disruptive technologies is

[1] Department of National Defence, *Leadmark 2050: Canada in a New Maritime World* (Ottawa: DND Canada, 2017), 35-36.
[2] Clayton M. Christensen, *The Innovator's Dilemma: When New Technologies Cause Great Firms to Fail* (Boston: Harvard Business Review Press, 2013), xv.

that when they first emerge, they do not necessarily perform better than their mainstream equivalent. However, their potential to become a game changer on a given market or part of the industry over time is substantial and that is the characteristic that is of value to the proposition.[3] In the case at hand, AM is widely considered to fall into the category of disruptive technology. First, it must be acknowledged that it is not a new concept. The technology was first developed in the 1980s and has evolved substantially over the last three decades. The fact that disruptive technology as a concept did not exist 30 years is likely the main reason why AM did not see widespread applications or investments then. But today, the true potential applications of AM as a disruptive technology are gathering increased interest and various sectors of industry are either already using, or exploring options to, integrate AM into their business. The DND/CAF are no exception to this. For example, the Canadian Army has already identified the potential operational and tactical applications of AM.[4] In the case of the RCN, the capability is already fielded and has been in use at FMF CS for approximately seven years.[5] But what is the next bound? It is clear that the RCN has been successful in fielding the capability, which has allowed FMF CS to manufacture a variety of parts which could no longer be procured off-the-shelf. Additionally, AM has enabled the RCN to make repairs and refurbish parts thereby alleviating the requirement to requisition them from depots or the necessity to procure from the industry.[6] However, the use of AM has been primarily limited to its potential as an engineering tool with little to no consideration given to its potential to innovate from a holistic sustainment perspective.

4. Back in 2014, the literature on AM and its use within the United States Department of Defense recognized that "AM can revamp the nature of supply chains by shifting them from transporting finished physical goods to moving design data and raw materials."[7] It essentially equates to a transition from physical warehouses to digital ones. In the case at hand, the intent is not to argue for a complete transition, but rather to highlight the tangible benefits of integrating AM into the RCN supply chain as a force multiplier. Currently, the RCN's use of AM consists in manufacturing parts which already exist in its inventory, but may not be physically available due to high demand or the absence of viable suppliers on the market. If the part has been manufactured in the past, it means that all the specifications and design data are already available. The information is simply not integrated into the greater supply chain records. Data integration is a key attribute of effective and efficient supply chains and the DND/CAF have invested efforts and resources over the past decade to reach a greater level of integration as it pertains to financial, supply chain and engineering management. As the RCN continues to use and evolve its AM capability, there will be an increasing requirement to look at integrating the capability within the supply chain. This is of

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[3] *Ibid*.
[4] Christopher Bayley, and Michael Kopac. "The Implications of Additive Manufacturing on Canadian Armed Forces Operational Functions." *Canadian Military Journal*, vol. 18, no. 3 (Summer 2018): 48.
[5] "3D Printing Transforms the RCN," Navy News Video, 4:14. Posted by the Royal Canadian Navy, 26 February 2016, http://www.navy- marine.forces.gc.ca/en/news-operations/news-view.page?doc=3d-printing- transforms-the-rcn/il3c32xa
[6] *Ibid*.
[7] Matthew J. Louis, Jim Joyce and Tom Seymour. "3D Opportunity in the Department of Defense: Additive Manufacturing Fires Up." *Deloitte University Press* (November 2014): 4.

particular relevance today as the DND/CAF launched the Modernization and Integration of Sustainment and Logistics (MISL) project last year.[8] In other words, AM integration into the supply chain shows the promise to enhance the way sustainment is delivered and there is currently an opportunity for integration as part of ongoing corporate supply chain transformation initiatives.

5. The integration of AM into the RCN supply chain has remarkable potential to enhance naval logistics readiness. The next part of this paper will outline relevant advantages and limitations related to AM and supply chain integration in order to depict a transparent picture of its potential.

a. Advantages of AM.

(1) Supply Chain Agility. One of the first advantages of integrating AM into the supply chain is that it carries the potential to move logistics from a just-in-time approach to a "just-in-production"[9] one. Whereas a traditional supply chain would order a new part from a supplier through a procurement mechanism, a supply chain in which AM is integrated would have the option of manufacturing the part as soon as it is requisitioned. While it is understood that not all parts could necessarily be manufactured in-house, there is a clear advantage to having an AM capability integrated into the supply chain by providing additional options to fulfil materiel requisitions.

(2) Shipping Costs Reduction. There are also potential savings which could be made on shipping costs. Indeed, AM integration into the supply chain would allow the RCN to bridge the gap between the point of manufacture and the point of use. If parts can be manufactured within the Fleet Maintenance Facilities (or even within the Naval Depots), it reduces not only the cost associated with shipping from a supplier, to the depots, and then to the end user (i.e.: a ship); it also translates into a faster turnaround time for delivery.

(3) Demand Forecasting. The RCN currently does not have the means to accurately predict failure rates for specific components of equipment or systems. Conversely, this means that the RCN supply chain cannot accurately forecast demand for parts by anticipating when they will be required. In that regard, integrating AM into the supply chain carries a substantial enhancement as "the ability to manufacture on demand reduces the need to forecast supply chain

[8] Royal Canadian Logistics Service. *The MISL Initiative: How DND / CAF is modernizing Warehousing and Distribution*. The Logistician vol. 3, issue 3 (September 2019): 16.

[9] Thomas A. Campbell, and Olga S. Ivanova. "Additive Manufacturing as a Disruptive Technology: Implications of Three-Dimensional Printing," *Technology and Innovation*, vol. 15 (2013): 69

capacity accurately."[10] A supply chain with a capability to manufacture parts (even if limited in scope) is bound to achieve a greater level of effectiveness and materiel readiness even without a demand forecasting capability. If the RCN invests in the integration of its existing AM capability into its supply chain, it will result in increased flexibility to fulfil certain demands that cannot be fulfilled through physical inventories or just-in-time procurement. Additionally, having historical data on manufactured parts can constitute a starting point towards building a demand forecasting framework.

(4) Efficiency and Self-Sufficiency. Another significant advantage of integrating AM into the supply chain is that it carries the potential to overcome obsolescence of aging platforms.[11] The fact that RCN ships and submarines are anticipated to remain in service anywhere from 30 to 40 years means that over time, certain original equipment manufacturer (OEM) parts for various systems will eventually be discontinued.[12] An AM capability integrated into the supply chain can alleviate the risks associated with the inability to procure parts for obsolete systems and equipment. As soon as a requisition for an obsolete part is submitted and it is confirmed that there is no stock in the inventory, the supply chain could automatically identify the part for manufacturing using organic AM capabilities and *build to suit*.

b. Limitations of AM.

(1) Qualification Standards. Manufacturing parts requires qualification standards. The latter "refers to a set of rules governing any aspect of the manufacturing process, including fabricator credentials, equipment used, raw material properties, workmanship, NDE [non-destructive testing], quality assurance testing, [and] record keeping."[13] It is widely known and commonly acknowledged that there are currently "few technical standards governing AM processes."[14] The adverse effect of this lack of qualification standards for parts manufactured using AM is that any form of technical approval is done in an *ad hoc* fashion across many organizations.[15] Clearly, this can be a cause for concern. Ships

[10] Louis et al., "3D Opportunity in the Department of Defense…", 4.
[11] Louis et al., "3D Opportunity in the Department of Defense…", 7.
[12] The issue related with discontinued OEM parts and obsolete systems is one that the RCN has faced in the past with previous classes of ships, and is currently facing to a certain extent with some systems on the Halifax-class frigates.
[13] C. Munro, "Review of Structural Additive Manufacturing for Defence Applications: Current State of the Art." (DRDC-RDDC-2018-R212, Defence Research and Development Canada, 2019), 42.
[14] *Ibid*.
[15] *Ibid*, 43.

from the same class share the same systems and equipment and it is expected that the specifications of every single part meet the same standard to ascertain performance and integrity. One possible solution to alleviate the impediment and risks associated with the lack of qualification standards would be AM integration into the naval supply chain. In practice, the vast majority of parts available in the Canadian Forces Supply System (CFSS) already have technical information available in its Enterprise Resource Planning (ERP) Platform known as the Defence Resource Management Information System (DRMIS). Hence, the deliberate integration of AM master data (i.e.: dimensions, technical data, specifications, etc.) into the existing system of records would result in all relevant information related to a given part being consolidated into a central information repository. In short, this amounts to *digitalizing* engineering data. In turn, the availability of integrated information would inform decision-making in instances when a part is requisitioned but not available in the physical inventory. An options analysis could then be made quickly to determine what the best course of action is: procurement or in-house manufacturing.

(2) Intellectual Property (IP) Rights. Parts or equipment for which the manufacturer holds IP rights are a definite disadvantage as the RCN would not be legally allowed to manufacture them using AM, unless the rights were sold by the manufacturer to the DND/CAF as part of a contractual agreement.[16] Involvement of legal advisors to ensure IP laws are respected and that the RCN does not infringe on any patents or IP rights of a manufacturer would be essential. On the other hand, locally managed and locally procured parts for which there are no IP rights could be manufactured using AM at a relatively low cost and with a shorter turnaround time than through procurement.

6. In his report from April 2019, Munro provides approaches in the form of three *visions*.[17] They are essentially proposed postures that the DND/CAF could adopt when it comes to AM.

a. Option One: Status Quo. The first approach entails maintaining the status quo and leaving the development of AM *as is* for the time being. Given that AM is already being leveraged by many organizations throughout industry as a truly disruptive technology, it would position the CAF at a disadvantage as a "late-adopter."[18] Moreover, "if AM growth continues, as

[16] *Ibid*, 49.
[17] *Ibid*, 48.
[18] *Ibid*.

industrial trends have suggested, then DND/CAF will miss out on the various benefits offered by AM for some time."[19]

b. Option Two: Conservative AM Integration. The second approach would see the DND/CAF accepting parts manufactured using AM (whether manufactured in-house or procured through a supplier).[20] Introducing AM parts in DRMIS could substantially enhance the overall supply chain performance by consolidating all the relevant technical data, historical usage, and manufacturing or procurement costs. Moreover, "integrating the AM management system into DRMIS could help capture cost and time savings, which could contribute to cost models and decision tools for AM use."[21] To remain an agile and responsive naval force, the RCN needs an equally responsive and agile supply chain capable of delivering parts and equipment in a timely manner. Procurement mechanisms and processes (i.e.: minimum and maximum levels for select parts) are in place to ensure that items can be procured on time and keep the warehouses shelves stocked. However, this business model has its drawback. When parts become discontinued or the supplier (or manufacturer) is not capable of meeting delivery timelines, the RCN's materiel readiness is compromised, which can directly impact the operational readiness and conduct of operations. Integrating AM into the RCN supply chain could potentially reduce the risk of long procurement lead-times and reduce costs in the mid to long-term while decreasing the operational risks associated with untimely delivery.

c. Option Two: Innovative AM Integration. The third approach proposed by Munro is intrinsically tied to the second one and involves leveraging "the design freedom offered by AM."[22] As for any parts entering the supply chain, their design flaws are often revealed after several years of usage by the end user. The introduction of AM into the RCN supply chain could result in an opportunity to rethink part design "to combine discrete parts, reduce weight, embed sensors, or to locally tailor material properties."[23]In turn, this can significantly improve materiel readiness from a supply chain management standpoint. Parts identified as worthy of design improvement could be labelled as such in DRMIS, and a search for a substitute be investigated through procurement or redesign options looked at using AM. While it is acknowledged that in-house AM may not be possible in all cases, an AM capability integrated in the supply chain would positively influence the part substitute search process and enhance the development of sound statements of requirements for procurement.

[19] *Ibid*.
[20] *Ibid*, 49.
[21] *Ibid*.
[22] *Ibid*, 50.
[23] *Ibid*.

CONCLUSION

7. This paper presented an overview of AM's potential and current state, demonstrated the value of integration into the supply chain, as well as presented options to consider for the future of AM and its impact on naval logistics readiness. As the RCN progresses with fleet recapitalization, the need for an agile, responsive and innovative supply chain to support all classes of ships through to the end of their operational service life will increase. As platforms age, finding spare parts for their equally aging systems will prove to be as much of a challenge as it has been in the past. AM is a disruptive technology that has tremendous potential to enhance overall naval materiel readiness. However, AM is currently not integrated into the naval supply chain and, as such, its true potential cannot be harnessed.

RECOMMENDATION

8. It is recommended that formal AM integration into the RCN supply chain be investigated in consultation with Defence Research and Development Canada, FMF CB and the Director of Naval Logistics. There are manifest benefits to integrating AM into the supply chain and building on the foundations of a successfully fielded capability. Furthermore, the ongoing efforts of the MISL project should b e leveraged to the fullest extent possible in the pursuit of AM integration.

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