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Additive Manufacturing Effects on Sustain Requires Formal CAF Commitment

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ADDITIVE MANUFACTURING EFFECTS ON *SUSTAIN* REQUIRES FORMAL CAF COMMITMENT

By Major Nick Tranquilla

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INTRODUCTION

There are a number of emergent technologies currently in development that have the potential to make drastic changes to the way that the Canadian Armed Forces does business. Artificial intelligence, the Internet of Things, Robotics and Additive Manufacturing are some of a number of disruptive technologies of the 21st Century. Disruptive technologies change with time but are considered technologies that significantly alter or displace an existing technology or creates an entirely new industry.[1]

In many cases, the Canadian Armed Forces (CAF) are not normally known for keeping pace with new technologies. One only needs to look as far as the 30-plus year-old Heavy Logistics Vehicle Wheeled (HLVW) fleet that has far surpassed its expected life, the Browning Hi-Power pistol from the 1940s that is still carried by the majority of deployed members, or the drastic change to Windows 10 on National Defence Computers nearly ten years after it was released. However, with these emerging disruptive technologies, staying up to date with current technology is a must in order be able to capitalize on the significant advantages that they will be able to provide to the benefit of the future of the CAF.

Of all of the emerging technologies, Additive Manufacturing (AM) will affect each of the operational functions in a positive and revolutionary manner, in particular the *Sustain* function. This brief essay will discuss how emerging AM technology is currently affecting the *Sustain* within the CAF and some opportunities that the CAF must embrace today. Although AM is still a relatively new technology and cannot yet be considered fully "deployable" or ready for mass

[1] Bayley, Christopher and M. Kopac, *The Implications of Additive Manufacturing on Canadian Armed Forces Operational Functions.* Canadian Military Journal Volume 18 No. 3 (2018) http://www.journal.forces.gc.ca/vol18/no3/page47-eng.asp 48

production, the CAF must begin to fully embrace the technology and must begin to invest time, money and other resources in order to be prepared to fully implement the technology when it is completely ready. AM simply offers too many advantages that the CAF will lose out on if it waits too long before developing an implementation plan.

WHAT IS ADDITIVE MANUFACTURING

Commonly referred to as 3D Printing, AM involves the process of creating objects by depositing layers of material based on an existing digital model. This differs from traditional "subtractive" manufacturing methods that begin with a large piece of material and removes material through various methods until the desired object is achieved. 3D Printing began in the 80s and 90s with expensive machines that only printed small inconsistent plastic items, however, has recently begun to expand exponentially in the past decade to a point where at-home printers are readily available and affordable and the availability of printable materials continues to expand. Figure 1 below shows the rate of market growth of the AM industry based on 2013 projections. Nearly as predicted, AM met $10M in 2020 and is now projected to grow from $10B to $51B in 2030.[2] The rate of growth of AM technology in general will mirror this market growth projection as more AM business and buy-in from governments and industry will directly affect AM technology evolution as the AM "community" grows.

[2] Metal AM, *AM Market Forecast to Reach $51 billion by 2030.* April 8, 2021. https://www.metal-am.com/am-market-forecast-to-reach-51-billion-by-2030/#:~:text=The%20value%20of%20additively%20manufactured,to%20%2451%20billion%20in%202030.

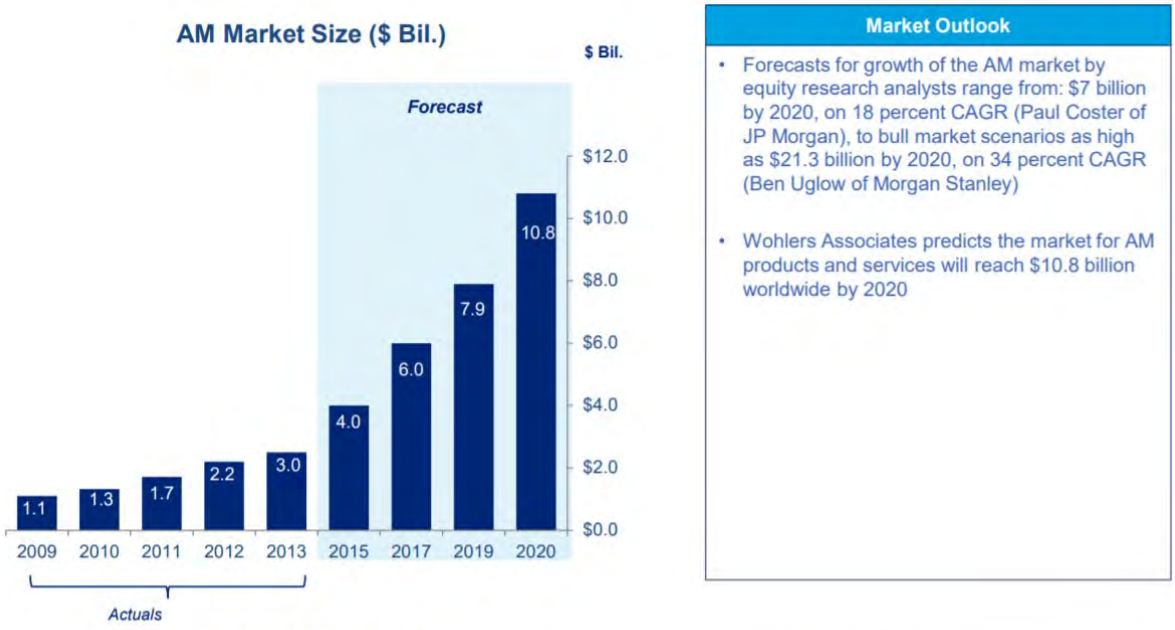

Figure 1: Additive Manufacturing Market Growth,[3]

Additive manufacturing provides many significant benefits over traditional manufacturing methods. Below are just some of the advantages that the Additive Manufacturing industry can provide to the CAF.

- Circumventing long lead-times for contractor procurement
- Reduction in high inventory and warehousing costs
- Reduction on reliance on sole-source suppliers
- Reduction in shipping costs as items can be produced on-site
- Circumvention of possible import/export restrictions
- Enabling increased functionality

[3] Cotteleer, Dr Mark J. *3D opportunity: Additive manufacturing paths to performance, innovation, and growth.* Deloitte Services LLP Presentation, October 1, 2014

- Allowance for optimized design[4]

Various different technologies are included in the AM bubble, each with their own advantages and disadvantages based on printing requirements and varied Technology Readiness Levels. Availability of printable materials has also significantly increased with everything between biomedical materials, polymers, cement, metals and combinations thereof now within the realm of the possible.[5]

IMPACT ON *SUSTAIN*

Only considering *Sustain* when speaking of the impact that AM will have on the CAF is omitting a large portion of its capability. AM can print firearms to better suit a soldier, missiles and ammunition components, vehicle and body armour, among many other applications depicted in figure 2. However, the most significant impact that AM can have within the CAF in the near-term is with *Sustain*.

[4] Bayley, Christopher and M. Kopac, *The Implications of Additive Manufacturing on Canadian Armed Forces Operational Functions.* http://www.journal.forces.gc.ca/vol18/no3/page47-eng.asp 47
[5] *Ibid* 47

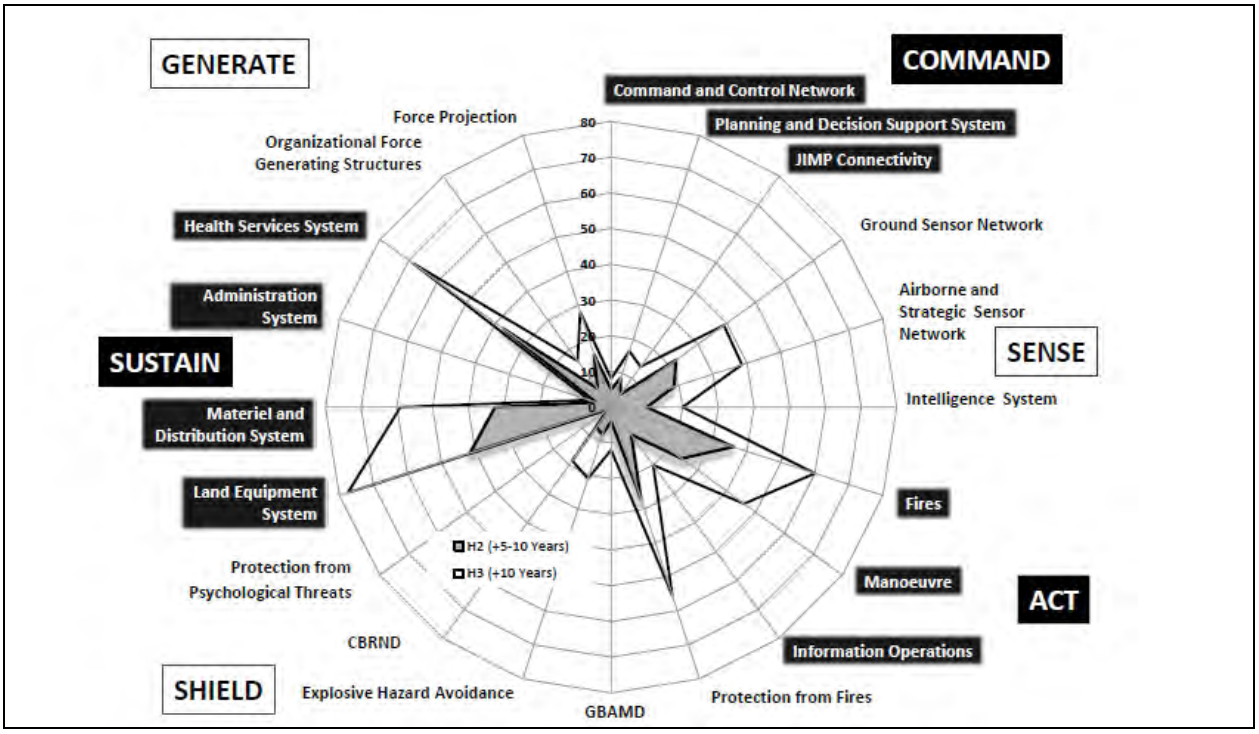

Figure 2: AM Impact on CAF Operational Functions[6]

Parts on Demand

One of the tenants of the Land Equipment Management System (LEMS) is *Repair as Far Forward as Possible.* In essence this means to repair a piece of equipment as close to where it failed as possible. AM makes this possible more than ever before as it reduces the reliance on the supply system that scales different parts at each echelon based on expected usage. With AM, in the near future it will be possible to replace a portion of the supply chain required to support a battle group with printing material and an electronic file of necessary parts. Impacts with the Navy are similar as ships can leave port with printers instead of storage rooms filled with potential parts required for a deployment.

Another significant issue faced by equipment managers across the CAF involves the procurement of obsolete parts. Given that the CAF tends to hang onto equipment past its advertised useful life, obsolescence issues are regularly encountered as Original Equipment

[6] *Ibid, 48*

Manufacturers often do not exist 30 years after production and supply shelves become empty. Equipment managers are forced to try and locate technical drawings and distribute to industry to determine if parts can be made prior to testing to ensure compliance. The AM industry has the ability to resolve many of these problems as the part can now be digitally scanned, analyzed for components, printed and installed.

Secondary impacts associated with printing parts where they are required include reduction in required warehouse space, reduction in transportation time and associated costs, and a decrease in contracting and procurement time among many more. Conventional manufacturing methods often takes years as it requires significant manpower and time to procure, time to test and qualify the part, as well as significant resources to ship, store, and manage the parts after delivered to the CAF.

AM technology continues to grow and capacities expand. The US Army was the first to deploy an AM facility into Afghanistan that they use to build spare parts rather than focus on procurement in order to better support deployed forces.[7] Where technologies are not yet advanced enough, the US Army has also developed the capacity to quickly print reinforced plastic parts as a form of temporary replacements to allow equipment to be used for a certain mission or requirement. These temporary replacements are not made to survive for a long period, only to fill the gap until the procurement system can deliver the acceptable substitute.

Free Form Manufacturing

AM provides the potential opportunity to create parts in a way that is not possible with conventional manufacturing methods. Parts can be created using a combination of different materials to provide required properties where required and can be created in unique designs.

[7] Panneerselvam, Prakash. *Additive Manufacturing in Aerospace and Defence Sector: Strategy of India*, Journal of Defence Studies Volume 12, No. 1 (2018). http://eprints.nias.res.in/1418/1/2018-JDS-Panneerselvam.pdf 48

This process will allow items to be fabricated lighter and in different configurations than possible with conventional milling and machining. NASA has also printed parts for a jet engine that have demonstrated the capacity to withstand the highest temperature and compressed pressures of any jet engine in history.[8] This capability opens many doors both for use within the CAF, but also opportunities within industry when designing equipment for CAF use.

Cement "Printing"

Polymers and metals are not the only printable components beneficial to the CAF. Technology exists that is capable of "printing" infrastructure and infrastructure components. Fiber-reinforced cement can be used to create structures in Camps and Forward Observation Bases or for humanitarian efforts and can significantly reduce the requirement for on-site personnel. Printing is done based off of digital models and can be done as structures on-site or pre-fabricated slabs or bricks that can be transported and later assembled. In terms of humanitarian assistance, structures fabricated from printed blocks can provide additional earthquake assistance as the pieces can move independently without sacrificing the stability of the entire structure.[9]

Health Services

AM also offers some significant benefits when it comes to health services. Printing of customized braces and supports is well advanced as most are printed from reinforced plastics. Technology exists to print pigmented skin patches to cover wounds and burns as well as to print organ tissue that, while not yet suitable for transplant to humans, is capable of replacing humans and animals for testing of various new drugs. Given the relationship with the civilian medical system and civilian medical experts, the use of AM for Health Services purposes within the CAF

[8] Panneerselvam, Prakash. *Additive Manufacturing in Aerospace and Defence Sector: Strategy of India*, http://eprints.nias.res.in/1418/1/2018-JDS-Panneerselvam.pdf 46
[9] Bayley, Christopher and M. Kopac, *The Implications of Additive Manufacturing on Canadian Armed Forces Operational Functions.* http://www.journal.forces.gc.ca/vol18/no3/page47-eng.asp 49

is likely not required, however, it is imperative that the CAF Medical System knowledgeable about the capabilities that AM can provide to the medical community. What AM does provide to the CAF though, is some significant potential for wounded members and veterans to get support that may not have been possible, or timely, when only using traditional manufacturing methods.[10]

CURRENT SHORTFALLS AND CHALLENGES

Although there are many significant AM capabilities already in use within the CAF and within industry, there remain some significant challenges. Intellectual Property, Rate of Technology Growth, Quality Control, and Data Management are just some of the challenges being faced by the AM Industry and that need resolution before full implementation within the CAF is possible.

Intellectual Property

One of largest challenges that the CAF will face when implementing portions of AM involves Intellectual Property. Many equipment procurement programs within the Air Force, Navy, and Army now include significant built-in sustainment packages that require the use of Original Equipment Manufacturer (OEM) parts who own the IP for their parts. With the current rate of technology evolvement, vehicle, ship, and airframe fleets that the CAF is purchasing today will have the ability to fully capitalize on incorporating AM replacement parts, however, this must begin to be considered and included in project procurement contracts today in order to set the conditions for AM implementation in the future. It has been estimated that AM will result in the loss of in excess of $100 billion annually in IP globally so working with industry today

[10] *Ibid, 49*

and considering AM during the procurement process will allow the CAF to take full advantage of AM capabilities.[11]

Technology Growth

Technology Readiness Levels (TRLs) for the multiple AM technologies vary greatly as some are ready for deployment now, while some will not be fully ready for a number of years. What is clear, however, is the rate of growth of the industry. The challenge the CAF faces with the rate of growth is knowing how much resources to invest in AM and when. Expensive state-of-the-art machines today will likely be out-dated by the time that AM is ready for implementation so CAF investment into machines and technologies that are not ready is not required. What is required, however, is maintaining awareness of the state of each technology in order to implement when appropriate.

Quality Control

Quality control is one of the biggest challenges faced by the AM industry as ensuring that one "print" is the same as the next can be challenging. Defence standards often require the production process to be verified and parts need to be certified to meet pre-determined quality control standards. Variations between machines, printing material suppliers, or even the location on the printing bed that a part is printed, has the potential to affect the quality and consistency of the end product.[12] In current applications, each printed part needs to be assessed while in traditional methods, established production lines only small samples are checked and only at the request of material managers. It is certain that the quality control issues will be resolved with the exponential growth of AM technology as a whole, however, will remain a concern until then.

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[11] Bayley, Christopher and M. Kopac, *The Implications of Additive Manufacturing on Canadian Armed Forces Operational Functions.* http://www.journal.forces.gc.ca/vol18/no3/page47-eng.asp 53; Panneerselvam, Prakash. *Additive Manufacturing in Aerospace and Defence Sector: Strategy of India*. http://eprints.nias.res.in/1418/1/2018-JDS-Panneerselvam.pdf 52

[12] Bayley, Christopher and M. Kopac, *The Implications of Additive Manufacturing on Canadian Armed Forces Operational Functions.* http://www.journal.forces.gc.ca/vol18/no3/page47-eng.asp 53

Digital Storage and Management

Although not a shortfall or challenge with the technology, data storage and protection is a problem that will need to be resolved within the CAF. The CAF will need to determine storage mediums to allow digital models to be stored, shared and utilized both in domestic and deployed scenarios. Complications with this include storing permissions for OEM-owned technical drawings, CTAT and ITAR protection requirements that may be required by allies, as well as prevention from cyber attacks to ensure that designs cannot be stolen or sabotaged in a means to decrease functionality or reliability.[13] Storage mediums have traditionally been a challenge for the CAF, however, in order to ensure that AM can be fully implemented across the CAF this challenge must be resolved to ensure that organizations are not working independently.

CAF GUIDANCE REQUIRED

The Journal of Defence Studies from India conducted a study and determined that India is slightly behind when it comes to adapting to AM. Canada is in a similar situation. The recommendations from the report can similarly be applied to the approach that Canada must take regarding AM. Three recommendations came from the analysis and are as follows:

1. Encourage Research
2. Entice Industry
3. Encourage Training and Skilling

Encourage Research

Encouraging research is well underway and in the hands of DRDC. The link between the DND and the CAF, however, must be strengthened in order to ensure that AM can be

[13] Bayley, Christopher and M. Kopac, *The Implications of Additive Manufacturing on Canadian Armed Forces Operational Functions.* http://www.journal.forces.gc.ca/vol18/no3/page47-eng.asp 53

implemented as it becomes feasible. Army Science and Technology Boards are held each year to discuss topics such as AM, however, a more dedicated medium is required in order to ensure the CAF is prepared to implement.

Entice Industry

Enticing industry is two-fold; encouraging further development and resolving potential IP constraints. AM inclusion in industry both permits designs to be configured in ways that was previously not possible, as well as increases the rate of evolution of the technology. Beginning discussions today with existing and potential suppliers will allow the resolution of potential IP issues. Even in the long term, there is no potential for AM to completely replace traditional manufacturing methods. Traditional methods will still out-perform (cost, speed, established production lines, etc) AM in certain circumstances so there will always be a requirement to maintain traditional manufacturing skills. Working with industry to determine how IP constraints can be avoided and resolved will be instrumental in ensuring that the CAF is able to meet these IP challenges.

Encourage Training and Skilling

The third recommendation, training and skilling, is an area within the CAF that needs dedicated attention. Many organizations at the tactical and operational levels have begun to implement portions of AM, however, much of this involvement is at their own requests. Mostly at their own requests, tactical level maintenance shops have begun to purchase 3D Printers most of whom have begun experimenting with low-risk plastic parts and prototyping. [14] At the Operational level, 202 Workshop Depot, the Quality Engineering and Test Establishment, and

[14] Ross, Maj Jessica and MWO Timothy Goldfinch. *Additive Manufacturing in LEMS – Repairing as far forward as possible.* Land Equipment Management System Journal, Issue 3 November 2019. https://www.canada.ca/content/dam/dnd-mdn/documents/reports/2019/lems-journal-issue3-september-2019.pdf 19; Tran, Cpl Joseph, Capt C Mooney, and Maj J Ross. *Fabricating the Future: Additive Manufacturing on Operation REASSURANCE.* Land Equipment Management System Journal, Issue 5 November 2020. https://rcemecorpsgemrc.ca/wp-content/uploads/2020/11/LEMSJournal_Issue5_EN-Accessible.pdf 14

Fleet Maintenance Facility (FMF) Cape Scott have begun taking an interest in AM and have begun prototyping and repairing some low-risk parts, and in the case of FMF Cape Scott, they were able to repair a capstan with a higher quality material that will increase its corrosion and wear resistance, without sacrificing required qualities.[15] The aspect of training and skilling has begun happening, however, what is missing is an overarching plan and top-down direction and influence in order to ensure that AM is integrated in accordance with a pre-developed plan. Top-down direction on the implementation of AM must continue to allow the tactical and operational level AM "experts" to continue to expand their skills and abilities with some freedom, however, an overarching AM implementation plan must be developed and communicated to all levels.

CONCLUSION

In conclusion, AM technology that is available now, and technology that will be available in the near-term, will offer a significant advantages to the CAF when it comes to all of the operational functions, most significantly *Sustain*. The ability to produce parts-on-demand will have a radical impact on CAF operations both in domestic and deployed scenarios as it has the potential to eliminate the often-long supply chain problems that are often encountered. Significant challenges still remain when it comes to AM, both as a technology, and when it comes to integrating within the CAF. IP problems must be discussed at high levels today to ensure that AM can be fully integrated when the technology is ready.

AM has begun happening at the tactical and operational levels, however, with the current lack of top-down direction, they are operating independently and are not able to fully capitalize on what AM has to offer. The CAF must develop, implement, and communicate an AM

[15] Canada, *3D printing transforms the RCN*. Government of Canada Navy News, dated 26 February 2016. https://www.navy-marine.forces.gc.ca/en/news-operations/news-view.page?doc=3d-printing-transforms-the-rcn/il3c32xa *;* Hui, Lt Spenser. *Third-line innovation: 3D Printing 202 Workshop Depot,* Land Equipment Management System Journal, Issue 1 April 2018. https://www.canada.ca/content/dam/dnd-mdn/documents/reports/2018/lems-journal-issue1-april-2018.pdf

implementation plan now as many other nations have already done. An implementation plan will allow maintenance facilities across the country to understand the emergence of AM and what it can offer and will allow units some flexibility and support in spending local budgets on printers. It also provides a new technology for young technicians and junior leaders to utilize and experience so they're not constantly supporting obsolete vehicle fleets and ships well past their expected life.

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