



Revolutionizing Military Logistics: The Role of Autonomous Delivery Systems in the CAF

Major Jonathan Desmarais

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Exercise Solo Flight

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Major Jonathan Desmarais

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REVOLUTIONIZING MILITARY LOGISTICS: THE ROLE OF AUTONOMOUS DELIVERY SYSTEMS IN THE CAF

INTRODUCTION

In an era defined by rapid technological advancements, the landscape of military operations is undergoing a profound transformation and recent conflicts have clearly demonstrated that modern warfare is now more complex and unpredictable than it has ever been before.¹ If nations are to maintain strategic superiority and operational efficiency within this new reality, there is an urgent call for them to reassess and innovate the way they conduct their military logistical operations. As a developed military, the Canadian Armed Forces (CAF) are no exception to this reality. While the recent digitization of the battlefield has greatly improved the supply chain management by enhancing visibility, optimizing resource allocation and reducing response times, it has failed to address the logistical challenges brought on by distance and geography.² More specifically, the heart of the challenge lies in what has been dubbed by the civilian industry as the ‘last mile’, which refers to the final segment of the delivery route, typically from a logistics hub to the actual end-user.³ It is with this in mind that the integration of autonomous delivery systems has recently emerged as a pivotal solution to mitigate some of the risks associated with the last mile. Given these considerations, it is worth exploring the roles autonomous delivery systems could play in CAF logistical operations and the associated ethical and legal considerations.

This essay will attempt to show that while integrating autonomous delivery systems into logistical operations presents numerous challenges, the roles these systems could fulfill significantly outweigh these obstacles. It will also demonstrate that while ethical and legal considerations are notable when it comes to autonomous delivery systems, they should not be a limiting factor for the integration of these technologies.

This essay will be divided into four parts. The first part will outline some of the key factors that should be motivating the CAF to adopt and integrate autonomous delivery systems. It will also discuss, as a counterbalance, the challenges linked to these systems and examine ways to address and mitigate them.

The second part will begin by describing some of the fundamental concepts that define a system as ‘autonomous’ and it will highlight some of the roles where the CAF could benefit from autonomous delivery systems.

¹ Minister of National Defence, ‘Our North, Strong and Free: A Renewed Vision for Canada’s Defence’, 8–10.

² Obadal, ‘From Efficient to Effective Modern Combat Logistics’, 2.

³ Apthorp, ‘Using Autonomy to Supply the ‘Last Mile’ Addressing the Challenges of Modern-Day Conflicts’, 4–5.

The third part will present systems and technologies that are currently available, or amid development, that could meet the needs of the CAF moving forward. Systems for each of the three primary elements (Land, Air, Sea) will be explored.

The fourth and final part will discuss the ethical and legal considerations associated with the use of autonomous delivery systems and demonstrate that they should not be a limiting factor for the integration of these technologies.

MOTIVATING FACTORS AND CHALLENGES

Motivating factors

Due to significant advancements in computing, communication and other technologies, civilian industries and militaries around the globe are investing significant amounts of resources towards the development, acquisition, and implementation of autonomous systems.⁴ The following will highlight some of the driving factors that should be motivating the CAF to invest in such capabilities.

Threats to soldiers

While the battlefield and vehicles have changed considerably throughout the years, the requirement for convoys that deliver supplies and personnel throughout the area of operation has remained consistent. For example, during operation Iraqi Freedom, 98% of the military's supplies and equipment were distributed by ground transportation.⁵ In a non-linear battlefield, similar to what the CAF experienced in Kandahar, Afghanistan from 2006 to 2011, the most significant threat to soldiers was during the conduct of convoy operations. In his article, *Delivery of Healthcare Resources Using AGV Systems*, Calvin Cheung points out that 44% of casualties (36 000 members) in Afghanistan and Iraq were the results of convoys being struck by IEDs.⁶ The future of warfare will still have a requirement for convoys but will demand more investments in precision, information, and automation, as well as a renewed focus on agility at every echelon. Conversely, this also means that the risk of attacks against convoys is expected to rise since our adversaries are also investing in newer technologies that will allow them to strike from a greater distance and with increased precision. However, by utilizing autonomous delivery systems, we are reducing the requirement for direct human involvement, which will ultimately lower the risks to soldiers.⁷

Just in time delivery

The recent conflict in Ukraine is a stark reminder that success or failure of logistics at lower levels of war (ie. tactical) will have a direct and critical influence on the

⁴ Padmaja et al., 'Exploration of Issues, Challenges and Latest Developments in Autonomous Cars', 1-3.

⁵ Cheung et al., 'Delivery of Healthcare Resources Using Autonomous Ground Vehicle Convoy Systems', 1-2.

⁶ Cheung et al., 4.

⁷ Mason et al., *The Future of Autonomous Vehicles*, 3;73.

operational and strategic objectives.^{8,9} During the early stages of the invasion, Russian forces failed to reach their stated objectives because they essentially ran out of critical, yet basic supplies, such as water, food, fuel and munition. Resupply could not keep up with operations because they simply lacked personnel and platforms to bring forward the required supplies at the right place and the right time.¹⁰ With the current lack of personnel and equipment in the CAF, brought on by retention, recruitment and budgetary issues, the CAF would surely find itself in a similar situation.¹¹ It is true that the CAF usually operate within a coalition, but at this time, they can barely handle their portion of the burden when it come to resupplying their own forces for that “last mile”.¹² With this in mind, utilizing autonomous delivery systems would require less personnel resources and could provide timely deliveries at the right place, also reducing the requirement to stockpile. Perhaps the initial outcome of the invasion may have turned out differently had the Russians been able to utilize such technologies.

Reduction of Human Errors

Autonomous systems are programmed to perform tasks with a high degree of accuracy and precision, thus minimizing the potential for human error.¹³ Furthermore, robots don’t experience sleep deprivation, meaning they can perform their duties on a continuous cycle and stopping only briefly to refuel and/or recharge. Some time for scheduled and unscheduled maintenance needs to be put aside, but this will always remain greatly inferior to the sleep cycles required by soldiers to be able to operate safely.¹⁴

Defence Policy Update (DPU)

Lastly, the DPU, *Our North, Strong and Free: A Renewed Vision for Canada’s Defence*, which has just been released in April 2024, states implicitly that in an effort to modernize its capabilities, Canada will:

make institutional investments in the Canadian Armed Forces and Department of National Defence, building civilian capacity, advancing defence procurement reform, fostering innovation and digitalization.¹⁵

⁸ Canadian Army Doctrine and Training Center, ‘CADN 22-01, Rear Area Security’, 5.

⁹ Ti and Kinsey, ‘Lessons from the Russo-Ukrainian Conflict’, 381.

¹⁰ Martin, Barnett, and McCarthy, ‘Russian Logistics and Sustainment Failures in the Ukraine Conflict’, 7.

¹¹ Dyson, ‘Canadian Armed Forces Facing Member Shortage “Crisis”’.

¹² Gilmore, ‘Military Recruiting Issues in West Raise Challenges for Defending Democracy: Defence Chief’.

¹³ Mayer, ‘Developing Autonomous Systems in an Ethical Manner’, 67.

¹⁴ Mayer, 67.

¹⁵ Minister of National Defence, ‘Our North, Strong and Free: A Renewed Vision for Canada’s Defence’, 20–22.

This opportunity must be seized by the CAF and serious consideration needs to be placed in the acquisition and integration of autonomous delivery systems.

Challenges related to using autonomous delivery systems

Technological Maturity

Although the technology of autonomous systems is advancing at an exponential rate, the platforms have not yet reached a state of maturity where they can be fielded in a military environment using fully autonomous capabilities. They are still too slow and brittle to be operationally relevant, and they generally don't adapt well to domains outside of their training area.¹⁶ In an operational environment, the autonomous systems will not only have to worry about getting from point A to point B, but also have to react to an adversary who is essentially trying to eliminate it. Systems must also possess the capability to adapt and respond swiftly to changing circumstances influenced by the environment (ie. sun, dust, wind, snow, rain) and be in a position to identify and navigate objects that appear in front of them at the last second. In order to bring their autonomous systems to a state of maturity and be able to navigate in a complex military environment, developers are putting software through thousands of hours of simulation.¹⁷

Another major challenge where scientists and developers are dedicating substantial efforts, is related to power and energy. The selection of the energy source for powering autonomous systems will depend on numerous factors and must be carefully measured in the intricate balance among the system's size, payload, maximum distance, speed and weight.¹⁸ Many systems up to now have been reliant on batteries and the main challenge has been distance due to their finite capacities. In order to overcome this challenge, some systems are outfitted with a hybrid system where a fuel-efficient combustion engine engages when the batteries are depleted. This comes at a trade-off with covertness and green energy, so research is also now focusing on renewable energy sources such as solar, wind and hydrogen fuel cells, which would also increase distance.¹⁹

Data Management

Data management presents a major challenge in logistics operations, with issues such as data reliability, security, and exploitation not being fully addressed. The greatest challenge for logistic operations is limited bandwidth, as priority is often given to mission critical functions. This requires careful prioritization and constant management.²⁰

Data transmission is vulnerable to attacks such as data theft, denial of service, and GPS spoofing. Robust data security and encryption practices must be implemented to

¹⁶ Mason et al., *The Future of Autonomous Vehicles*.

¹⁷ Mason et al.

¹⁸ Zhang et al., 'Energy Efficient Path Planning for Autonomous Ground Vehicles with Ackermann Steering', 1-3.

¹⁹ Ivanova, Gallash, and Jordans, 'Automated and Autonomous Systems for Combat Service Support: Scoping Study and Technology Prioritisation', 11.

²⁰ Ivanova, Gallash, and Jordans, 10.

protect systems from these threats.²¹ As an example, in 2011, Iranian forces captured an American Lockheed Martin RQ-170 Sentinel unmanned aircraft (UAS) by allegedly jamming control signals and using GPS spoofing forcing the UAS to land in Iran.²²

The increase in sensors leads to more data to process and exploit, and this has ultimately led to more analysts being required at the receiving end to interpret the data for decision makers. For example, the surge in data gathered by the predator UAS for the US Department of Defense (DoD) has led to 30% rise in the number of analysts required to process the data. Downsizing large data volumes before transmission will be crucial due to bandwidth limits, but as platforms become more and more autonomous, there will be less of a requirement for data to be sent to the controlling stations. Maneuvers such as take-off/landing, navigating, threat avoidance and health monitoring will be done mostly internal to the system and with the assistance of GPS, thus reducing the use of limited available bandwidth and analysts.²³

Industry and Private Sector

While there is certainly an advantage in leveraging the private sector's technological advancements, relying on the private sector for national supply chains and logistics can expose vulnerabilities that can also affect military operations.²⁴ Defence industrial capacity has significantly shrunk in recent years resulting in systems and components not being readily available or simply cease to exist at a moment's notice. Fragile commercial practices combined with limited military capacity to surge production may leave many militaries vulnerable to wartime disruptions, the CAF being no exception. Many militaries are already taking steps to develop more robust and effective approaches, focused on more resilient, reliable and long lasting systems. That being said, it is quite reassuring to read in the new CAF DPU that Canada is looking at:

supporting defence industrial initiatives and strategies to build resilient supply chains, incentivize private industry to scale up or open new production lines, secure sources of supply, and roll out domestic workforce and acquisition strategies that invigorate their economies.²⁵

The aim is for the adversary to be aware that our logistical support will always be available, ensuring that our warfighters can access essential capabilities whenever needed.

Cost

²¹ Ivanova, Gallash, and Jordans, 10.

²² Agence France-Presse, 'Iran to "reverse-Engineer" Seized U.S. Stealth Drone after Hacking Operating System'.

²³ Ivanova, Gallash, and Jordans, 'Automated and Autonomous Systems for Combat Service Support: Scoping Study and Technology Prioritisation', 10.

²⁴ Obadal, 'From Efficient to Effective Modern Combat Logistics', 4–6.

²⁵ Minister of National Defence, 'Our North, Strong and Free: A Renewed Vision for Canada's Defence', 20.

The initial investment for autonomous delivery systems will without a doubt come at a significant cost when we factor in the investments in research and development, testing, and acquisition of technology. As a counterargument, autonomous platforms will lead to logistical efficiencies and ultimately reduce operational costs, including fuel costs, maintenance expenses and overhead associated with traditional delivery methods.²⁶ More importantly, especially in a CAF context where recruitment and retention issues are significant, autonomous platforms will reduce the need for human operators, leading to reduction in personnel-related expenses and rendering available personnel for higher priority tasks.²⁷ In the *FY 2014 US Defence Budget Report*, CBSA states that the cost per service member deployed to Afghanistan was \$2.1 million per year.²⁸

CAF Budget and Procurement System

As implicitly stated in the CAF DPU, “Defence procurement takes too long in Canada and needs to be faster and more effective”.²⁹ Although Public Services and Procurement Canada, Science and Industry, and the Treasury Board Secretariat have launched a review of the procurement system, it will take some time before any proposed changes get officially translated into policies.

The current procurement system simply can’t match the pace at which technology advances. However, it is promising to observe that the government of Canada is now actively seeking to implement measures to expedite the timeline of major acquisitions. One of its aims is to minimize the operational and financial risks associated with delays as well as the gaps between retiring capabilities and integrating new ones.³⁰

CONCEPT OF EMPLOYMENT

The narrative of disruptive innovations in warfare suggests that understanding how best to use a new technology is more important than developing the technology first, or even having the best technology.³¹ This underscores the necessity for experimentation, prototyping, and an iterative approach to concept development and technological advancement. Crucially, it highlights the vital role of cultivating a military culture that is open to experimentation and receptive to novel combat methods. True revolutionary advancements in war first stem from the potential to leverage emerging technologies in innovative ways, rather than simply applying new tools within existing doctrines. When

²⁶ Cheung et al., ‘Delivery of Healthcare Resources Using Autonomous Ground Vehicle Convoy Systems’, 4.

²⁷ Resig, Woodaman, and Curtin, ‘Operational-Level Autonomous Logistics: A Multi-Objective Model Formulation and Solution Procedure’, 27.

²⁸ CSBA, ‘Chaos and Uncertainty - The FY2014 Defense Budget and Beyond’, 11.

²⁹ Minister of National Defence, ‘Our North, Strong and Free: A Renewed Vision for Canada’s Defence’, 20.

³⁰ Minister of National Defence, 20.

³¹ Wirtz, ‘A Strategist’s Guide to Disruptive Innovation’.

autonomous systems challenge established doctrines or operational concepts, their potential benefits should be enthusiastically embraced.³²

Fundamental Concepts

Autonomous systems will not replace war fighters, just as the earlier innovations of firearms, steam powered ships, or tanks did not eliminate the need for combatants.³³ The need for human judgment and decision making in combat will also not change. There is a general difficulty in understanding the term ‘autonomous’ as people tend to refer to three completely different concepts when referring to the same word. These are :

- the human-machine command-and-control relationship;
- the sophistication of the machine’s decision making;
- the type of decision or function being automated.³⁴

The human-machine command relationship is often categorized using terms like 'human in the loop,' referring to situations where machines can execute functions for a period but require human input at certain junctures. 'Human on the loop' typically applies to machines that can perform a function on their own but are monitored by humans. 'Human out of the loop' describes systems that operate autonomously without human intervention.³⁵

The sophistication of decision making, is the parameter described by terms such as 'automatic' (basic, mechanical responses), 'automated' (complex, rule-based systems), and 'autonomous' (machines demonstrating self-direction, self-learning, or emergent behavior).³⁶

The nature of the decision or function being automated serves as the foundation for discussions on whether a machine is 'autonomous' or 'semi-autonomous'. Referring to a machine as ‘autonomous’ or ‘semi-autonomous’ is pointless without specifying the particular task or function it is designed to automate. This distinction is crucial as it directly influences the complexity and potential risks involved in utilizing the system.³⁷

With these foundational principles and consideration, the focus concerning the development and utilization of autonomous systems should revolve around determining which tasks are best suited for machine execution and which tasks are better suited for human involvement, rather than solely fixating on achieving ‘full autonomy’ for machines. In the short term, or at least till the technology has matured, the CAF should be

³² Scharre, ‘The Opportunity and Challenges of Autonomous Systems’, 7.

³³ Scharre, 7.

³⁴ Ivanova, Gallash, and Jordans, ‘Automated and Autonomous Systems for Combat Service Support: Scoping Study and Technology Prioritisation’, 2.

³⁵ Ivanova, Gallash, and Jordans, 2.

³⁶ Scharre, ‘The Opportunity and Challenges of Autonomous Systems’, 10–11.

³⁷ Scharre, 11–12.

focusing on ‘human in the loop’ autonomous platforms, which will also help to gradually build expertise.

Roles

The recently published DPU outlines three powerful trends that are now reshaping our world and which are of primary interest to the CAF :

- “Climate change is disproportionately affecting our Arctic making it increasingly accessible, leaving Canada with new security challenges in the region.”
- “Autocracies and disruptive states are challenging the international order that keeps Canada safe and prosperous, Russia and China been flagrant examples.”
- “New and disruptive technologies are rapidly redefining conflict in what it takes to be safe and secure.”³⁸

Starting with the security concerns in the Arctic, the CAF could greatly benefit from investing in autonomous delivery systems, such as autonomous sea vessels, to tackle challenges in areas like the Northwest Passage and the wider Arctic region. According to figures provided by the *International Arctic Council*, “the number of unique vessels operating in the Canadian Arctic rose from 35% to 212% between 2016 and 2022, as the ice continues to melt.³⁹ These numbers are surely going to keep rising as more and more international stakeholder will be looking at using the Northwest Passage, ultimately challenging Canada’s sovereignty. The DPU states “We will secure our Arctic and North by increasing the presence, reach, mobility and responsiveness of the Canadian Armed Forces’ in the region, and along our coasts and maritime approaches”,⁴⁰ but one can argue that it currently doesn’t have enough resources or personnel to effectively do so. To address the issue, autonomous sea vessels could be utilized to perform surveillance patrols and deliver supplies to isolated stations or infrastructure. These vessels require fewer personnel and can operate efficiently over long periods of time.

Given the CAF’s significant presence in Latvia as the framework nation, they have an ideal operational context for testing and trialing autonomous delivery systems. Latvia's diverse terrain and complex operational environment offer a unique setting to explore innovative employment concepts for autonomous systems and evaluate which approach is best to suit the CAF’s needs in the future.⁴¹ Initially, the CAF might find it

³⁸ Minister of National Defence, ‘Our North, Strong and Free: A Renewed Vision for Canada’s Defence’, 3–10.

³⁹ Reynolds, ‘Arctic Ice Retreat Leads to Increased Ship Traffic through the Northwest Passage’.

⁴⁰ Minister of National Defence, ‘Our North, Strong and Free: A Renewed Vision for Canada’s Defence’, 3–5.

⁴¹ McKay, ‘An Interim Report on the Defence of Canada in a Rapidly Changing Threat Environment’, 26–29.

most beneficial to concentrate on addressing challenges related to ‘last mile’ delivery, which encompasses the final stages of transporting supplies to frontline units or isolated outposts. Autonomous delivery systems can play a crucial role in delivering essential supplies such as ammunition, medical supplies, blood, and other necessary items to the front lines.^{42, 43} These systems can also facilitate casualty evacuation, routing the risks to human personnel and enhancing the efficiency of logistics operations. In doing so, the CAF can improve the safety and well-being of its personnel while ensuring timely and reliable delivery of critical resources.⁴⁴ Further analysis will be necessary to determine who will be the optimal operators and trades for the platforms, what technical training is required, how will these platforms be sustained and what are the infrastructure/IT requirements to support this emerging technology. Although these aspects are critical for successful integration, they will not be covered in this essay.

Autonomous delivery systems would also offer significant advantages during domestic operations, such as providing support to local authorities during forest fires and floods. In such scenarios, soldiers are often asked to operate in remote and isolated areas where intricate and complex road infrastructure is the only way to gain access. Autonomous delivery systems have the ability to navigate high risk zones that would otherwise be too dangerous for human operated platforms due to the potential loss of life for soldiers or civilians. They can deliver essential goods, such as firefighting equipment, medical supplies, and emergency provisions, directly to affected areas without putting personnel in harm's way. Ultimately, autonomous systems can operate around the clock and would allow for a more immediate and coordinated support to disaster stricken regions.⁴⁵

Autonomous delivery systems could also play a crucial role in various operational environments, including humanitarian aid missions, Disaster Assistance Response Team (DART) missions, Search and Rescue, UN Peace Missions, stability operations, COIN, SOF missions and Indo-Pacific related operations. Their versatility and adaptability would make them indispensable tools for improving operational efficiency and ultimately providing a strategic advantage in support of successful outcomes in complex and diverse scenarios.

RELEVANT AND AVAILABLE CAPABILITIES FOR THE CAF

Industries and militaries around the world are now investing billions of dollars into the development of autonomous delivery systems. They are truly recognizing the sheer benefits these type of platforms can bring in terms of increased efficiency, long term cost savings, safety and strategic advantage in the case of the military.⁴⁶ This section

⁴² Gilmore, Chaykowsky, and Thomas, *Autonomous Unmanned Aerial Vehicles for Blood Delivery*, 1–8.

⁴³ Gibson, Merchant, and Vigneron, ‘Autonomous Systems in the Combat Environment: The Key or the Curse to the U.S.’

⁴⁴ European Defence Review, ‘Ukrainian Forces Are Taking Full Advantage of Their THeMIS UGVs’.

⁴⁵ Edwards et al., ‘Use of Delivery Drones for Humanitarian Operations’, 1646–49.

⁴⁶ Scharre, ‘The Opportunity and Challenges of Autonomous Systems’, 5.

will present a few examples of autonomous delivery systems related to the three main domains (Air, Land, Sea) that could be pertinent for CAF operations.

Air

Autonomous Unmanned Aerial Vehicles (UAV) encompass a variety of shapes and sizes, ranging from mini-UAVs to large airframes. Their abilities and uses differ significantly based on variations in range, endurance and payload capacity.⁴⁷ The CAF should be concentrating on platforms tailored for last mile logistics, where autonomous UAVs could rapidly and effectively bring urgent supplies such as ammunition, parts and blood to isolated and contested areas. As an example, the VOLY M20 hybrid autonomous UAV designed by Volansi can carry a payload of 20 lbs in addition to a 10 lbs Intelligence, Surveillance and Reconnaissance (ISR) system, over a 350 mile range at a speed of 75 mph (see figure 1). It is designed to operate in complex environments and requires minimal to zero infrastructure needs.⁴⁸



Figure 1 – UAV VOLY M20 by Volansi

Source : Drone makes first autonomous aerial delivery between two military vessels, 2

On a larger scale, the Traverse Aero's Orca autonomous cargo drone can transport palletized loads within its 1.7 m³ cargo bay for a payload of 550 lbs over 625 miles at a cruising speed of 150 mph (see figure 2). The Orca's AI co-pilot allows one human pilot/operator to manage up to 50 Orcas from a single remote flight station. Another very interesting aspect of the Orca is that it can operate in GPS denied and/or communication denied environments due to its pre-programmed functionalities. The US DoD is currently funding the Traverse Aero's Orca project as a potential solution for time-sensitive, last

⁴⁷ Ivanova, Gallash, and Jordans, 'Automated and Autonomous Systems for Combat Service Support: Scoping Study and Technology Prioritisation', 15–17.

⁴⁸ Tingley, 'Drone Makes First Autonomous Aerial Delivery Between Two Military Vessels'.

mile resupplying in isolated and contested areas, whether it be land-land, land-ship or even ship-ship.⁴⁹



A typical usage scenario for the Orca Traverse Aero Corporation

Figure 2 – Orca by Traverse Aero Corporation

Source : Shipping-pallet-friendly Orca cargo drone is designed to fit in, 2

Land

Although modern military operations incorporate advanced transportation methods like rail lines, aircraft, and helicopters, ground vehicles continue to be the main method of transportation for last mile deliveries.⁵⁰

Though the benefits of using autonomous ground delivery vehicles are apparent, numerous challenges remain, which accounts for the fact that no military has yet fielded fully autonomous ground vehicles for operational use.⁵¹ Unlike air corridors and sea lanes where navigation is generally predictable and mostly free of obstacles, the ground is quite another story. Automation is quite capable of handling tasks such as managing speed, direction, and lane assignment effectively, but when it comes to navigating complex, unmarked terrain where the enemy gets a vote, the technology cannot safely and reliably be employed yet. What we're seeing instead, as an interim solution until the technology is

⁴⁹ 'Autonomous Drones – Next Evolution of Military Logistics'.

⁵⁰ Cheung et al., 'Delivery of Healthcare Resources Using Autonomous Ground Vehicle Convoy Systems', 2.

⁵¹ Luckenbaugh, 'Just In: Army "Pressing Forward" With Autonomous Vehicle Transport-System'.

mature enough, is the introduction of driver-assist technologies⁵² and leader-follower platforms.^{53,54}

The US Army is pressing forward with the development of autonomous transport systems as part of their Leader-Follower program, and they've targeted the M1075 as the initial target platform, and they expect to have 410 platforms fielded by fiscal year 2029.⁵⁵ As another example, in late 2022, BAE Systems Australia held a battlefield simulation for the Australian Army using two autonomous Rheinmetall-MAN HX2 vehicles, where they successfully demonstrated the leader-follower capabilities of the systems (see figure 3)⁵⁶



Figure 3 – Rheinmetall-MAN demonstrated leader-follower capabilities using two Rheinmetall-MAN HX2 military trucks fitted with an automation kit
Source : The winding path of autonomous vehicles, 2

Closer to home, Rheinmetall Canada has developed a compact autonomous unmanned ground vehicle (UGV), the Mission Master series, designed to assist dismounted soldiers in various types of missions, with the ability to carry a payload of up to 1000 kg over 750 km (see figure 4).⁵⁷ The platform can be fully autonomous, it can operate in a GPS degraded environments and can be configured to carry critical supplies

⁵² Driver-assist technologies, also known as advanced driver-assistance systems (ADAS), are a set of features and technologies designed to enhance vehicle safety and improve the driving experience by assisting the driver in various tasks. These technologies use sensors, cameras, radar, and other advanced systems to monitor the vehicle's surroundings and provide feedback or take action to avoid accidents or improve driving efficiency.

⁵³ Leader-follower platforms, also known as leader-follower systems or platooning, refer to a group of vehicles or robots that work together autonomously, where one designated vehicle (the leader, which could be human operated) sets the pace and direction, and the other vehicles (the followers) automatically adjust their speed, distance, and trajectory to follow the leader.

⁵⁴ Feller, 'The Winding Path to Military Autonomous Vehicles'.

⁵⁵ Luckenbaugh, 'Just In: Army "Pressing Forward" With Autonomous Vehicle Transport-System'.

⁵⁶ Feller, 'The Winding Path to Military Autonomous Vehicles'.

⁵⁷ Rheinmetall, 'Pamphlet : The Rheinmetall Mission Master Family a Pioneering Line of Autonomous Unmanned Ground Vehicles'.

and casualties autonomously over the ‘last mile’. Rheinmetall has just secured a multimillion-dollar contract with Japan who will be procuring some of these platforms for testing.⁵⁸ A similar platform, the THeMIS UGV by Milrem Robotics is also currently being tested in combat by the Ukrainian forces, with a human-in-the-loop functionality for now (see figure 5). Fourteen platforms have been sent over, where seven of them are being used for Cargo and casualty evacuation and seven for route clearance and demining.⁵⁹



Figure 4 – Rheinmetall Mission Master SP in its cargo configuration

Source : The Rheinmetall mission master family a pioneering line of autonomous unmanned ground vehicles

⁵⁸ Kajal, ‘Rheinmetall to Supply Mission Master SP UGVs to Japan for Testing’.

⁵⁹ European Defence Review, ‘Ukrainian Forces Are Taking Full Advantage of Their THeMIS UGVs’.



Figure 5 – The THeMIS unmanned ground vehicles (UGVs) by Milrem Robotics

Source : Ukrainian forces are taking full advantage of their THeMIS UGVs

Sea

Although not as prominent, significant advances have also been made with regards to autonomous sea vessels. The interest in sea vessels has gained recent interest, especially from the US, to address some of the anticipated logistical challenges tied to operations in the Indo-Pacific. As tensions increase, in addition to distance, logistic operations will also be challenged by the proliferation of advanced anti access/area denial capabilities, which will ultimately disrupt supply chains and increase the risk to personnel.⁶⁰ As discussed in the previous section, Canada should also be interested in such platforms to address and mitigate some of its challenges related to securing the North.

In late 2022, the US Navy conducted a series of tests on an unmanned logistic prototype, the USNS Apalachicola (EPF 13), “where the aim was to conduct point-to-point autonomous navigation, vessel handling, and transfer of ship control from manned to unmanned mode”.⁶¹ A contract was awarded to Austal USA and the first vessel was delivered to the US Navy in February 2023. It is the first fully operational US naval ship to have autonomous capabilities, including the ability to navigate within a commercial vessel traffic lane. It can operate for up to 30 days without human intervention and haul 600 tons of cargo at 35 knots, which opens up so many opportunities for unmanned mission in various operations as an autonomous prototype.⁶²

⁶⁰ Munoz and Roaten, ‘AUSA 2023: US Army Eyes Autonomous Vessels for Contested Logistics in Indo-Pacific’.

⁶¹ Lagrone, ‘Crew-Optional USNS Apalachicola Delivers to the Navy, Ship’s Unmanned Future Unclear’.

⁶² Lagrone.



Figure 6 – USNS Apalachicola (EPF 13) by Austal USA

Source : Crew-Optional USNS Apalachicola Delivers to the Navy, Ship’s Unmanned Future Unclear

ETHICAL AND LEGAL CONSIDERATIONS

In his paper, *The Opportunity and Challenge of Autonomous Systems*, Paul D.Scharre states that “understanding how to best incorporate autonomous systems into military forces will require a cross-disciplinary collaboration of not only military, engineers and practitioners but also of lawyers and ethicists.”⁶³

Although there are many ongoing debates regarding the legality and ethics pertaining to the use of lethal autonomous weapon systems (LAWS), autonomous delivery systems, assuming they are unarmed, do not raise the same moral and legal questions. However, there still remains a crucial concern regarding accountability in the event that an autonomous delivery system is involved in an accident where there are civilian casualties and/or important damage to infrastructures.⁶⁴ The remainder of the section will focus on highlighting the factors that demonstrate how the use of autonomous delivery systems fits within current legal constructs and CAF ethics principles.

Law

The emergence of autonomous systems has raised concerns among numerous states and civil societies with regards to the International Humanitarian Law (IHL). At present, there is no specific international treaty expressly forbidding the use of autonomous systems. However, the UN Secretary-General, in his 2023 New Agenda for Peace, advocated for states to finalize by 2026 a legally binding agreement aimed at

⁶³ Scharre, ‘The Opportunity and Challenges of Autonomous Systems’, 4.

⁶⁴ Yazdanpanah et al., ‘Reasoning about Responsibility in Autonomous Systems’, 1456–57.

banning lethal autonomous weapons systems that operate without human control or oversight and/or cannot adhere to IHL principles.⁶⁵

Ensuring adherence to IHL “depends on autonomous systems upholding the principles of distinction, proportionality, necessity, and precautions in attack”.⁶⁶ It is therefore essential to address legal accountability in the event of malfunctions. Mechanisms must be in place to assign responsibility for unlawful actions by autonomous systems, whether to individuals involved in design, production, programming, or to the user state.⁶⁷

If autonomous delivery systems are used in a manner that violates these principles, such as causing indiscriminate harm to civilians or disproportionate damage to civilian infrastructure, then their use would indeed be contrary to IHL. However, if these systems are employed in a manner that respects these principles, their use would likely be considered lawful under IHL, even if fully autonomous.⁶⁸ The *Committee on Legal Affairs and Human Rights (Council of Europe)* also emphasized that user states must thoroughly test and verify autonomous systems to ensure they are predictable, reliable, and in accordance with IHL.⁶⁹ It is with these conditions in mind, that autonomous delivery systems could be employed legally under the IHL and under the Article 36 of Additional Protocol 1 of the Geneva Convention.⁷⁰

Ethics

As discussed previously, the ethical considerations for autonomous delivery systems will differ greatly than those concerning LAWS, assuming once again that they are not equipped with an autonomous weapon platform.

The adoption of autonomous delivery systems not only lowers risk for military personnel by handling ‘dangerous, dull, and dirty’ tasks, but it would also reduce accidental harm to civilians during military operations. These systems can process increased amounts of information, allowing them to react more accurately to unexpected situations, such as a child suddenly running in front of an autonomously operated supply

⁶⁵ Office for Disarmament Affairs, ‘Lethal Autonomous Weapon Systems (LAWS)’.

⁶⁶ Cottier, ‘Emergence of Lethal Autonomous Weapons Systems (LAWS) and Their Necessary Apprehension through European Human Rights Law’, 1.

⁶⁷ Arnold, ‘The Legal Implications of the Use of Systems with Autonomous Capabilities in Military Operations’, 89–93.

⁶⁸ Office for Disarmament Affairs, ‘Convention on Certain Conventional Weapons — Group of Governmental Experts on Lethal Autonomous Weapons Systems’.

⁶⁹ Cottier, ‘Emergence of Lethal Autonomous Weapons Systems (LAWS) and Their Necessary Apprehension through European Human Rights Law’, 2–3.

⁷⁰ Article 36 – New Weapons : In the study, development, acquisition or adoption of a new weapon, means or method of warfare, a High Contracting Party is under an obligation to determine whether its employment would, in some or all circumstances, be prohibited by this Protocol or by any other rule of international law applicable to the High Contracting Party.

truck.⁷¹ According to transport Canada, the leading causes for fatal motor vehicle accidents in Canada (2021), were speed (24.7%), distraction (19.7%), impairment (18.4%) and fatigue (3.4%).⁷² Ultimately, machines will not be affected by sleep deprivation, which is often the case for soldiers, and they will respect all of the conditions it was programmed to follow, such as speed, distance and route.⁷³

Another way that autonomous vehicles may lessen the risk to civilians is by eliminating emotional influences on decision-making. For instance, supply truck drivers may drive recklessly out of fear of being ambushed or simply because they've been overtaken by road rage. Although less probable during logistic convoys, but not impossible, autonomous systems will not seek revenge for a fallen comrade, which can lead to war crimes.⁷⁴

Although autonomous delivery systems have the potential to mitigate the risks to humans, it wouldn't be fair to omit mentioning some of the associated concerns. One of the ethical concerns is with regards to the risks associated with hackers, where the autonomous system could be taken over and cause deliberate harm to civilians and infrastructure, leading to a situation where the IHLs are violated. As discussed earlier, this brings back the question of accountability.⁷⁵ There is also the situation where the system simply malfunctions and ends up causing unintended harm to civilians, but then one can ask themselves the question as to how does this differ from other military systems operated by humans involved in an accident?

Another concern and as stated by Chris Mayer in his essay, *Developing Autonomous Systems in an Ethical Manner*, it will be a question of time before the enemy adapts his strategies towards autonomous systems. On the psychological front, killing a robot does not have the same impact as killing a human, which may force the enemy combatant to redirect efforts elsewhere, potentially putting more civilians in harm's way.⁷⁶

On the institutional front, although less pivotal, there are also concerns that the use of autonomous systems might decrease soldiers' willingness to take risks in the future. If machines handle all the dangerous tasks, soldiers may become reluctant to perform these tasks themselves if they are ever required to do so.

⁷¹ Mayer, 'Developing Autonomous Systems in an Ethical Manner', 70.

⁷² Government of Canada. Transport Canada, 'Canadian Motor Vehicle Traffic Collision Statistics: 2021'.

⁷³ Mayer, 'Developing Autonomous Systems in an Ethical Manner', 67.

⁷⁴ Mayer, 70.

⁷⁵ Klincewicz, 'Autonomous Weapon Systems, Asymmetrical Warfare, and Myth', 183–86.

⁷⁶ Mayer, 'Developing Autonomous Systems in an Ethical Manner', 76.

CONCLUSION

The technology and use of autonomous systems have progressed to the point where they are now being incorporated into future operational concepts by both civilian industries and militaries. This essay has demonstrated that although many challenges still remain, autonomous delivery systems could play a significant role in the CAF logistic operations moving forward. Not only would they greatly minimize the risks to soldiers, CAF's most precious resource, but they could greatly enhance operational efficiency when it comes to addressing the challenges associated with the 'last mile' deliveries. The CAF should leverage the initiatives presented in the DPU to modernize its capabilities, where the government promises to build an innovative and effective defence industrial base and streamline the procurement process.

The CAF has also been presented with the perfect testing ground in Latvia where it could trial various autonomous delivery systems that could bring essential supplies and other necessary items to the front lines during their multinational exercises. This would allow them to develop and trial various concepts of employment to be ready if the conflict were to escalate. The same could be said regarding the security and sovereignty of Canada's North which has been named one of the top priorities of the Canadian government. A progressive approach could be used where the first technologies adopted would be employed with a 'human in the loop' to mitigate some of the risks until the technology becomes more reliable.

While there are challenges and ethical/legal considerations associated with these technologies, they should not impede their adoption. Instead, thoughtful integration and adherence to ethical guidelines could allow the CAF to leverage these systems for strategic advantage while ensuring responsible use. Many first world militaries have taken the bound and are investing significant amounts of money and resources towards the development and acquisition of autonomous delivery systems. While it may seem self-serving, the CAF could greatly benefit from taking advantage of opportunities where initial developmental challenges and expenses are shouldered by other parties, or perhaps, the CAF could enthusiastically embrace this opportunity and become a significant player in the domain of autonomous systems, as it did with cyber security.

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