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AUTONOMOUS CONVOYS

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AIM

1. The aim of this service paper is to outline the current research into autonomous and semi-autonomous vehicle systems used in convoy operations. The paper will discuss the current systems being developed and outline some of the strengths and weaknesses of each to inform the reader on the future options for autonomous convoys for the Canadian Army and joint logistics organizations.

INTRODUCTION

2. The Canadian Army's capstone future operating concept document *Close Engagement: Land Power in an Age of Uncertainty* retains some elements of the former doctrine of adaptive dispersed operations. Amongst these former elements is the tenant of adaptive dispersion which is the "coordinated actions by widely dispersed teams to achieve effects in support of an operational design…"[1] This dispersed nature of Army elements on an operation could lead to strain on the logistics system. Providing logistics to multiple locations will require a fairly substantial logistics table of organization and equipment (TO&E) in order to ensure there are adequate vehicles and operators in a theatre to transport commodities to these dispersed teams. In an era of mission manning caps and the desire to increase the number of soldiers creating effects on the ground, a large logistics organization is not palatable to many commanders. In order to reduce the requirement for logicians in theatre, the Canadian Army should investigate the use of autonomous or semi-autonomous vehicles to support the forward delivery of

[1] Department of National Defence, *Close Engagement: Land Power in an Age of Uncertainty: Evolving Adaptive Dispersed Operations* (Kingston, ON: Canadian Army Land Warfare Centre, 2019), 17.

commodities to dispersed teams. This will also have the added benefit of exposing few soldiers to danger by sending them on convoys in relatively unarmoured vehicles.

3. This paper will provide a synopsis of the types of autonomous systems currently being developed and outline some of the strengths and weakness of each of these systems.

DISCUSSION

4. *Advancing with Purpose: The Canadian Army Modernization Strategy*, which sets forth the plan to modernize the Canadian Army in the 2021 to 2026 timeframe, states that the Army will continue to monitor and pursue emerging technologies and how they can be integrated in to Army operations.[2] Autonomous systems are included within these technologies. The Army is investigating how it can use such systems to complete dull, dirty and dangerous tasks either autonomously or as part of a human-machine system.[3]

5. The United States Army includes convoy operations in the list of dull, dirty and dangerous tasks. They state that convoys are dull due to the long duration and monotony of the task, dirty in that they operate in areas that threaten personal health and dangerous because they offer extensive risk to human life[4] in that the logistics vehicles used on convoy operations are generally unarmoured and therefore more susceptible to enemy attack.

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[2] Department of National Defence, *Advancing with Purpose: The Canadian Army Modernization Strategy* (Ottawa, ON: HQ, Canadian Army, 2020), 51.
[3] *Ibid.*
[4] Shawn McKay et al, *Automating Convoys: Technical and Tactical Risks and Opportunities* (Santa Monica: RAND Corporation, 2020), 7.

6. Types of systems. There are three methods of integrating autonomous or semi-autonomous vehicles into logistics convoys that are currently being researched and developed.

a. Fully Autonomous. In these systems humans are completely removed from the vehicle and convoy operations are monitored remotely from control station. These vehicles can be manually controlled by remote operators if the automated systems becomes overwhelmed by the driving environment.[5]

b. Partially Unmanned. In these systems existing logistics vehicles are fitted with a leader-follower automation kit. This kit allows for a manned vehicle to set a path for unmanned follower vehicles.[6] In the event that the follower vehicle is unable to continue in the lead vehicles path a driver would have to dismount from an accompanying armoured vehicle to take manual control of it until the leader-follower path can be re-established.[7]

c. Minimally Manned. This system is similar to the partially unmanned system in that a lead vehicle establishes a path for follow on vehicles. The difference however is that each follower vehicle is minimally manned with a single person.[8] The follower vehicle will generally drive itself however the driver is available to monitor vehicles diagnostics and the tactical situation. The driver is able to take manual control of the vehicle if required.[9] This avoids the potential

[5] *Ibid*, 3.
[6] *Ibid.*
[7] *Ibid*, *16*
[8] *Ibid*, 3.
[9] *Ibid*, 16.

danger of having a driver move between vehicles as in the partially unmanned option but adds the risk of having more people in unarmoured vehicles for the duration of the convoy.

7. While research into fully autonomous vehicles continues there is still a lot of work that needs to be done in order to create a system that is able to properly function in normal civilian traffic, let alone in a combat environment. This is due to the fact that completely self driving vehicles require large quantities of driving data in order to facilitate machine learning. This data is acquired through video footage of good driving in all possible scenarios. To achieve this machine learning systems would require footage of all driving situations, some of which seldom happen and would be difficult to replicate, such as a nearby collision.[10] This is proving difficult enough to do in civilian traffic, and while some of this machine learning could be incorporated into military autonomous vehicles, there is also the requirement for the vehicles to learn what to do in tactical situation. Due to the difference in the type of driving reaction required between civilian traffic and a tactical situation the vehicles will need to learn to differentiate between the two so they do not try to push through an obstacle in civilian traffic as they would during an ambush. This will add an additional layer of complexity that will need to be incorporated into military autonomous convoys as compared to civilian ones.

8. Additionally, fully autonomous convoys will require a secure network to be able to communicate with each other and reach back to a remote control station in the event

[10] Kelsey Piper, "It's 2020. Where are our self-driving cars?" *Vox,* February 28, 2020, https://www.vox.com/future-perfect/2020/2/14/21063487/self-driving-cars-autonomous-vehicles-waymo-cruise-uber.

that the vehicles encounter a situation which they cannot autonomously navigate.[11] Until the Canadian Forces is able to ensure such a network fully autonomous convoys would not be suitable in electronically contested environment.

9. As such, it is highly unlikely that the Canadian Army will be able to integrate fully autonomous vehicles into logistics convoys in the 10-15 year span covered by *Close Engagement*, therefore they should focus on integrating the leader-follower type systems, discussed above in the partially unmanned or minimally manned integration method. These systems can act as a stepping stone to fully autonomous systems once they are technologically mature enough to be used in a military setting.

10. The technological requirements for both partially unmanned and minimally unmanned vehicles is more or less the same. The main difference is the complexity of the human machine interface in the truck that would allow the embarked driver to take manual control of the vehicle. In a minimally manned vehicle the human machine interface would likely be more robust and provide more data to the driver as they would always be present in the cab to monitor the operation of the vehicle.[12] In a partially unmanned vehicle the level of data displayed on the human machine interface would not need to be as detailed as the driver would only be embarked for a short period to perform a certain task and then dismount therefore there would be a minimal requirement to monitor the overall performance of the vehicle from within the cab.[13]

[11] McKay et al, *Automating Convoys…*, 20.
[12] *Ibid,* 17.
[13] *Ibid*.

11. There are currently two main types of leader-follower systems being studied. The first type uses a combination of GPS, radar and light detection and ranging (LiDAR) technology to maintain the track of the manned lead vehicle, ensure spacing between convoy vehicles and avoid obstacles. This is the same technology which is being integrated into many civilian personal and commercial vehicles today to allow for automatic collision avoidance, emergency braking, lane keeping and self parking[14]. And while this technology is advancing to the point where it will be standard equipment in many civilian vehicles in the near future, there are disadvantages to integrating it into tactical vehicles. This system is reliant on the lead vehicle "dropping" GPS way points at regular interval for the following vehicles to follow.[15] Without GPS the following vehicles cannot track the path of the lead vehicle which will likely cause it to stop and try to reacquire the path, or require a driver to take manual control.[16] As a result in a GPS contested environment this type of vehicle would no longer be able to be autonomous and require manual operation until a GPS signal could be re-established. Further, the use of radar and LiDAR in these vehicles creates a much larger electronic signature than a traditional fully manned convoy.[17] This will make logistics convoys using this type of leader-follower technology easier to find based on this signature thus making them more vulnerable to attack. Finally due to their reliance on electronic signals, this type of leader

[14] Ksenia Ivanova, Guy Edward Gallash and Jon Jordans, *Automated and Autonomous Systems for Combat Service Support: Scoping Study and Technology Prioritization,* (Edinburgh: Land Division, Defense Science and Technology Group, 2016), 19.
[15] William E Travis, *Path Duplication using GPS Carrier Based Relative Position for Automated Ground Vehicle Conoys, (*Auburn: Auburn University, 2010), 102.
[16] McKay et al, *Automating Convoys…*,29.
[17] Ivanova et al, *Automated and Autonomous Systems…, 19.*

follower vehicle may be susceptible to friendly electronic countermeasures which could unintentionally render them inoperable.[18]

12. The second type of leader-follower vehicles uses a vision based robotic follower vehicle which can be programmed to follow any specified object. This system mitigates many of the disadvantages posed by the above mentioned GPS based system in that there is no information relayed electronically between the vehicles therefore there is little threat of electronic interference or an increased electronic signature.[19] This system uses a pan/tilt/zoom camera system to allow the follower vehicle to track the lead vehicle in much the same way that a human driver would. The follower vehicle is programmed to follow at a certain distance or time behind the lead vehicle and maintains this spacing based on the relative size of the lead vehicle in the field of view. It also uses this relative size to determine and remember the path of the lead vehicle, allowing it to follow automatically. [20]

13. In addition to the fact that the vision based system does not create an additional electronic signature or rely on GPS, there are the added benefits that such as system is much more cost effective than GPS based systems, therefore allowing a wider distribution of semi-autonomous systems across the Army.[21] Also, a vision based system is designed to follow any object that is designated as the leader without the lead vehicle requiring additional equipment to be installed.[22] This would allow for greater flexibility

[18] J. Giesbrecth, *Development of a Vision-Based Robotic Follower Vehicle*, (Suffield: Defence Research and Development Canada, 2009), iii.
[19] *Ibid, 2.*
[20] *Ibid.*
[21] *Ibid.*
[22] *Ibid.*

in choosing the lead vehicle based on the threat environment and terrain. It could also allow for a hand off of a convoy between elements as a convoy moves from a relatively safe area to an area of higher threat.

14. A vision based system does have its disadvantages. Due to the fact that it's operation relies on the follower vehicle visually tracking the lead vehicle it must maintain a near constant line of sight, therefore if this line of sight is broken by an obstacle or obscured by environmental factors such as dust or smoke the follower vehicle may lose sight of its lead and be unable to continue.[23] Additionally the vibrations caused by travel over rough terrain may impair the clarity of the video causing the follower vehicle to misinterpret the data it is receiving and go off course.[24] Both of these issues would currently limit the environments in which these systems could effectively operate, restricting them to open and smooth terrain in order for them to be most effective. These issues could be somewhat mitigated if these vehicles were used in a minimally manned convoy and drivers were constantly present in the cab to take manual control of the vehicle in the event that clear sight of the lead vehicle was lost.

CONCLUSION

15. The integration of autonomous or semi-autonomous systems into Canadian Army logistics convoys provide the opportunity to reduce the logistics footprint in a theatre of operations and decrease the number of soldiers being sent into harms way in unarmoured or lightly armoured vehicles on convoy operations. While there are current technical and data challenges in developing fully autonomous convoy systems there continue to be

[23] Travis, *Path Duplication…*, 14-15.
[24] Giesbrecth, *Development of a Vision-Based…, 2.*

regular advances in this technology which will make it a reality in future army operations. However, in the short to mid term, partially unmanned and minimally manned vehicle integration methods are a more likely solution to reducing the logistics foot print and potential danger to soldiers. Each of these methods decrease the number of soldiers in a convoy and in the case of a partially unmanned system, allow them to travel in armoured vehicles when they are not required to be manually operating the vehicles.

16. Both of these integration methods employ a leader-follower vehicle technology that allows a semi-autonomous follower vehicle to follow in the path of a manned leader vehicle. Currently there are two types of systems being developed to allow for this leader-follower interaction, a GPS/radar based system and a vision-based system. Both have their weakness with the former relying on a secure network and being susceptible to detection due to the large electronic signature created by its sensors, and the latter requiring near constant line of sight with the lead vehicle, leaving it susceptible to environmental conditions and obstacles. Therefore further research and development is required on both systems before they can become operational on the battlefield of the future.

RECOMMENDATION

17. It is recommended that the Canadian Army continue to monitor the development of autonomous and semi-autonomous convoy systems and begin to develop a concept on how to integrate such systems into logistics operations, once they are mature enough to be deployed in an operational setting.

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