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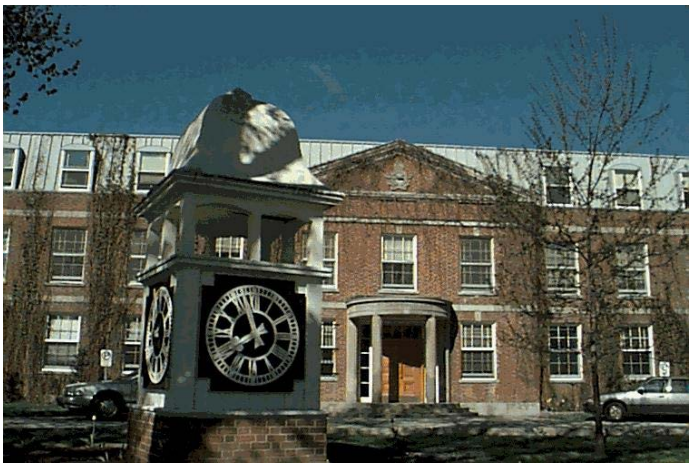

LESSENING THE INFANTEER'S BURDEN: IS ROBOTICS THE ANSWER?

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JCSP 45

Service Paper

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AIM

1. The aim of this service paper is to recommend that the Canadian Army should continue to research and develop robotics in order to improve the capabilities of the 21st century Infanteer, specifically in the dismounted or light role. Robotics research continues to expand into numerous fields that could assist the Infantry; this paper will focus on those that are worn on the soldier, such as exoskeletons as well as robotic carriers.

INTRODUCTION

2. For hundreds of years scientists have been trying to reduce the physical burden on the soldiers while concurrently, advances in technology have resulted in the addition of more and more equipment. The solution to any capability gap for the dismounted soldier must be assessed against its impact on the system burden, especially weight. Soldier modernization programs have fielded important new technologies and capabilities down to the individual soldier level (e.g., GPS, soldier radios, night vision equipment, weapon-mounted sensing, aiming and illumination aids, under-slung grenade launchers, breaching equipment or electronic countermeasures equipment[1]). The threat of Improvised Explosive Devices (IEDs) also results in more protective equipment being worn. Infanteers must now carry many types and sizes of batteries since most of these new capabilities require power, and batteries are not standardized across equipment procurements, further adding to their weight burden. [2] Studies at DRDC and similarly by other NATO partners have established the weight ratio burden limits of 30% of average body weight

[1] Stephen Thorne, "Rise in soldiers' loads are a matter of life and death, experts say", Legion Magazine. Last modified 2 May 2018. https://legionmagazine.com/en/2018/05/rise-in-soldiers-loads-are-a-matter-of-life-and-death/
[2] Canada. Government of Canada, "Soldier Systems Technological Roadmap: Capstone Report and Action Plan, 2011, 47.

for fighting/assaulting and 45% for march loads.[3] Annex A is a table from the Infantry School that shows that each member of a dismounted section is substantially over each limit. Efforts are being made in upcoming "Soldier Systems" projects as well as further scientific research to reduce the weight of certain capabilities and systems by improving the materials used, standardizing the power requirements and reconsidering what the soldiers wear as integrated systems.[4]

3. The general tasks of the Infantry have not changed in this century and still remain extant. According to the Canadian Infantry's doctrine manual "The Infantry Battalion in Battle,"[5] the infantry battalion may be assigned the following tasks:

a. to destroy the enemy in close combat;

b. to defend a position by the holding of ground;

c. to fight as covering force troops;

d. to act as all or part of a reserve to counter-attack or block;

e. to participate in airmobile, airborne or amphibious operations;

f. to establish surveillance and conduct patrols;

g. to conduct security tasks, including rear area security; and

h. to exploit the effects of NBC weapons.

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[3] Canada. Dept. of National Defence. Infantry Section and Platoon in Operations. edited by Department of National Defence: CADTC/DAD ACT Infantry on the authority of Commander Canadian Army 2013. 10A-1.
[4] Canada. Government of Canada, "Soldier Systems Technological Roadmap: Capstone Report and Action Plan, 2011, 25.
[5] Canada. Dept. of National Defence. The Infantry Battalion in Battle. Vol. 1. Ottawa: Issued on the authority of the Chief of the Defence Staff, Dept. of National Defence, 1992. 1-2-1.

4. The nature of counter-insurgency and adaptive dispersed operations[6], deployed to missions that support *Strong, Secure, Engaged: Canada's Defence Policy*[7], can make re-supply difficult, particularly in immature theatres of operation. Sustainment loads of consumables (such as ammunition, batteries, food and water) may be higher than ever due to a lack of confidence in re-supply therefore dismounted soldiers are conducting operations having to carry even more supplies.

5. Consider the body's reaction; as load weight increases, so do ground reaction forces, and forces and moments acting on the ankle, knee or hip joints. As backpack loads increase, hip flexion or trunk forward lean increases significantly, a strategy adopted by users to move the load over their body's base of support. Increasing load weight significantly decreases stride length and increases stride frequency, and the amount of time that both feet are in contact with the ground during the gait cycle. Such gait adaptations are likely intended to maintain speed of movement while retaining stability.[8] This can result in short term or long term injury to the soldiers, ranging from blisters and strains to stress fractures and compression injuries especially affecting the hips, back, knees and feet. To mitigate this problem, this paper will examine potential Human Augmentation systems and robotic carriers, as two possible solution sets for reducing the burden.

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[6] Canada. Dept. of National Defence. Land Operations 2021: Adaptive Dispersed Operations: A Force Employment Concept for Canada's Army of Tomorrow. Kingston, Ont: Directorate of Land Concepts and Doctrine, 2007

[7] Canada. Dept. of National Defence. Strong, Secure, Engaged: Canada's Defence Policy. Ottawa, Ont.: National Defence 2017.

[8] Billing, D.C., A.J. Silk, P.J. Tofari, and A.P. Hunt. 2015. "The effects of military load carriage on susceptibility to enemy fire during tactical combat movements." Journal of Strength and Conditioning Research 29 (11S):S134-S138

DISCUSSION

Human Augmentation Systems

6. Human Augmentation Systems, such as exoskeletons, offer the opportunity to create "super human soldiers" who are more effective on operations, better able to carry loads, further, faster, longer, with perhaps less potential for acute musculoskeletal injuries and more resilient to the stresses of combat. This will result in increased combat effectiveness and decreased medical and rehabilitation costs to the CAF.

7. Not all exoskeletons are created the same, but they are evolving at a rapid pace. While the initial prototypes were heavy and bulky and not necessarily suited for field conditions, newer versions are generally being designed in lighter weight materials and are apparently "field ready."[9] While military focus in exoskeletons was initiated by the Special Forces communities, research is starting to proliferate into the wider army space, as the requirements will often be different.

8. A major differentiator between the currently developing systems is how they are powered. The lightest suits are unpowered and can include combinations of pulleys and gears or simply a frame that is connected directly to the ruck sack that extend to the wearer's boot. They can be soft, like clothing, biologically inspired "exosuits"[10] and assist normal muscular action through actuated cables. Systems like these boast the ability to reduce the weight burden by 30-50% and do not require additional batteries or actuators. As for the powered suits, those also have a multitude of designs and capabilities. Most of these have hydraulic systems and vary

[9] Mawashi Science and Technology, "UPRISE Technology Overview." Last modified 10 May 2017. http://www.mawashi.net/images/Mawashi_UPRISE_Technology_Overview_20170510.pdf
[10]Alan T. Asbeck and al, "Biologically-inspired Soft Exosuit", 2013 IEEE 13th International Conference on Rehabilitation Robotics, 2013

between assisting only the lower extremities (hip-down) with a backpack-like frame to mount the loads while some include a support along the wearer's spine and neck. This could further reduce the burden of the body armour and tactical vest, not just the pack.[11] The powered suits have approximate ranges of 20km when soldiers move at 4 km/h. They could reach maximum speeds of 11km/h over long durations or short bursts 16 km/h carrying loads as high as 91 kg.[12] The heaviest of the current prototypes weighs 95 kg and is a full body exoskeleton that assists the wearer's legs, back and arms. This suit boats the ability to lift at a ratio of 17:1 and enables the wearer to lift over 20 kg with each arm without any perceived exertion and punch through wood blocks. This suit is currently seen to be a strategic asset, best suited for moving logistic loads.[13]

9. There are a number of advantages and disadvantages between the soft exosuits and the rigid braces of the exoskeletons and between the powered and unpowered frames. Industry continuously strives to improve their solutions by making the equipment lighter, more ergonomic and flexible and less cumbersome. Many of these systems are still unreliable prototypes (Technological Readiness Level 7 or lower) and are 5-10 years away from being ready for mainstream use.[14] Challenges remain if exoskeletons are ever to become mainstream, particularly for dismounted soldier application, including: weight power demands (though there is certainly potential for exoskeletons to also support power generation to a limited degree), uncomfortable interfaces, reliability and maintainability issues, requirement for customized fit,

[11] Mawashi Science and Technology, "UPRISE Technology Overview." Last modified 10 May 2017. http://www.mawashi.net/images/Mawashi_UPRISE_Technology_Overview_20170510.pdf
[12] Army Technology Website, "Human Universal Load Carrier, Lockheed Martin."Accessed 10 October 2018. https://www.army-technology.com/projects/human-universal-load-carrier-hulc/
[13] Army Technology, "Raytheon XOS 2 Exoskeleton, Second-Generation Robotics Suit." Accessed 10 October 2018. https://www.army-technology.com/projects/raytheon-xos-2-exoskeleton-us/
[14] Joyce Conant, "Prototype exoskeleton suit would improve Soldiers' physical, mental performance", US Army Website, 14 July 2017

compatibility with wide range of soldier sizes, equipment, and tasks.[15] Many of these are very rigid and heavy and would potentially limit the types of movements required of an Infanteer, such as getting down into the prone position and back up, and jumping over low walls.

Robotic Carriers

10. An alternative for empowering the soldier to carry an increased weight burden is to load the extra personal kit and 1st line of supplies on a robotic carrier or "follower". This could reduce the weight burden by 20-25 kg per soldier, depending on the system. The technology for these machines have also advanced in recent years with new prototypes being able to be electromagnetically "leashed" to the leader and move across all types of rough terrain[16]. Besides only carrying equipment for the infantry section, it can also provide portable power to recharge batteries and carry casualties. With the ever changing contemporary operating environment, Infanteers require the ability to be flexible. They must have, at close reach, the equipment required to rapidly shift to conduct capacity building missions as well as have non-lethal weapons available in addition to their regular fighting equipment. Examples of robotic carriers vary between remote controlled or autonomous variants of small utility vehicles that can be either wheeled or tracked[17]. Many of these are ready to be fielded now. Further, for the most complex terrain types, prototypes of quadruped robotic mules are being developed. For example, a four-legged robot, the size and shape of a horse, can carry 180 kg and can sense and negotiate most terrain types. It can walk quietly at 2-4 km/h or run on flat surfaces at up to 12 km/h, although not nearly as quietly. They boast operating time of 20 hours and ranges of 24 km,

[15] Steven .H. Collins, M. B. Wiggin, and G. S. Sawicki. "Reducing the energy cost of human walking using an unpowered exoskeleton." *Nature* 522, 11 June 2015. 212-215.
[16] Stew Magnuson "Robotic Mule Ready to be Fielded, Vendors say" National Defense, Vol. 96, No. 696, Nov 2011.
[17] Qinetic Canada, "Cargo Handing Robots and Mules: Cargo Handling Raider II." https://www.qinetiq.com/what-we-do/robotics/cargo-handling-robots-and-mules

which seems appropriate for the tasks of the Infanteer.[18] One of the challenges is to confirm how all the carriers would integrate with the section and what distance they should stay at. Another challenge is how to make carriers affordable, depending on the sensors and algorithms required. Combat engineers have been using robots to defeat improvised explosive devices and while these could carry some supplies, they do not have the ability to move over rough terrain and still require a human to control. All robotic carrier solutions have challenges to overcome for the near to mid-term, particularly related to portable power, stealth, and ability to traverse very complex terrain under harsh weather conditions.

CONCLUSION

11. The role of the infantry is to close with and destroy the enemy, by day or by night, in all weather conditions, and terrain.[19] In order to accomplish this, each soldier requires a myriad of equipment that is only getting heavier and heavier. The soldier overload has contributed to many injuries, resulting in disability payments, loss of combat readiness, and potentially casualties and fatalities in the battlefield. All efforts to improve and add new equipment must take into consideration the weight. There are a number of potential solutions that could remove or reduce the weight burden on the soldiers. Human Augmentation Systems, worn on the soldier range from cable-enhanced clothing to systems with pulleys and gears, light weight titanium braces to motorized and high pressure hydraulically powered exoskeletons with computers at each joint that are highly ergonomic but still are untested in field conditions. Robotic Carriers are further along in technology, with some simply being converted All-Terrain vehicles with sensors to

[18] Defense Advanced Research Projects Agency, "Legged Squad Support System (LS3) Program Information." Accessed 10 October 2018. https://www.darpa.mil/program/legged-squad-support-system
[19] DND. 2013. Infantry Section and Platoon in Operations. edited by Department of National Defence: CADTC/DAD ACT Infantry on the authority of Commander Canadian Army

navigate and avoid collisions. Being wheeled or tracked does limit their ability to move across all terrain types and therefore four-legged robots are being developed to bridge that capability gap although these are far from being ready for distribution. In the end, the Infanteers are carrying much too much weight and long term effects are being felt from a medical standpoint as well as an operational readiness point of view.

RECOMMENDATION

12. Just as the factors contributing to soldier burden are multi-faceted, so must the strategies be for mitigating the burden. It is recommend that the Canadian Army continues to follow the work being done in the Special Forces communities for Human Augmentation Systems and starts developing its own requirements specific to the different task and mission sets across the Army. Currently most exoskeletons are too heavy, too complex and unproven on operations and may actually pose more risk than opportunity for the Infanteer, but with further user involvement and testing they could become a game-changer in the future. It would be further recommended that the goal of employing an exoskeleton suit must be to reduce the burden on the soldiers, not to allow more weight to be carried. The employment of Robotic carriers can be a viable mid-term solution. However, in the short term, it is recommended that all efforts continue towards small incremental reductions in weight of the complete "soldier system" or improvements in the load carriage design. From better, lighter materials for body armour, to caseless ammunition, and common power supplies for all electronic devices, there are a plethora of opportunities to reduce the physical burden on our soldiers which then affect the perceptual and cognitive abilities that our Infanteers need in the performance and execution of assigned tasks. While it is less expensive to procure common equipment for all soldiers, since the Infanteers carry the heaviest burdens, maybe it is time to consider specific load carriage solutions specific for them.

Annex: A. Typical load carried by dismounted Canadian infantry soldiers, by role, during recent operations in Afghanistan.

BIBLIOGRAPHY

Canada. Canadian Army Doctrine and Training Centre and Canada. Dept. of National Defence. The Infantry Section and Platoon in Operations. Kingston, Ont: Army Doctrine Centre, Canadian Army Doctrine and Training Centre Headquarters, 2016.

———Dept. of National Defence. Land Operations (English). Fort Frontenac, Kingston, Ont: Issued on the authority of the Chief of Land Staff by the Army Publishing Office, 2008.

———Dept. of National Defence. Command in Land Operations (English). Ottawa: National Defence Headquarters, 2007.

———Dept. of National Defence. Land Operations 2021: Adaptive Dispersed Operations: A Force Employment Concept for Canada's Army of Tomorrow. Kingston, Ont: Directorate of Land Concepts and Doctrine, 2007.

———Dept. of National Defence. Strong, Secure, Engaged: Canada's Defence Policy. Ottawa, Ont.: National Defence 2017.

———Dept. of National Defence and Canada. The Infantry Battalion in Battle. Vol. 1. Ottawa: Issued on the authority of the Chief of the Defence Staff, Dept. of National Defence, 1992

Army Technology, "Raytheon XOS 2 Exoskeleton, Second-Generation Robotics Suit." Accessed 10 October 2018. https://www.army-technology.com/projects/raytheon-xos-2-exoskeleton-us/

Army Technology, "Human Universal Load Carrier, Lockheed Martin." Accessed 10 October 2018. https://www.army-technology.com/projects/human-universal-load-carrier-hulc/Bernton, Hal. The Seattle Times, "Weight of War Gear that Protects Troops also Injures Them," 13 February 2011. Accessed 10 October 2018. http://www.seattletimes.com/nation-world/weight-of-war-gear-that-protects-troops-also-injures-them/

Collins, S. H., M. B. Wiggin, and G. S. Sawicki. 2015. "Reducing the energy cost of human walking using an unpowered exoskeleton." *Nature* 522 (7555):212-215.

Conant, Joyce, US Army, "Prototype exoskeleton suit would improve Soldiers' physical, mental performance," Last modified 14 July 2017. https://www.army.mil/article/190776/prototype_exoskeleton_suit_would_improve_soldiers_physical_mental_performance

Defense Advanced Research Projects Agency, "Legged Squad Support System (LS^3) Program Information." Accessed 10 October 2018. https://www.darpa.mil/program/legged-squad-support-system

Qinetic Canada, "Cargo Handing Robots and Mules: Cargo Handling Raider II." https://www.qinetiq.com/what-we-do/robotics/cargo-handling-robots-and-mules

Orr, R, R Pope, V Johnston, and J Coyle. 2012. "The operational load carriage context of the Australian army soldier." First Australian Conference on Physiological and Physical Employment Standards, Canberra, Australia, 27-28 November 2012

Thorne, Stephen, “Rise in soldiers’ loads are a matter of life and death, experts say” Legion Magazine. Last modified 2 May 2018. https://legionmagazine.com/en/2018/05/rise-in-soldiers-loads-are-a-matter-of-life-and-death/

White, Andrew, “Reducing the Burden: Managing Combat Loads Carried by Dismounted Soldiers, Military Technology Magazine, June 2016

Annex A: Typical load carried by dismounted Canadian infantry soldiers, by role, during recent operations in Afghanistan

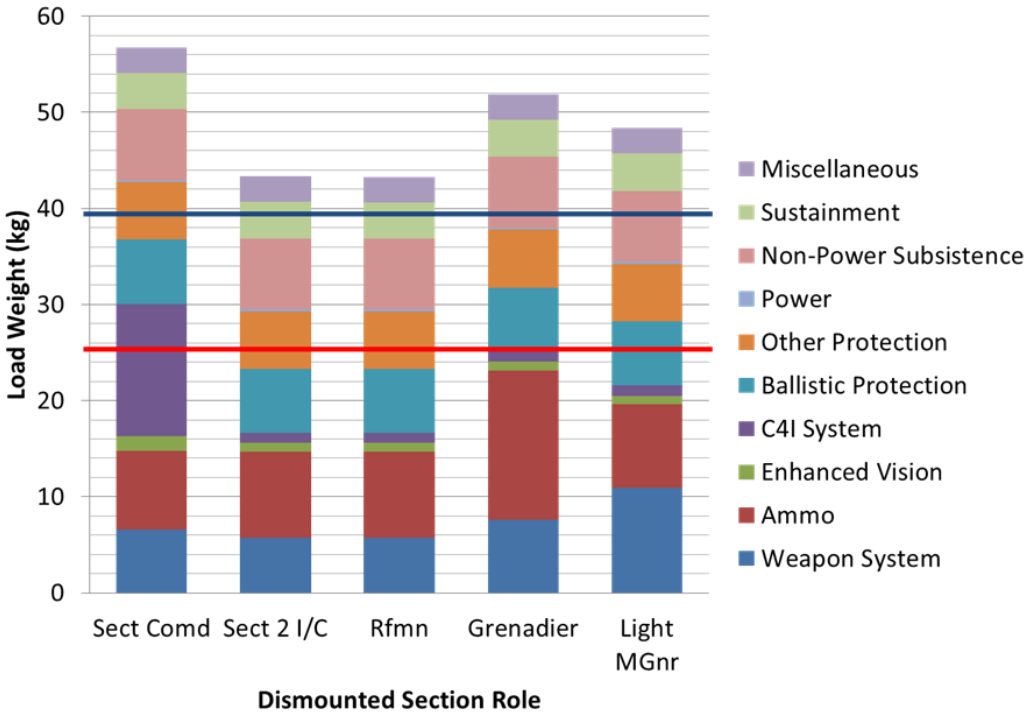

Figure 1. Consensus on Canadian dismounted infantry loads, by dismounted infantry section role, for a typical Afghanistan mission (for equipment category descriptions[i]). Horizontal lines represent maximum recommended or doctrinal loads for the average soldier weight (86.8 kg): the upper blue line represents 45% of average body weight for administrative moves or marching order, and the red line represents 30% of body weight for patrolling, advance to contact missions or fighting order. (Sect Comd = Section Commander, Sect 2 I/C = Section Second in Command, Rfmn = Rifleman, Light MGnr = Light Machine Gunner).

[i] Figure 1 equipment categories are summarized as follows: Weapon – includes rifle, pistol, ancillary equipment (cleaning kits, spare barrels, slings), sights, weapon aiming and illumination aids; Ammo – All ammunition, grenades and pyrotechnics; Enhanced vision – head-mounted (night vision goggles), or hand-held (binoculars, laser range finders) but not weapon-mounted, which are reflected in weapon system); C4I – Equipment related to command, control, communications and computing equipment, including radios, ancillary equipment (antennae, headsets), displays, digital maps, GPS, and also pencil and paper; Ballistic Protection – ballistic helmet, eyewear and body armour (soft and hard plates); Other Protection – environmental protection (raingear, footwear, gloves, hat) and hearing protection (if not integrated with radio headset, in which case it fall under C4I); Power – batteries, rechargers, energy harvesters; Non-Power Subsistence – water, food and food preparation equipment; Sustainment – load carriage equipment, overnight gear; Miscellaneous – includes identification, emergency first aid gear, personal items (tobacco, reading material); and mission-specific gear (from ladders, stretchers, breaching tools, jamming devices, etc).