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USER NEEDS ANALYSIS FOR BURDEN MITIGATION SUPPORT TO ARMY STAKEHOLDER ORGANIZATIONS

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Abstract

Physical and cognitive burdens on the soldier are a multi-factorial problem that is affected by the actions and decisions of many different Canadian Army stakeholder organizations. Under Defense Research and Development Canada's (DRDC) Soldier System Effectiveness (SoSE) project, a WBE has been established to address the problem of soldier burden. The goals of this WBE are to better understand the factors contributing to soldier burden and to develop, validate and recommend strategies to mitigate the associated burden. The aims of this project were to review the needs of stakeholder organizations and to identify, and prioritize, strategies for the way ahead.

Focus group discussions were held with six stakeholder organizations including the Army Combat Development Board (ACDB), the Canadian Army Land Warfare Centre (CALWC), the Canadian Army Doctrine and Training Command (CADTC), the Director Land Requirements (DLR 5), the Director Soldier System Project Management (DSSPM), the Infantry School, Combat Training Centre Gagetown, and the Medical Group at 2 Field Ambulance.

The overwhelmingly consistent need of stakeholder organizations from the Burden Mitigation WBE is scientific evidence to support burden-related decisions. Stakeholders require scientific evidence to support and justify difficult decisions, valid measures and standards to control and shape the sources of burden, and knowledge and awareness of the effects and causes of burden, necessary to transform the enabling culture of overburdening in the Canadian Army. In reviewing the stakeholder needs for scientific evidence to fill gaps in knowledge and to support the development and implementation of solutions, several action streams are recommended.

Executive Summary

USER NEEDS ANALYSIS FOR BURDEN MITIGATION SUPPORT TO ARMY STAKEHOLDER ORGANIZATIONS

**David Tack, HumanSystems[®] Incorporated; Contractor Report submitted in partial fulfillment of PWGSC contract No. W7701-166107/001/QCL
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Burdening the soldier is not new. The soldier has had to bear moderately heavy loads as a condition of their profession throughout recorded history. However, a number of new and emerging soldier system advances and technologies have greatly added to the soldier's burden in both physical and mental terms. Increases in soldier protection systems have increased carried weight, bulk, and stiffness of the equipped load. Advances in soldier system digitization have added new sensors, radios, soldier computers, navigation tools, illuminators, etc., each requiring batteries and collectively adding to the burden on the soldier and their weapon. New information systems, down to the soldier level, may be increasing the cognitive burden on the soldier and throughout the reporting chain of command. Physical and mental burden are known to contribute to overuse injuries, reduced operational task performance, and deficiencies in combat effectiveness. Exposure to these burdens for extended durations and frequent periods over a career can reduce the length of careers and organizationally reduce battle readiness.

Under Defense Research and Development Canada's (DRDC) Soldier System Effectiveness (SoSE) project, a WBE has been established to address the problem of soldier burden. The goals of this WBE are to better understand the factors contributing to soldier burden (physical, cognitive and psychological) and to develop, validate and recommend strategies to mitigate the burden associated with the soldier's equipment through targeted S&T in niche knowledge gap areas and through leverage of international S&T in burden mitigation.

Physical and cognitive burdens on the soldier are a multi-factorial problem that is affected by the actions and decisions of many different Canadian Army stakeholder organizations. Key to the goals of the Burden WBE is an understanding of the issues and needs of these stakeholder organizations for burden support from DRDC. The aims of this project were to review the needs of stakeholder organizations and to identify, and prioritize, strategies for the way ahead.

Focus group discussions, lasting 2-4 hours, were held with stakeholder organizations including the Army Combat Development Board (ACDB), the Canadian Army Land Warfare Centre (CALWC), the Canadian Army Doctrine and Training Command (CADTC), the Director Land Requirements (DLR 5), the Director Soldier System Project Management (DSPPM), the Infantry School, Combat Training Centre Gagetown, and the Medical Group at 2 Fd Amb.

The overwhelmingly consistent need of stakeholder organizations from the Burden Mitigation WBE is scientific evidence to support burden-related decisions. Army stakeholders intuitively recognize that physical and cognitive burden can increase the likelihood of soldier injuries (physical and mental), reduce battle readiness, shorten careers, reduce physical and mental performance in the fight, and ultimately reduce operational effectiveness. However, it is difficult for stakeholders to act, efficiently and effectively, on intuition alone. To be effective, stakeholders require scientific evidence to support and justify difficult decisions, valid measures and standards to control and shape the sources of burden, and knowledge and awareness of the effects and causes of burden, necessary to transform the enabling culture of overburdening in the Canadian Army. In reviewing the stakeholder needs for scientific evidence to fill gaps in knowledge and to support the development and implementation of solutions, several action streams are recommended.

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FIGURE 1: SUPPORT REQUIRED FROM BURDEN MITIGATION WBE10

1. Introduction

Burdening the soldier is not new. The soldier has had to bear moderately heavy loads as a condition of their profession throughout recorded history. However, a number of new and emerging soldier system advances and technologies have greatly added to the soldier's burden in both physical and mental terms. Increases in soldier protection systems have increased carried weight, bulk, and stiffness of the equipped load. Advances in soldier system digitization have added new sensors, radios, soldier computers, navigation tools, illuminators, etc., each requiring batteries and collectively adding to the burden on the soldier and their weapon. New information systems, down to the soldier level, may be increasing the cognitive load on the soldier and throughout the reporting chain of command. Physical and mental burden are known to contribute to overuse injuries, reduced operational task performance, and deficiencies in combat effectiveness. Exposure to these burdens for extended durations and frequent periods over a career can reduce the length of careers and organizationally reduce battle readiness.

Under Defense Research and Development Canada's (DRDC) Soldier System Effectiveness (SoSE) project, a WBE has been established to address the problem of soldier burden, entitled "Mitigation of Soldier Burden induced by the Soldier System". The goals of this WBE are to better understand the factors contributing to soldier burden (physical, cognitive and psychological) and to develop, validate and recommend strategies to mitigate the burden associated with the soldier's equipment through targeted S&T in niche knowledge gap areas and through leverage of international S&T in burden mitigation.

Physical and cognitive burdens on the soldier are increasing, with the advent of new and emerging soldier systems, and are a multi-factorial problem that is affected by the actions and decisions of many different Canadian Army stakeholder organizations. Key to the goals of the Burden WBE is an understanding of the issues and needs of these stakeholder organizations for burden support from DRDC.

1.1 Aims

The following aims were fulfilled by this project:

- Review the needs of stakeholder organizations for support from the Burden Mitigation WBE.
- Identify and prioritize strategies for the way ahead.

2. Approach

Focus group discussions, lasting 2-4 hours, were held with each of the following stakeholder organizations.

- Army Combat Development Board (ACDB)
- Canadian Army Land Warfare Centre (CALWC) and the Canadian Army Doctrine and Training Command (CADTC)
- Director Land Requirements (DLR 5)
- Director Soldier System Project Management (DSSPM)
- Infantry School, Combat Training Centre Gagetown
- Medical Group at 2 Fd Amb

For each focus group, presentations were provided to the attendees on the issues of physical and cognitive burden for soldiers, evidence of DRDC approaches and new technologies which might offer burden mitigating strategies and interventions, followed by facilitated discussion of issues, utility and usability associated with potential strategies, and needs pertinent to each stakeholder organization.

3. Findings

Focus group results are summarized in this section and are detailed in Annex A.

Burden Mitigation WBE support to evidence-based decision-making was a common theme expressed in all six stakeholder focus group sessions. These support requirements are organized into two groupings: filling critical gaps in knowledge and development and/or assessment of potential solutions. Focus group findings are organized in this section according to the framework depicted below in Figure 1.

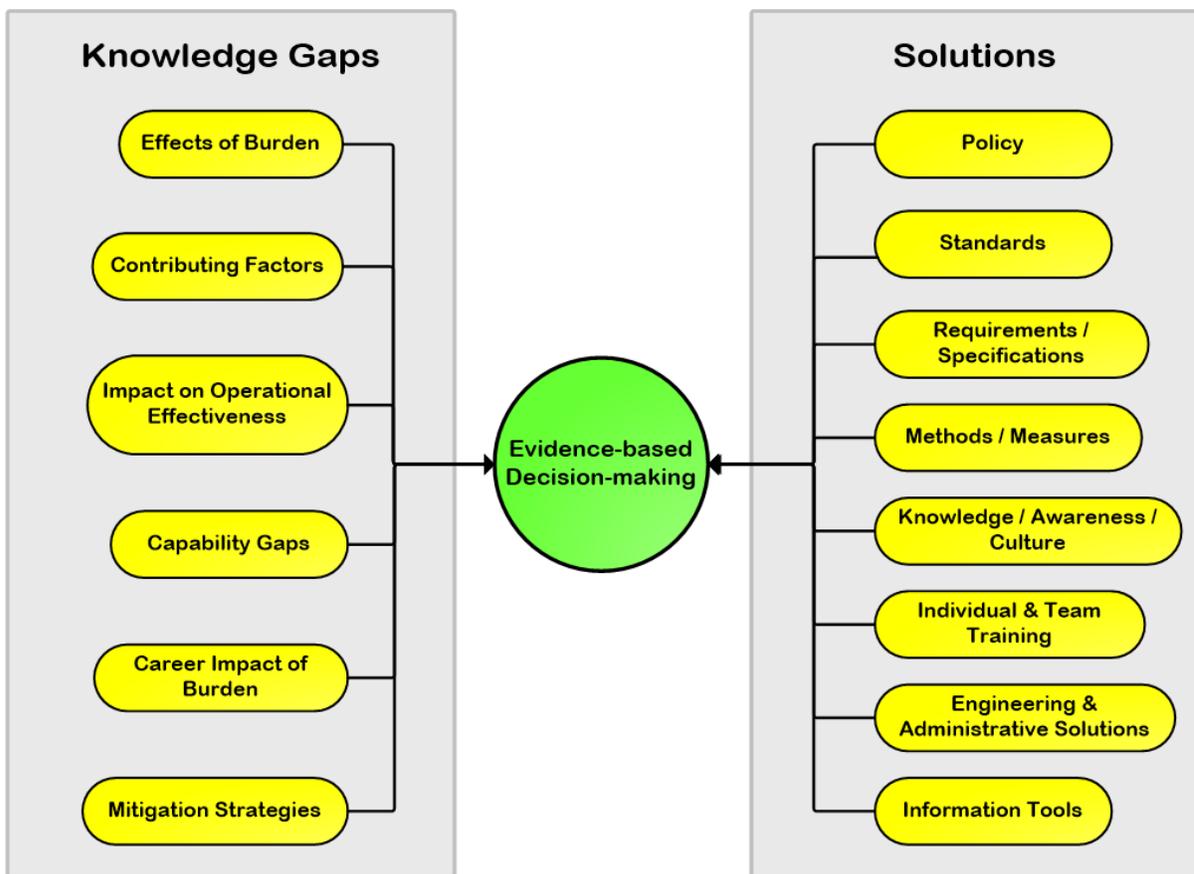


Figure 1: Support Required from Burden Mitigation WBE

3.1 Knowledge Gaps

Stakeholders indicated that there were significant gaps in their knowledge that limited their ability to meaningfully reduce soldier burden. Stakeholders were seeking support from the Burden Mitigation WBE in the following areas.

3.1.1 Effects of Burden:

Stakeholders generally recognize that physical and cognitive burden is undesirable when these exceed a soldier's capacity to some degree but they lack the scientific evidence to understand the relative impact on wellbeing, performance, survivability, and overall mission effectiveness. Physical and cognitive workload comments are summarized below.

Physical Burden:

- DLR needs the scientific evidence for the adverse affects of over-burdening the soldier on performance, wellbeing, and survivability, so that this can be used to influence decision-making in the setting of requirements and throughout the acquisition chain.
- CALWC/CADTC needs scientific study to more accurately determine the cost of various dimensions of physical burden on soldier performance, as these relate to a range of soldier characteristics (e.g. strength, endurance, size, shape). There is also a need for a risk analysis or risk model development to relate the dimensions of physical burden and soldier capacity to outcomes, such as performance, injury, and operational effectiveness.
- ACDB needs evidence-based information on the performance and injury effects of burden to better inform the risk management process during decision-making. ACDB would like to recast the question of burden in terms of performance or risk optimization. In this way, all the risk factors that influence soldier casualties can be considered together to ensure the best balance of threat protection, individual performance, individual and team sustainment, firepower, injury risk, and ultimate survivability.
- ACDB also suggested that a Pareto analysis needs to be undertaken of all clothing and equipment items, in terms of burden, to determine their relative and absolute contribution to overall burden effects on performance, wellbeing, survivability and effectiveness.
- Infantry School instructors know intuitively and through experience that heavier loads reduce soldier performance and that this loss of effectiveness may affect Unit effectiveness, but there is a general lack of knowledge about the true performance effects of overburdening a soldier. Instructors also know that heavier loads increase a soldier's risk of injury but, again, mechanisms of injury and associated load factors are not well understood.

Cognitive Workload:

- There is an ongoing and increasing proliferation of information systems on the battlefield and these systems are becoming more ubiquitous at the small Unit and soldier level. There remains an outstanding concern that such systems could distract soldiers from their procedural tasks of soldiering and cognitively overload them, reducing their capacity to cope with the cognitive demands of immediate operations and exposing them to higher levels of mental workload and combat stress.

ACDB needs to understand the current cognitive demands on soldiers and Unit commanders, their capacity to take on further cognitive demands, and the impact of exceeding cognitive capacity on soldier/commander performance, wellbeing and effectiveness.

- CALWC needs more scientific study to characterize the types of information burden possible at each soldier and command level, the likely effects of being overloaded in personal wellbeing, performance and effectiveness, and the implications for mission effectiveness, contrasted against the added benefits of providing such information.
- Infantry School instructors suggested that the Army needs to understand the levels and sources of cognitive workload associated with new information systems on the battlefield, and determine the extent to which these demands might be problematic. There also needs to be an evidenced-based assessment of the impact of increasing cognitive burden in terms of task performance, individual and team effectiveness, mental workload, and mental stress, according to different soldier roles, missions, situations, and conditions.

3.1.2 Contributing Factors:

Stakeholders recognize that there are many direct and indirect contributing factors leading to soldier burden.

- Infantry School instructors suggested that there needed to be a greater understanding and awareness of all the burden factors that contribute to reduced performance in operations and career injuries among all stakeholders: chain of command, trainers, Unit commanders, acquisition and requirements professionals, medical branch, and soldiers. These burden factors need to be identified, qualified by acceptable limits, informed by burden management strategies and practices, communicated widely to all stakeholders, and incorporated into training at all levels.
- DSSPM needs to know information about soldiers, their tasks, their conditions of use, and their performance to be better able to relate operational requirements and limits to the procurement requirements necessary to meet them.
- DLR feels that the contributing factors to burden are only partially understood. Factors such as weight are known but the trade-offs between stiffness, bulk, placement on the body, etc. are not as well understood. DLR needs a prioritized listing of burden factors, and their mitigation goals, to better craft requirements that are mindful of burden effects.
- ACDB needs to better understand the perceptions of resupply in operations among soldiers and small Unit commanders that encourages such a “worst case” load planning mindset. These perceptions need to be contrasted with reality experienced by Combat Service Support (CSS) and the Units in the field to better inform decision-making by soldiers and commanders regarding the risk of not being resupplied (i.e. frequency of actual late resupplies and severity on individual and Unit effectiveness).
- ACDB needs more scientific study to clarify and objectify the measurable effects of all the multi-factorial elements of burden in terms of soldier performance and wellbeing measures in both immediate and prolonged exposure terms. Until these effects are understood it will be difficult for commanders to make informed trade-off decisions between mission kit,

protection levels, and discretionary items across a range of possible environmental conditions, terrain, and mission durations, in order to optimize individual and Unit readiness and operational effectiveness.

3.1.3 Impact on Operational Effectiveness:

It is also understood by stakeholders that, when burdens become excessive, they can result in significant discomfort, injury, overload, reductions in individual performance, and, ultimately, reductions in operational effectiveness.

- CALWC needs scientific evidence to be able to relate when and how different types of physical and cognitive burden will affect operations over time. Ideally, these data would be able to be expressed as soldier/team/mission risk, in terms of probability and associated severity according to the levels of burden and the duration of exposure, to measurable soldier/team/mission outcomes.
- CALWC expressed concern that soldiers and commanders will be overburdened by information systems on the battlefield and that this could reduce individual and Unit combat effectiveness.
- ACDB suggested that the operational impact of burden, burden criteria, and measures of burden need to be determined in a soldier system context.
- ACDB recommends that a review of demands needs to be set in the timeline context of operational scenario to be able to relate the occurrence of cognitive demands to the operational situation, and the associated demands of that situation. This investigation also needs to compare and contrast operational effectiveness with and without information systems to better understand the associated trade-offs with cognitive burden.

3.1.4 Capability Gaps:

It is common to measure and detail capability gaps prior to embarking on solutions to fill these gaps. Unfortunately, these gaps are not well understood nor well documented.

- The capability gap that DSSPM is trying to fill through acquisition is often not known nor measured. Task analysis is often not done as part of item definition at the start of any procurement project to detailing User needs, task requirements, conditions of use, etc.
- Burden was identified by CALWC as one of the Army's 'hard problems'. The challenge to soldier systems is to identify the capability gaps, or levels of burden, that exceed acceptable limits as defined by injury, performance, and mission effectiveness. These gaps need to be qualified, quantified, and prioritized to determine which gaps to manage or mitigate according to Army goals and objectives.

3.1.5 Career Impact of Burden:

The performance and wellbeing effects of physical burden will likely shape a career through self-selection to less demanding trades, reductions in capacity through injury, career-ending disability, and so on. Little is known about the type, severity, and pattern of acute or chronic musculo-skeletal

injuries and disabilities over the course of a soldier's career. Little is also known about the economic, personal, and army capability losses associated with physical and mental burden.

- CALWC needs a study to improve the Army's understanding of long-term personal and organizational costs of physical and mental burden.
- According to the Infantry School, soldiering can be extremely demanding, both physically and mentally. These demands take a toll on the body, and the mind, and repeated wear-and-tear and injuries accumulate to hasten retirement in some soldiers and typically remain with them in their life after service. The impact of physical and cognitive burden on a soldier's career path, morbidity, mortality/longevity needs to be better understood.

3.1.6 Mitigation Strategies:

Strategies and technologies for mitigating the unwanted effects of physical and cognitive burden are many and varied, and not well understood by stakeholders. While many stakeholders could point to obvious strategies like weight reduction they were not aware of the many different engineering and administrative options available to reduce soldier burden. More than a mere accounting of possible ways and means to reduce burden, stakeholders require more insight into the effectiveness of different strategies contrasted with the associated costs of development, implementation, and maintenance of these strategies. A scientific business case model is suggested to provide stakeholders with the necessary cost-benefit insights of different individual and organizational mitigation strategies.

3.2 Solutions

Stakeholders recognize there are many possible solution pathways to reducing soldier burden but they lack the scientific evidence necessary to evaluate, characterize, and prioritize these options into a comprehensive, effective strategy to reduce soldier burden. Stakeholders were seeking support from the Burden Mitigation WBE in the following areas.

3.2.1 Policy:

A policy that can control burden at the point of acquisition is seen as a powerful method of managing the burden issue in both physical and cognitive terms.

- DLR needs a policy or agreed testing protocol, acceptable to PWGSC, for ensuring that controls can be applied on design-related burden at the bid evaluation stage of procurement. For example, the U.S. Marine Corps has sought to manage the escalation of Marine burden through a policy of testing any bid item or modified item to ensure that it doesn't contribute to additional burden and rewards solutions that reduce burden. The USMC employ a Key Performance Parameter (KPP) for Marine mobility that they use to test any new item against the in-service loadout using their Load Effects Assessment Program (LEAP).
- ACDB suggested that bid submissions that meet the essential aims of the item and reduce existing burden elements should be rewarded. The recent USMC policy, to use a Key

Performance Parameter (KPP) for mobility in all acquisitions of anything worn, carried, or consumed by the Marine, ensures that burden creep is prevented, managed, or reversed at the point of bid evaluation, thereby punishing vendors that increase burden and rewarding those that reduce it.

3.2.2 Standards:

Burden standards are necessary to guide decision making in acquisition, training, and operations.

- DSSPM needs validated Canadian military burden-relevant performance standards for all Soldier System items in key performance areas and baseline performance data for in-service items to enable the development of burden-related requirements.
- The Qualification Standard for infantry does not dictate the weights to be carried nor kit to be worn by course participants in training. This introduces potentially significant variability in the choices made from one instructor to another for the same course. There are also no guidelines, checks or balances, in the system to ensure that extreme loads are not used to make a course more “hardcore” or to make a training course into a selection course by the level of hardship applied.

Infantry School instructors indicated a need for guidelines, standards, and limits to be set for each course to ensure the training goals and objectives are met without exceeding safe burden loads that may increase injury risks. If documented and binding, then an instructor would be giving an unlawful command to exceed these safe levels in training. Operations would necessarily have no such limits but such a limit in training may improve retention and reduce the likelihood of career-shortening injury, while improving knowledge and awareness for burden trade-off decisions in operations.

3.2.3 Requirements / Specifications:

Burden mitigating or managing requirements and specifications are essential in the bid acquisition process to ensure early down-selection of bid solutions to less burdensome options. Such requirements will also signal to manufacturers that Canada has placed a priority on burden mitigation to encourage the development of less burdensome designs.

- DSSPM needs defensible requirements and specifications to better manage the trade-offs of adding equipment, protection, etc. to a soldier through acquisition against the burden demands placed on soldiers in terms of risk of injury and the performance of their tasks.
- DSSPM recognizes that burden negatively impacts the hardship of soldiering, has negative medical and performance implications, and can limit careers. To help reduce burden, DSSPM can use the acquisition process to minimize burden by incorporating burden criteria in bid evaluations. However, DSSPM needs support in identifying appropriate burden criteria for each item being acquired, suitable methods for evaluating bids against these criteria, and assigning cut-offs or graded scoring to the results of testing to support the procurement of low-burden items.
- DLR requires scientifically validated requirements and specifications for procurement. Validated operational requirements and specifications are essential to ensuring that

procured items meet real needs of soldiers to the levels necessary to fulfill the required performance objectives. These requirements need to be sufficiently defensible to justify sourcing product solutions outside of Canada if no domestic solution can meet the requirements.

- CALWC suggests that efforts should be undertaken to produce guidelines and design advice to inform the acquisition and employment of information devices on the battlefield to minimize cognitive burden and ensure operational effectiveness.

3.2.4 Methods / Measures:

Before you can mitigate burden effectively, set requirements, and develop standards, you need to be able to measure the key criteria of burden that you wish to manage.

- DSSPM currently lacks standardized performance parameters, human factors tests, and cut-off scoring or limits for burden-related issues related to User acceptance and operational performance. Specifically, DSSPM needs to know:
 - a) Range of motion effects on tasks performance, including range of motion measures and tools.
 - b) Insights into critical trade-offs such as the trade-offs between level/amount of protection, mobility, and vulnerability under fire.
 - c) Information from the CAPSAC database in a non-classified form.
 - d) Clear design criteria and limits for hard armour plate size and shape, in relation to variability in body size, shape, and organ position.
 - e) Measures and methods of assessing the thermal burden of different item designs.
- DLR needs to know which valid test methods and procedures to include in the statements of requirements for soldier system items. If such test methods are not yet developed then they need to be developed so that levels of physical and psychological burden can be measured for each item and compared to a valid requirement limit or criteria.

3.2.5 Knowledge / Awareness / Culture:

Stakeholders generally agreed that the lack of knowledge and awareness of the effects of burden, in the short and longer term, and factors contributing to burden represents a significant obstacle to tackling the problem of over-burdening soldiers. This lack of knowledge and awareness has led to a culture that believes that over-burdening is the status quo, and is therefore acceptable or even desirable, soldiers can adapt and toughen up to handle it, and that suffering under load builds good soldiers. As the true cost of over-burdening becomes known, the fallacy of this cultural attitude to burdening can be seen in the shortening of careers, the reduced battle readiness of soldiers, mobility decrements in soldiering performance, and the negative impact on operational effectiveness.

- DLR recognizes that soldiers often take more clothing and equipment on a mission than necessary. This often stems from a culture that supports the notion of carrying “worst-case” loads. At each level, there is a culture of caution and risk aversion (e.g. extra clothing, more

magazines, more armour all the time) that results in over-burdening the soldier, increasing the risk of injury and discomfort, and reducing individual and collective performance. Only improved evidence-based knowledge and awareness can change the current culture of “carry everything” to one that seeks a better balance of risks, costs, and outcomes.

- CALWC indicated that there are several aspects of our current culture that exacerbate burden effects on soldiers. Trainers often relate extreme loads and high physical demands in training to ‘making the cut’. Commanders will often be very risk averse to having any ballistic, blast, or fragmentation casualties and will require soldier to wear the maximum available ballistic protection for all situations. Soldiers themselves will often adopt a machismo mindset where it is important to show they are tough and can withstand hardship.
- Infantry School instructors, and the training branch, need evidence about burden effects on a soldier’s career to encourage a change in training culture. All instructors in the focus group had been subjected to or witnessed the use of extreme physical and mental burden in training as a means to make a course tougher, “raise the bar”, make it “hardcore”, and make it a “right of passage”. Increasing the demands and challenges of a course are seen to build esprit de corps, confidence in one’s self, and a sense of accomplishment. Instructors acknowledged, however, that there was often a fine line between challenging and injurious, and that this line was crossed at times. The instructors need to better understand the elements of physical and cognitive burden, and the implied limits, to ensure that training conditions are challenging but safe.
- Soldier clothing and equipment are designed according to certain fit assumptions that relate to size tariffing and issue sizes. When the designed fit assumptions are not met, through unavailability, improper size issuance at stores, or ineffective adjustment by the soldier, soldier acceptance and performance are likely to suffer. DSSPM needs to have a better way of educating supply technicians and soldiers on the importance of proper fit, how to determine correct sizing, and how to achieve best fit through adjustment of each item.
- Medical technicians report that they pack their medical bags with as much medical materials as possible under the assumption that they will not be resupplied. This likely results in heavier than necessary loads. Assumptions about unreliable resupply were also reported by soldiers as the reason they carried extra supplies. In the cases of both soldiers and medical technicians, however, neither could provide examples when resupply was inadequate or failed. Therefore, there need to be efforts made to exercise resupply in collective training, to educate and inform the true risk of untimely or inadequate resupply so that soldiers and medical technicians can make better informed packing decisions and, hopefully, carry less load.

3.2.6 Individual & Team Training:

Soldiers that are more self-aware of their personal capacity to endure burdens, physical and psychological, will be better able to adopt coping strategies to personally mitigate burden.

- DLR needs soldiers and commanders to have the most up-to-date knowledge and comprehension of the true risks that are associated with carried and worn loads in different environmental and terrain conditions for different missions and tasks. This scientific

- evidence needs to be available and usable during training to ensure that this decision-support information is comprehended and employed in operational load decisions.
- CALWC suggests that measuring indices of burden during training and providing immediate feedback to soldiers and commanders can be used to educate and improve awareness by relating the effects of burden in the moment to the tasks and conditions at the time. Experience and knowledge gained from this feedback can then be employed by individuals and commanders in operations to mitigate burden effects.
 - ACDB suggests that we need to educate and inform future leaders during training so that the knowledge gained could be effectively employed in operations. Targeting future leaders during training would shape behaviour and lead to culture change regarding the importance of burden management, and ultimately inform doctrine.
 - Medical technicians noted that some casualties are the result of soldiers not being self-aware of their physical limitations and capacity for load carrying, the signs and symptoms of heat stress, nor their level of hydration. Soldiers need to use their training opportunities to better understand their own limits and then to take that knowledge and use it to make good packing and load configuration decisions to minimize their own physical burden and risk of injury. The same level of personal responsibility is needed to ensure soldiers hydrate. Soldiers need specific training on physical demands and how they can personally mitigate their own response to these demands.
 - Medical technicians also suggested that soldiers would also benefit from being made more self-aware of the symptoms of escalating high mental stress symptoms in general and, specifically, more insight into their own personal response to stress. Training provides the venue for such high mental stress awareness training. Physiological monitoring may be more effective in a training environment at first to help soldiers recognize their own symptoms, and their symptoms progression, so that they can learn personal stress management strategies that would help them avoid an episode in combat.

3.2.7 Engineering & Administrative Solutions:

Stakeholders indicated that they were aware of a number of possible engineering and administrative solutions for mitigating physical and cognitive burden but they lacked the human factors knowledge to value, prioritize, select, and implement these solutions.

- Stakeholders recognize that there are many engineering and administrative solutions available and emerging in the soldier system space (e.g. modular and scalable protection, novel pack systems, load transfer devices, exoskeletons, mules). Stakeholders need evidence-based, scientific support to understand which options are effective for reducing burden, when, and at what cost. These options need systematic investigation and their “benefit” needs to be reflected in the larger context of soldier systems, tasks, equipment, and soldiers, with consideration of the time and costs associated with the implementation of any option.
- Medical technicians need a load carrying solution that is designed to be integrated and compatible with other load carrying equipment (e.g. rucksacks, packs, and combat loads) to minimize load forces on the medical technician as much as possible. Medical technicians

carry a full combat load during a mission, similar to other soldiers in their attached Unit, but they also carry the additional load of their medical bag (~40 lbs). On long range patrols, they must carry their rucksack, their medical bag, and their combat load, typically totally about 150 lbs. They noted that they themselves are at significant risk of become mobility, exertional or heat stress casualty as well.

- Medical technicians indicated that the advent of soldier computers and body-worn physiological monitoring sensors would be able to support the location and triaging of casualties faster and better. Such systems could assist the medical technician by prioritizing casualties in most need of critical care to optimize the allocation of medic care to best meet the medical demands. Medical technicians also indicated that it would be important to know if the casualty were “life signs absent” so that they could ensure their time was being best spent saving casualties. Ideally, such technology would be able to support the collection of vital information, patient tagging, recording of medical technician information, and reporting of patient history. Concepts like a digital dog tag could be used to store patient history and medical background. Soldier-worn computers, in concert with physiological monitoring sensors, could record vital signs data, send out alarms and alerts to medical staff, and provide a venue for transmitting 9-liner reports and recording MIST data. In this way, patient information and treatment data would remain current, be easily added to the 9-liner and MIST reports, and travel digitally with the patient as they move to other locations for trauma care. This would reduce the cognitive burden on the medical technician and improve the timeliness and quality of medical care for the soldier.
- CALWC recommends further study to investigate the potential ways and means of employing physiological monitoring to reduce the effects of soldier burden. Technology has advanced to the point where we can remotely monitor the physiological state of the soldier and provide status reports to the individual soldier, the Unit command structure, and the medical chain. How might this information be used to predict, prevent, or manage the effects of soldier burden? What information should be measured and what information should be provided, to whom, when, and in what form?
- CALWC needs more investigation into the potential ways and means of mitigating information overburdening. How can the distribution of information technologies, filtering and display of information, the timing and frequency of presentation, and characteristics of displayed information be designed to mitigate potential cognitive load effects from providing such information? The need for these investigations applies to soldiers and commanders at all levels, as information needs and conditions of use vary considerably.
- ACDB suggests that there needs to be careful investigation, consideration, and design of information provided to soldiers to ensure it is relevant and usable for the role, minimizes time to review and comprehend, is appropriate for the operational situation, can be filtered and managed during periods of high demand, and is value-added to individual and Unit effectiveness.
- For the Infantry School, to manage cognitive burden, they need scientific support and guidance to determine how information is provided to the soldier; how much is provided; when it is provided; who gets what information; and whether soldiers can self-manage the push and pull of information through controls on the devices. The instructors indicated that

these choices will be critical in determining the cognitive burden associated with the systems. At the same time, the systems and their software interface needs to be sufficiently user friendly as to not require significant training. Instructors pointed out that the training system itself is already heavily burdened by the volume and number of courses required to train soldiers. Additional add-on courses for information systems should be a further consideration in the design of future systems and their concepts of use.

3.2.8 Information Tools:

The advent of new soldier system computers opens the door for wide range of possible digital decision aides and information tools.

- DSSPM needs to know information about soldiers, their tasks, their conditions of use, and their performance to be better able to relate operational requirements and limits to the procurement requirements necessary to meet them.
The current Soldier System Architecture software program being developed by DRDC would seem to have the information that DSSPM needs. The Soldier System architecture not only includes a large repository of soldier system information to inform stakeholders but it also focuses the discussion on soldier and equipment capability gaps and provides a holistic common operating system tool that informs stakeholders about the relationships between equipment, tasks, and the soldier.
- CALWC needs tools developed to inform and support the Army decision-makers. For the soldier, this might be an aide memoir about avoiding and minimizing burden through better load decisions, packing aides, etc. For the unit and sub-unit commander, this might be a mission planning calculator that relates soldier loads to climate and terrain to support load leveling in the unit, route planning to minimize physiological demands, and recommend the timing of rest and hydration breaks.
- CALWC believes that technology and scientific knowledge has progressed to the point where digital decision aides can be used to better manage burden effects at the individual and small Unit levels, in both training and operations. For example, route planning can be overlaid on real 3D terrain data with climate conditions and related to the loads being carried by soldiers, in relation to their personal capacity, in the context of mission goals and timings. Such an analysis can identify if any particular soldier will be overloaded and suggest load sharing optimization within the Unit to minimize total Unit burden. It could also prescribe the timing of rest breaks and hydration breaks, and recommend consumption amounts to avoid heat stress injury.
- ACDB needs an evidence-based decision aide to support the Unit commander with the latest scientifically valid information about burden risk factors to help them balance off the operational risks of the mission and the climatic conditions. Unit commanders need to be empowered to make decisions about combat loads and protection levels, based on mission conditions, but there is limited information available to them. The problem space is multi-factorial and complex so commanders would benefit from evidence-based decision aides.
- Infantry School instructors suggest that the Army needs a decision aide, using evidence-based science, to inform the chain-of-command of the burden implications to soldier performance and wellbeing of different load order decisions, in light of the mission

requirements, mission duration, environmental and terrain conditions, anticipated physical demands, and so on. Such a decision aide would also be valuable to inform the training branch so that loads could be selected to achieve sufficient hardship without risking serious injury.

4. Discussion

The overwhelmingly consistent need of stakeholder organizations from the Burden Mitigation WBE is scientific evidence to support burden-related decisions. Army stakeholders intuitively recognize that physical and cognitive burden can increase the likelihood of soldier injuries (physical and mental), reduce battle readiness, shorten careers, reduce physical and mental performance in the fight, and ultimately reduce operational effectiveness. However, it is difficult for stakeholders to act, efficiently and effectively, on intuition alone. To be effective, stakeholders require scientific evidence to support and justify difficult decisions, valid measures and standards to control and shape the sources of burden, and knowledge and awareness of the effects and causes of burden, necessary to transform the enabling culture of overburdening in the Canadian Army.

In reviewing the stakeholder needs for scientific evidence to fill gaps in knowledge and to support the development and implementation of solutions several action streams are suggested. The following streams are prioritized for level and timing of effort, with earlier streams suggesting more immediate action.

4.1 Stream 1: Exploit Existing Knowledge

Despite our gaps in knowledge, considerable information does exist in the scientific literature that could benefit Army stakeholders but it is not in a form that is readily exploitable by them. To be exploitable this accumulated knowledge needs to be distilled into useful and actionable information and this information then needs to be operationalized in a way that best serves each particular stakeholder organization. This distillation would not take the form of a scientific literature review but rather it would take the contents of such literature and translate the included knowledge into army-relevant actionable guidance.

This is the lowest “hanging fruit” for mitigating burden because it only requires transforming existing knowledge rather than creating new knowledge, so the timelines are shorter and costs are minimal by comparison. Such low hanging fruit can also introduce an immediate and significant impact in all stakeholder organizations and communities. To be most effective requires consultation with stakeholder Subject Matter Experts (SME) to ensure that transformed knowledge is truly useful, relatable, and actionable for each organization’s needs.

In many cases existing knowledge can be exploited fastest through integration of this “new” information or newly transformed and actionable information into existing training and through an information awareness campaign directed at soldiers. Such an Awareness Program can package “new” burden information and guidance into easily consumable knowledge-bites like social media channels for soldiers, posters, newsletters, comic strips or books. Such programs can be a very effective way of changing behaviour and the culture of burden.

4.2 Stream 2: Determine the Organizational Impact of Burden

While stakeholders universally recognize overburdening soldiers as undesirable and problematic, there remains a lack of knowledge or understanding about the total organizational impact of burden

within the Army in terms of careers, injuries and illness, performance, and operational effectiveness. In other words, the business case for mitigating burden, at the level of organizational commitment and investment, is missing.

A business case for mitigating burden is recommended to provide a measure of magnitude and criticality to the burden mitigation effort. Is burden merely an issue of discomfort that can be mitigated through training and work-hardening or is it more impactful and insidious by limiting careers, battle readiness, and operational effectiveness? If it's the latter then how prevalent are these concerns, how costly are they to the Army, and what level of investment is justified for mitigation?

4.3 Stream 3: Progress from Problem Definition to Solution Pathways

As indicated by several stakeholders, a deficiency analysis is necessary to determine the capability gaps in burden that require engineering and administrative solutions. Without a clearly defined, measurable deficiency it is difficult to select the best solution, or mix of solutions, and determine the magnitude of solution required to close the capability gap. Having determined a deficiency there needs to be a pathway to a solution.

The following steps are recommended:

1. **Gap Analyses:** As the old saying goes “a well-defined problem is half solved”. Currently, stakeholders recognize the problem but have no way of assigning a magnitude to it nor a measured way of prioritizing which gaps to pursue. As a first step, areas of possible deficiency should be identified and these areas should be assessed for their degree of concern in burden terms. Gaps should be expressed in percentage terms (i.e. current state vs target state or goal) so that different gaps can be compared. As well, a magnitude of severity needs to be assigned to each deficiency area as it relates to the overburdening problem so that ‘high impact’ mitigation areas can be targeted first.
2. **Mitigation Strategy SOAR:** Burden is a complex, multi-faceted problem requiring a wide, multi-faceted range of solutions. A State Of the Art Review (SOAR) of burden mitigation solutions, along with any research or information about the effectiveness of each solution, is necessary to generate a catalogue of possible solution options to employ when closing identified gaps.
3. **Engineering & Administrative Solutions:** The selection of the most effective, affordable mix of engineering and administrative solutions for any given capability gap or deficiency is complex and challenging. Each solution needs to be weighed against the particular gap to be closed and considered in light of effectiveness for reducing burden, cost, availability, development, implementation, maintenance, and so on. Solutions may be engineering or administrative in nature or a combination of the two. A business case model approach is recommended to ensure that solutions are considered in a holistic way that considers the effectiveness of a solution in the context of our ability to successfully action it.

4.4 Stream 4: Control Burden through Acquisition and Standards

Stakeholders recognize that the requirements set out in soldier system acquisition often set the stage for the upper limits of burden and the options remaining for mitigating it. For example, the

volume requirement of a main pack may be seen as a measure for mission kit capacity, and the design may offer capacity expansion for packing flexibility, but high-capacity packs also offer a significant opportunity for over-burdening in terms of excessive total weight, unbalanced load distribution, load shifting inertial forces, and so on. Acquisition stakeholders need scientific evidence to navigate the complex trade-offs between burden and other system requirements and have expressed a need for requirements with essential and desirable specifications and valid measurement methods for evaluating bid contenders. The acquisition community needs to identify future acquisition items early so that scientific supports efforts can be initiated in time to ensure that necessary measures, metrics, and criteria are in place in time for the bid process.

Standards have been identified by stakeholders as essential guidance needed to limit burden in training, operations, and acquisition. Some standards like MIL-STD-1472G suggest load limits of 30% of body weight for assault loads, which are so far below our current reality that they are impossibly unachievable and, as such, are unusable. The Canadian Army stakeholders need usable, achievable standards that can be employed in training and operations to limit severe over-burdening. By beginning with such achievable standards now, the worst over-burdening can be avoided and a meaningful programme of continuous development and burden mitigation can ensue.

4.5 Stream 5: Develop Information Tools for Training and Operations

Stakeholders identified a number of tools and technologies for informing and advising soldiers and the chain of command on the effects and management of burden. Technologies, such as physiological monitoring, were seen to be an effective way to educate soldiers about the effects of burden, their personal limits, and the most effective strategies for personally coping with physical and mental burden. Stakeholders felt that such technologies would be best introduced into a training environment to develop individual awareness, where the integration of the technology could also be assessed in a low threat environment for future use in operations.

Tools for planning were seen as a way of organizing complex burden information in a mission-relevant form that offers advice and guidance on soldier load management, team load distribution, workload and thermal management through route planning and rest/hydration breaks, and total soldier load matching to mission task demands and threats. Initially, such a tool would be a training aide but, with experience, the tool would become a valuable decision aide.

4.6 Stream 6: Continue to Close Knowledge Gaps

Despite the extensive amount of burden research done to date, there remain significant gaps in our knowledge about the equipment-related contributors to burden, the range of medical, physical, cognitive, and performance effects of that burden, and the associated trade-offs between soldier equipment, performance decrements, vulnerability, and hence, overall integrated survivability and effectiveness. Defence Research and Development Canada (DRDC) is using the Load Effects Assessment Program (LEAP) instrumented simulated combat mobility course, the Virtual Immersive Soldier Simulator (VISS), and a range of lab and field study methods to continue to close these knowledge gaps. Such research, by Canada and our international allies, is necessary to achieve our most effective, and cost efficient, burden mitigation solutions for the future.

5. References

Tack, D. W., Nakaza, E.T., and Osborne, A. (2013). FSAR Lessons-Learned Survey. DRDC Toronto Report No CR-2013-067

6. ANNEX A: Stakeholder Focus Group Notes

Focus group notes are organized by stakeholder group as follows:

Director Land Requirements (DLR)	27
Director Soldier System Project Management (DSSPM)	29
Canadian Army Land Warfare Centre (CALWC) and Canadian Army Doctrine and Training Command (CADTC)	31
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6.1 Director Land Requirements (DLR)

Focus Group Participants: Director Land Requirements (DLR)

Date: 4 March 2016 in Ottawa, ON

Attendees: Representatives from DLR 5 (1 x Major, 2 x Captains)

General Needs:

1. Need to know the effects of burden on performance to influence culture.

DLR recognizes that soldiers often take more clothing and equipment on a mission than necessary. This often stems from a culture that supports the notion of carrying “worst-case” loads. For example, soldiers in theatre routinely carry 10+ magazines of 5.56 ammunition but research shows that CAF soldiers only expended 2 magazines in firefights, on average (Tack et. al, 2013). Some of the load amounts are determined by the soldier themselves, some by the Senior NCOs, and some things, like protective equipment, are determined by the Task Force Commander. At each level, there is a culture of caution and risk aversion (e.g. extra clothing, more magazines, more armour all the time) that results in over-burdening the soldier, increasing the risk of injury and discomfort, and reducing individual and collective performance.

DLR needs scientific evidence to inform all levels of the ‘kit list’ decision chain as to the trade-offs in mobility, risk of musculo-skeletal or exertional injury, performance, and comfort with the associated increases in carried weight. Only improved knowledge and awareness can change the current culture of “carrying everything” to one that seeks a better balance of risks, costs, and outcomes.

2. Need to better understand the effects of burden and the contributing factors.

DLR needs the scientific evidence for the adverse effects of over-burdening the soldier on performance and wellbeing so that this can be used to influence decision-making in the setting of requirements and throughout the acquisition chain. The contributing factors to burden are only partially understood. Factors such as weight are known but the trade-offs between stiffness, bulk, placement on the body, etc. are not as well understood. DLR needs a prioritized listing of burden factors, and their achievable mitigation goals, to better craft requirements that are mindful of burden effects.

3. Need to provide evidence-based decision support training at all levels.

DLR needs soldiers and commanders to have the most up-to-date knowledge and comprehension of the true risks that are associated with carried and worn loads in different environmental and terrain conditions for different missions and tasks. This scientific evidence needs to be available and usable during training to ensure that this decision-

support information is comprehended and employed in operational load decisions.

4. Need scientifically validated requirements and specifications for procurement.

Validated operational requirements and specifications are essential to ensuring that procured items meet real needs of soldiers to the levels necessary to fulfill the required performance objectives.

DLR needs scientifically validated requirements for all soldier system items that are measurable and defensible. These requirements need to be sufficiently defensible to justify sourcing product solutions outside of Canada if no domestic solution can meet the requirements.

5. Need testing methods and procedures to measure burden levels and effects.

DLR needs to know which valid test methods and procedures to include in the statements of requirements for soldier system items. If such test methods are not yet developed then they need to be developed so that levels of physical and psychological burden can be measured for each item and compared to a valid requirement limit or criteria.

Specially, DLR noted the need for quantifying burden effects and differences between modular and scalable armour and load carriage concepts.

6. Need a policy that manages the burden issue up-front in the acquisition process.

The focus group facilitator described how the U.S. Marine Corps has sought to manage the escalation of Marine burden through a policy of testing any bid item or modified item to ensure that it doesn't contribute to additional burden and rewards solutions that reduce burden. DLR suggested that they needed a similar policy or agreed testing protocol, acceptable to PWGSC, for ensuring similar controls on burden can be applied at the bid evaluation stage of procurement.

6.2 Director Soldier System Project Management (DSSPM)

Focus Group Participants: Director Soldier System Project Management (DSSPM)

Date: 4 March 2016 in Ottawa, ON

Attendees: Representatives from Clothing, Weapons, Person Protective Equipment, and Human Factors (1 x Major, 1 x CWO, 2 x CIV)

General Needs:

1. Need support in reducing burden through acquisition.

DSSPM recognizes that burden negatively impacts the hardship of soldiering, has negative medical and performance implications, and can limit careers. To help reduce burden, DSSPM can use the acquisition process to minimize burden by incorporating burden criteria in bid evaluations. However, DSSPM needs support in identifying appropriate burden criteria for each item being acquired, suitable methods for evaluating bids against these criteria, and assigning cut-offs or graded scoring to the results of testing to support the procurement of low-burden items.

2. Need measurable, documented, capability deficiency data for in-service items.

The capability gap that DSSPM is trying to fill through acquisition is often not known nor measured. Task analysis is often not done as part of item definition at the start of any procurement project to detailing User needs, task requirements, conditions of use, etc. A gap analysis for burden issues should be done for any new acquisition and a statement of deficiency should be produced before embarking on a statement of requirement.

3. Need validated performance standards for all Soldier System items and the System as a whole.

DSSPM needs validated Canadian military burden-relevant performance standards for all Soldier System items in key performance areas and baseline performance data for in-service items to enable the development of burden-related requirements.

4. Need knowledge about Users, how an item is used, the conditions of use, and more insight into soldier needs.

DSSPM needs to know information about soldiers, their tasks, their conditions of use, and their performance to be better able to relate operational requirements and limits to the procurement requirements necessary to meet them.

The current Soldier System Architecture software program being developed by DRDC would seem to have the information that DSSPM needs. The Soldier System architecture not only

includes a large repository of soldier system information to inform stakeholders but it also focuses the discussion on soldier and equipment capability gaps and provides a holistic common operating system tool that informs stakeholders about the relationships between equipment, tasks, and the soldier.

5. Need defensible requirements and specifications for procurement.

DSSPM needs to better understand the trade-offs of adding equipment, protection, etc. to a soldier with the burden demands placed on soldiers, their risk of injury, and the performance of their tasks.

6. Need key performance metrics and standardized tests.

DSSPM currently lacks standardized performance parameters, human factors tests, and cut-off scoring or limits for burden-related issues related to User acceptance and operational performance. Specifically, DSSPM needs to know:

- a) Range of motion effects on tasks performance, including range of motion measures and tools.
- b) Insights into critical trade-offs such as the trade-offs between level/amount of protection, mobility, and vulnerability under fire.
- c) Information from the CAPSAC database in a non-classified form.
- d) Clear design criteria and limits for hard armour plate size and shape, in relation to variability in body size, shape, and organ position.
- e) Measures and methods of assessing the thermal burden of different item designs.

7. Need to educate the supply system and the soldier about fit.

Soldier clothing and equipment are designed according to certain fit assumptions that relate to size tariffing and issue sizes. When the designed fit assumptions are not met, through unavailability, improper size issuance at stores, or ineffective adjustment by the soldier, soldier acceptance and performance are likely to suffer. DSSPM needs to have a better way of educating supply technicians and soldiers on the importance of proper fit, how to determine correct sizing, and how to achieve best fit through adjustment of each item.

6.3 Canadian Army Land Warfare Centre (CALWC)

Focus Group Participants: Canadian Army Land Warfare Centre (CALWC)

Date: 9 March 2016 in Kingston, ON

Attendees: Representatives from CALWC and CADTC (3 x Lieutenant Colonels, 2 x Majors)

General Needs:

1. Need to relate physical and cognitive burden effects to operational effectiveness.

It is generally understood that physical and cognitive burden are undesirable for our soldiers but soldiering is a difficult job and some discomfort and challenges are expected. It is also understood that, when burdens become excessive, they can result in significant discomfort, injury, overload, reductions in individual performance, and, ultimately, reductions in mission effectiveness.

CALWC needs scientific evidence to be able to relate when and how different types of physical and cognitive burden will affect operations over time. Ideally, these data would be able to be expressed as soldier/team/mission risk, in terms of probability and associated severity according to the levels of burden and the duration of exposure, to measurable soldier/team/mission outcomes.

2. Need to determine the capability gap for the burden hard problem in both physical and cognitive terms.

Burden was identified by CALWC as one of the Army's 'hard problems'. The challenge to soldier systems is to identify the capability gaps, or levels of burden, that exceed acceptable limits as defined by injury, performance, and mission effectiveness. These gaps need to be qualified, quantified, and prioritized to determine which gaps to manage or mitigate according to Army goals and objectives.

3. Need information and tools to inform and assist Army decision-making.

The Army needs evidence-based decision making at all levels from the soldier, unit commander, Task Force commander, and so on. Currently there is insufficient knowledge of risks and associated trade-offs. For example, if risk of injury due to small arms fire is deemed to be high then, in the absence of burden considerations, the simple solution is to maximize ballistic protection. However, such a course of action will increase the soldier's physical and thermal burden which, in hot temperatures in mountainous terrain, can result in a higher risk of heat casualties, mobility injuries, and reduced mobility performance which

could also increase soldier exposure to the enemy and increase the likelihood of being hit by small arms fire.

CALWC needs tools developed to inform and support the Army decision-makers. For the soldier, this might be an aide memoir about avoiding and minimizing burden through better load decisions, packing aides, etc. For the unit commander, this might be a mission planning calculator that relates soldier loads to climate and terrain to support load leveling in the unit, route planning to minimize physiological demands, and recommend the timing of rest and hydration breaks.

4. Need objective, scientific evidence of issues to change the culture of decision-making at all levels.

There are several aspects of our current culture that exacerbate burden effects on soldiers. Trainers often relate extreme loads and high physical demands in training to ‘making the cut’. Commanders will often be very risk averse to having any ballistic, blast, or fragmentation casualties and will require soldier to wear the maximum available ballistic protection for all situations. Soldiers themselves will often adopt a machismo mindset where its important to show they are tough and can withstand hardship.

CALWC needs scientific evidence to inform decision-makers of the risks and trade-offs of overburdening the soldier, both physically and cognitively. This evidence can be used to educate and inform, which will change the culture over time.

5. Need to provide insight and feedback on actual burden levels in training to educate soldiers and their leadership.

Measuring indices of burden during training and providing immediate feedback to soldiers and commanders can be used to educate and improve awareness by relating the effects of burden in the moment to the tasks and conditions at the time. Experience and knowledge gained from this feedback can then be employed by individuals and commanders in operations.

Physical Burden Needs:

1. Need to better understand the cost of physical burden on soldier performance.

The costs of physical burden and the notion that the effects are related to individual capacity are generally understood as a construct. However, a construct is not sufficiently diagnostic nor prescriptive enough to support effective decision-making.

CALWC needs scientific study to more accurately determine the cost of various dimensions of physical burden on soldier performance, as these relate to a range of soldier

characteristics (e.g. strength, endurance, size, shape). There is also a need for a risk analysis or risk model development to relate the dimensions of physical burden and soldier capacity to outcomes, such as performance, injury, and operational effectiveness.

2. Need a study to determine the effects of physical burden over a soldier's career.

The performance and wellbeing effects of physical burden will likely shape a career through self-selection to less demanding trades, reductions in capacity through injury, career-ending disability, and so on. Little is known about the type, severity, and pattern of acute or chronic musculo-skeletal injuries and disabilities over the course of a soldier's career. Little is also known about the economic, personal, and army capability losses associated with physical burden.

CALWC needs a study to improve the Army's understanding of long-term personal and organizational costs of physical burden.

3. Need a tool to support mission planning that considers the effects of physical burden.

Technology and scientific knowledge has progressed to the point where digital decision aides can be used to better manage burden effects at the individual and small Unit levels. The focus group facilitator provided an example of route planning, overlaid on real 3D terrain data with climate conditions, and related this route to the loads being carried by soldiers, in relation to their personal capacity, in the context of mission goals and timings. This example analysis identified if any particular soldier would be overloaded and suggested load sharing optimization options within the Unit to minimize total Unit burden. The tool could also prescribe the timing of rest breaks and hydration breaks, and recommend consumption amounts to avoid heat stress injury. CALWC indicated that such a tool could be very effective in training and in operations.

4. Need to better understand the opportunities and issues with physiological monitoring.

Technology has advanced to the point where we can remotely monitor the physiological state of the soldier and provide status reports to the individual soldier, the Unit command structure, and the medical chain. How might this information be used to predict, prevent, or manage the effects of soldier burden? What information should be measured and what information should be provided, to whom, when, and in what form?

CALWC recommend further study to investigate the potential ways and means of employing physiological monitoring to reduce the effects of soldier burden.

Cognitive Burden Needs:

- 1. Need to know more about the potential cognitive burden effects of distributed information systems on the battlefield.**

Personal computing and information systems are ubiquitous in society and are increasingly being introduced into soldiering. There has been, and remains, a concern that soldiers and commanders will be overburdened by information systems on the battlefield and that this could reduce individual and Unit combat effectiveness.

CALWC needs more scientific study to characterize the types of information burden possible at each soldier and command level, the likely effects of being overloaded in personal wellbeing and performance terms, and the implications for mission effectiveness, contrasted against the added benefits of providing such information.

- 2. Need to determine how potential information overburdening can be mitigated.**

How can the filtering and display of information, the timing and frequency of presentation, and characteristics of displayed information be designed to mitigate potential cognitive burden effects from providing such information.

CALWC suggests that efforts should be undertaken to produce guidelines and design advice to inform the acquisition and employment of information devices on the battlefield.

6.4 Army Combat Development Board (ACDB)

Focus Group Participants: Army Combat Development Board (ACDB)

Date/Location: 22 March 2016 in Kingston, ON

Attendees: 30 Representatives from the ACDB Meeting

General Needs:

1. Need evidence-based, defensible information to inform decision making.

Unit commanders need to be able to make decisions about combat loads and protection levels to fulfill mission objectives under various threats. However, decisions about protection levels are typically made at the Task Force Commander level and are seen to err on the side of overprotection. This casualty averse approach of over-armouring soldiers does not seem to balance the burden effects of reduced soldier performance and mobility, musculo-skeletal injury, and heat-related injuries. It is believed that non-battle injuries due to burden overload far exceed actual battle casualties and that overload injuries can affect battle readiness. How can we strike a better balance?

ACDB needs evidence-based information on the performance and injury effects of burden to better inform the risk management process during decision-making. ACDB would like to recast the question of burden in terms of performance or risk optimization. In this way, all the risk factors that influence soldier casualties can be considered together to ensure the best balance of threat protection, individual performance, individual and team sustainment, firepower, and injury risk.

2. Need decision aides to support Commanders and soldiers in training and operations.

Unit commanders need to be empowered to make decisions about combat loads and protection levels, based on mission conditions, but there is limited information available to them. The problem space is multi-factorial and complex so commanders will often err on the side of safety.

ACDB needs an evidence-based decision aide to support the Unit commander with the latest scientifically valid information about burden risk factors to help them balance off the operational risks of the mission and the climatic conditions.

Such a tool could be used to educate and inform future leaders during training so that the knowledge gained could be effectively employed in operations. Targeting future leaders during training would shape behaviour and lead to culture change regarding the importance of burden management, and ultimately inform doctrine.

3. **Need to start burden management at the point of kit procurement.**

More and more equipment is being added to the soldier for protection, sustainment, information systems, and lethality over time and the collective burden has increased appreciably over the last 25 years to the point where burden is seriously affecting combat effectiveness of our soldiers. As new items are procured, and old items replaced, there is the potential to manage the burden creep at the point of acquisition.

ACDB suggested that bid submissions that meet the essential aims of the item and reduce existing burden elements should be rewarded. As an example that supported this idea, the focus group facilitator described the recent USMC policy, to use a Key Performance Parameter (KPP) for mobility in all acquisitions of anything worn, carried, or consumed to ensure that burden creep is prevented, managed, or reversed at the point of bid evaluation, thereby punishing vendors that increase burden and rewarding those that reduce it. ACDB agreed that such a concept would help reduce burden at the point of acquisition.

ACDB also suggested that a Pareto analysis needs to be undertaken of all clothing and equipment items, in terms of burden, to determine their relative and absolute contribution to overall burden effects on performance and wellbeing. In this sense, the operational impact of burden, burden criteria, and measures of burden need to be determined in a soldier system context.

Physical Burden Needs:

1. **Need to better understand the trade-offs between combat load and soldier performance.**

Soldiers are very adaptable and able to withstand significant hardship. If asked to carry more and work harder they will, but human capacity and physical limitations are real and when those limits are approached or exceeded performance, wellbeing, and perhaps survivability will suffer. The logic is obvious but the underlying interrelated burden factors and differences in individual capabilities among soldiers make this a very complex and poorly understood problem.

ACDB needs more scientific study to clarify and objectify the measurable effects of all the multi-factorial elements of burden in terms of soldier performance and wellbeing measures in both immediate and prolonged exposure terms. Until these effects are understood it will be difficult for commanders to make informed trade-off decisions between mission kit, protection levels, and discretionary items across a range of possible environmental conditions, terrain, and mission durations, in order to optimize individual and Unit readiness and operational effectiveness.

2. Need to understand the actual resupply timeliness in operations.

Soldiers and commanders often plan loads that presume a worst-case resupply situation (i.e. no resupply for 48-72 hours). For example, soldiers carry more magazines so that they won't run out in a prolonged fire fight. However, soldiers commonly carried 10 magazines of 5.56 although studies show (Tack et. al., 2013) that they rarely used more than 2 magazines, suggesting that they were carrying 8 pounds of unnecessary weight. The problem is compounded when you bring the same mindset to water, food, clothing, and so on, likely resulting in soldiers carrying considerable amounts of unnecessary weight. Part of the reason for this mindset seems to stem from a concern that they may not be resupplied in a timely manner. During discussions in the ACDB focus group, Combat Service Support (CSS) personnel could not recall an instance of resupply arriving too late. The belief was that such an occurrence would be an "extreme exception", suggesting that Units were likely planning loads for the extreme exception and overloading soldiers unnecessarily.

ACDB needs to better understand the perceptions of resupply in operations among soldiers and small Unit commanders that encourages such a "worst case" load planning mindset. These perceptions need to be contrasted with reality experienced by CSS and the Units in the field to better inform decision-making by soldiers and commanders regarding the risk of not being resupplied (i.e. frequency of actual late resupplies and severity on individual and Unit effectiveness).

Cognitive Burden Needs:

1. Need to understand the impact of increasing cognitive burden on soldiers.

There is an ongoing and increasing proliferation of information systems on the battlefield and these systems are becoming more ubiquitous at the small Unit and soldier level. There remains an outstanding concern that such systems could distract soldiers from their procedural tasks of soldiering and cognitively overload them, reducing their capacity to cope with the cognitive demands of immediate operations and exposing them to higher levels of mental workload and combat stress.

ACDB needs to understand the current cognitive demands on soldiers and Unit commanders, their capacity to take on further cognitive demands, and the impact of exceeding cognitive capacity on soldier/commander performance and wellbeing. This review of demands needs to be set in the timeline context of operational scenario to be able to relate the occurrence of cognitive demands to the operational situation, and the associated demands of that situation. This investigation also needs to compare and contrast operational effectiveness with and without information systems to better understand the associated trade-offs with cognitive burden.

2. Need to be able to measure cognitive burden.

We know cognitive demands exist in soldiering and commanding activities in both training and operations, and we know that we need to manage the levels of cognitive demand as new information systems are introduced.

ACDB needs measures of cognitive burden, and valid measurement methods, to relate these burdens to individual and Unit performance, in both wellbeing and performance terms, to measures of mission effectiveness so that the trade-offs between cognitive burden and the presumed benefits to mission effectiveness from information technology insertion can be properly evaluated.

3. Need to know how to mitigate any cognitive burden from information systems.

Information management is key to managing cognitive burden due to new information systems on the battlefield. The volume of information can be managed; does everyone need to see everything? The content of information can be managed; does everyone need to receive the same type of information? The format of information displayed can be managed; only key items of information in a readily comprehensible format.

ACDB suggests that there needs to be careful investigation, consideration, and design of information provided to soldiers to ensure it is relevant and usable for the role, minimizes time to review and comprehend, is appropriate for the operational situation, can be filtered and managed during periods of high demand, and is value-added to individual and Unit effectiveness.

6.5 Infantry School, CTC Gagetown

Focus Group Participants: Infantry School, CTC Gagetown

Date: 29 February 2016 at CFB Gagetown

Attendees: Infantry Instructors (2 x Captains, 3 x WOs, 4 x Sergeants)

General Needs:

1. Need to understand the career-long impact of burden.

Soldiering can be extremely demanding, both physically and mentally. It is commonly understood that these demands take a toll on the body, and the mind, and that repeated wear-and-tear, and injuries accumulate to hasten retirement in some soldiers and typically remain with them in their life after service.

Instructors suggested that there needed to be a greater understanding and awareness of all of the burden factors that contribute to reduced performance in operations and career injuries among all stakeholders: chain of command, trainers, Unit commanders, acquisition and requirements professionals, medical branch, and soldiers. These burden factors need to be identified, qualified by acceptable limits, informed by burden management strategies and practices, communicated widely to all stakeholders, and incorporated into training at all levels.

2. Need to understand the impact of burden in training on the Army.

All instructors in the focus group had been subjected to or witnessed the use of extreme physical and mental burden in training as a means to make a course tougher, “raise the bar”, make it “hardcore”, and make it a “right of passage”. Increasing the demands and challenges of a course are seen to build esprit de corps, confidence in one’s self, and a sense of accomplishment. Instructors acknowledged, however, that there was often a fine line between challenging and injurious, and that this line was crossed at times.

The instructors need to better understand the elements of physical and cognitive burden, and the implied limits, to ensure that training conditions are challenging but safe. As well, there needs to be a better comprehension of the potential effects of injuries sustained in training and their implications for Army retention and readiness, the careers of soldiers, and quality of life after service. One example given was a Pathfinder course where participants needed to carry 150 lbs packs and routinely take a knee while wearing the pack throughout the course. The course was known to damage knees and these instructors wondered how many good soldiers had to retire early because of such burden demands in training.

Instructors, and the training branch, need evidence about burden effects on a soldier’s

career to encourage a change in training culture.

3. Need burden decision aides to inform critical mission and training trade-off decisions.

During operations the chain-of-command, and the soldiers themselves, will need to make critical decisions about mission-critical kit to be carried, protection levels to be worn, route plans, sustainment amounts of water and food, etc., etc. All of these decisions involve critical trade-offs and, in the absence of critical guidance regarding burden, these often result in heavy mission loads being borne by the soldier in both training and operations. In the absence of evidence-based, defensible guidance, Senior NCOs and Junior Officers will be reluctant to adapt loads and protection levels to changing conditions. Generally speaking, Senior NCOs and Junior Officers felt that they had very little control over what their soldier wore or carried.

Instructors suggest that the Army needs a decision aide, using evidence-based science, to inform the chain-of-command of the burden implications to soldier performance and wellbeing of different load order decisions, in light of the mission requirements, mission duration, environmental and terrain conditions, anticipated physical demands, and so on. Such a decision aide would also be valuable to inform the training branch so that loads could be selected to achieve sufficient hardship without risking serious injury.

Physical Burden Needs:

1. Need to know the performance effects of overburdening.

While instructors know intuitively and through experience that heavier loads reduce soldier performance and that this loss of effectiveness may affect Unit effectiveness, there is a lack of knowledge about the true performance effects of overburdening a soldier. Instructors also know that heavier loads increase a soldier's risk of injury but, again, mechanisms of injury and associated load factors are not well understood.

2. Need to define safe limits for burden for training purposes.

The Qualification Standard for infantry does not dictate the weights to be carried nor kit to be worn by course participants in training. This introduces potentially significant variability in the choices made from one instructor to another for the same course. There are also no guidelines, checks or balances, in the system to ensure that extreme loads are not used to make a course more "hardcore" or to make a training course into a selection course by the level of hardship applied.

Instructors need standard guidelines and limits set for each course to ensure the training goals and objectives are met without exceeding safe burden loads that may increase injury risks. If documented and binding, then an instructor would be giving an unlawful command

to exceed these safe levels in training. Operations would necessarily have no such limits but such a limit in training may improve retention and reduce the likelihood of career-shortening injury, while improving knowledge and awareness for burden trade-off decisions in operations.

Cognitive Burden Needs:

1. Need to understand and manage information overload.

The introduction of hand-held computers and other information systems into small Unit operations offers to increase Unit capabilities, situation awareness, tempo, and mission effectiveness but there remains a concern that all these new information devices could distract, overload, and detract from command presence and the execution of soldiering. At the same time, soldiers and junior officers are very familiar with information systems and devices in non-military applications and may integrate such devices seamlessly into military tasks. However, the effect of such systems remains a concern in the operating force.

The instructors suggested that the Army needs to understand the levels and sources of cognitive burden, associated with new information systems on the battlefield, and determine the extent to which these demands might be problematic. There also needs to be an evidenced-based assessment of the impact of increasing cognitive burden in terms of task performance, individual and team effectiveness, mental workload, and mental stress, according to different soldier roles, missions, situations, and conditions.

The instructors suggested that before something like cognitive burden can be managed we need to know if there is a problem, how significant, for whom, doing what, when. Once these issues are understood administrative, procedural, and engineering solutions can be applied to mitigate burden levels and effects as needed.

2. Need to design information systems to limit training and information burden.

Key to managing cognitive burden are the choices made in how information is provided to the soldier; how much is provided; when it is provided; who gets what information; and whether soldiers can self-manage the push and pull of information through controls on the devices.

The instructors indicated that these choices will be critical in determining the cognitive burden associated with the systems. At the same time, the systems and their software interface needs to be sufficiently user friendly as to not require significant training. Instructors pointed out that the training system itself is already heavily burdened by the volume and number of courses required to train soldiers. Additional add-on courses for information systems should be a further consideration in the design of future systems and their concepts of use.

6.6 Medical Group at 2 Fd Amb

Focus Group Participants: Medical Group at 2 Fd Amb

Date: 5 April 2016 at CFB Petawawa

Attendees: Medical Technicians (5x Cpl to Sgt, deployment experienced) and
Medical Officers (2x Captains)

Physical Burden Needs:

1. Need to reduce total physical load on soldiers.

The medical technicians regularly treat the musculo-skeletal injuries experienced by soldiers. Injuries commonly include lower back, knee, and ankle strains, and medical technicians believe that the incidence and severity of these injuries are related to heavy loads being carried and the dynamic tasks required of soldiers. Medical technicians report that many of these injuries can become recurring as soldiers are more likely to push on rather than rest the injury. To reduce the incidence and severity of these types of injuries medical technicians suggest that soldier loads should be reduced.

2. Need to improve total load carriage integration for Medical Technicians.

Medical technicians carry a full combat load during a mission, similar to other soldiers in their attached Unit. However, medical technicians also carry the additional load of their medical bag (~40 lbs). On long range patrols, they must carry their rucksack, their medical bag, and their combat load, typically totally about 150 lbs. They noted that they themselves are at significant risk to become a mobility casualty as well. In shorter missions, where other soldiers would carry a combat pack, medical technicians must find space in their medical pack for their personal kit and, due to the small available capacity, they are often required to do without important items like environmental clothing.

Medical technicians need a load carrying solution that is designed to be integrated and compatible with other load carrying equipment (e.g. rucksacks, packs, and combat loads) to minimize load forces on the medical technician as much as possible.

3. Need to improve confidence in the resupply chain.

Medical technicians report that they pack their medical bags with as much medical materiel as possible, under the assumption that they will not be resupplied; this likely results in heavier than necessary loads. Assumptions about unreliable resupply were also reported by participants as the reason they carried extra supplies. In the cases of both soldiers and medical technicians, however, neither could provide examples when resupply was inadequate. Therefore, there needs to be efforts made to educate and inform the true risk

of untimely or inadequate resupply so that soldiers and medical technicians can make better informed packing decisions and, hopefully, carry less load.

4. Need to train soldiers to self-assess physical state and personal limits.

Medical technicians noted that some casualties are the result of soldiers not being self-aware of their physical limitations and capacity for load carrying, or their level of hydration. Soldiers need to use their training opportunities to better understand their own limits and then to take that knowledge and use it to make good packing and load configuration decisions to minimize their own physical burden and risk of injury. The same level of personal responsibility is needed to ensure soldiers hydrate. Similarly, soldiers need to learn to read their hydration state during training opportunities to ensure that they are not a heat casualty in operations. Soldiers need specific training on physical demands and how they can personally mitigate their own demands.

Cognitive Burden Needs:

1. Need to identify and triage casualties faster and better.

In the midst of a firefight, medical technicians report that it can be very challenging to identify casualties, locate them in the fight, and prioritize them for transport and further treatment. Currently the medical technician will respond to radio calls and shouted instructions to move from casualty to casualty until such time as a Casualty Collection Point (CCP) can be set up. The associated uncertainty and urgency in such situations places a significant cognitive burden on the medical technician and increases the challenges of providing timely care to the casualties.

Given the advent of soldier computers and body-worn physiological monitoring sensors, it would be advantageous to use technology to support the location and triaging of casualties. A casualty could self-assess and issue a medic request through their soldier computer, if they are able, to indicate their location and urgency. If they are not able then physiological monitors (e.g. HR, breathing rate, blood pressure) could trigger a medic request automatically if life sign measures dropped to critical levels. Such systems could also assist the medical technician by prioritizing casualties in most need of critical care to optimize the allocation of medic care to best meet the medical demands. Medical technicians also indicated that it would be important to know if the casualty were “life signs absent” so that they could ensure their time was being spent saving casualties.

2. Need to improve predictive monitoring of soldiers.

Often medical technicians will need to react to a medical situation that has developed in a soldier that was not detected until too late. Heat casualties are an example. While there are signs of heat stress that are observable by a medical technician or by buddy-care it often goes undetected until there is an evident heat casualty, which can then significantly affect

the mission. Medical technicians suggested that soldier computers could employ physiological monitoring sensors to provide an early warning to the soldier to hydrate and to the medic to inform of developing heat stress so that an early, recoverable intervention can be applied.

While the concept is appealing, medical technicians did note that there would need to be considerable study to confirm the technology, establish the reliability and validity of the physiological measures and the technology, and determine the best means of providing and displaying this information to soldiers, medical technicians, medical chain, and chain of command.

3. Need to ensure that information systems do not overload medical technicians.

Soldiering is both physically and mentally demanding. Pushing new information content and sources to the medical technician risks increasing the levels of cognitive burden. Medical technicians were quick to emphasize that any new device needed to display simple, instructive information that could be quickly and easily understood, and actioned.

4. Need to improve the reporting and flow of patient information.

Casualties on the battlefield are triaged by the medical technician for processing and, for serious injuries, evacuation to a trauma centre or combat hospital. Currently, the medical technician will use a 9-liner report to initiate the evacuation and they will complete a MIST (Mechanism of Injury, Symptoms and Treatments) form and tag the casualty. However, with more casualties, medical technicians report that the form-filling becomes less possible to complete, and the medical officers present in the meeting indicated that very few (10%) of casualties arrive at a trauma centre with any pre-hospital information. This lack of pre-hospital information could affect patient outcomes.

Ideally, technology would be able to support the collection of vital information, patient tagging, recording of medical technician information, and reporting of patient history. Concepts like a digital dog tag could be used to store patient history and medical background. Soldier-worn computers, in concert with physiological monitoring sensors, could record vital signs data, send out alarms and alerts to medical staff, and provide a venue for transmitting 9-liner reports and recording MIST data. In this way, patient information and treatment data would remain current, be easily added to the 9-liner and MIST reports, and travel digitally with the patient as they move to other locations for trauma care.

Medical technicians also noted that treating casualties during combat is a high stress event so medics can also suffer stress effects that can affect tasks like form-filling. One option suggested was to investigate using voice recordings, with speech-to-text recognition, for the MIST reports so that they could be done quickly, hands-free, and more naturally for a medic under stress.

5. Need to train soldiers to self-assess psychological state.

While medical technicians are often associated with the physical care of soldiers, they report that they are also looking out for the soldier's mental wellbeing as well. This includes counseling and watching for signs of extreme stress, depression, and other forms of mental illness. High stress episodes (e.g. "going into the black") can occur during combat, rendering a soldier ineffective and possibly a danger to themselves or others.

Being able to identify the signs leading up to a high stress episode would enable a medical technician, and even the soldier themselves, to intervene earlier in the escalation of symptoms to prevent or minimize the effects of the episode. Ideally, there would be a means of physiological monitoring that could predict such a high stress escalation and provide a digital warning to the soldier and the medical technician.

Medical technicians also suggested that soldiers would also benefit from being made more self-aware of the symptoms of an escalating high stress symptoms in general and, specifically, more insight into their own personal response to stress. Training provides the venue for such high stress awareness training. Physiological monitoring may be more effective in a training environment at first to help soldiers recognize their own symptoms, and their symptoms progression, so that they can learn personal stress management strategies that would help them avoid an episode in combat.

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13. ABSTRACT/RÉSUMÉ (When available in the document, the French version of the abstract must be included here.)

Physical and cognitive burdens on the soldier are a multi-factorial problem that is affected by the actions and decisions of many different Canadian Army stakeholder organizations. Under Defense Research and Development Canada's (DRDC) Soldier System Effectiveness (SoSE) project, a WBE has been established to address the problem of soldier burden. The goals of this WBE are to better understand the factors contributing to soldier burden and to develop, validate and recommend strategies to mitigate the associated burden. The aims of this project were to review the needs of stakeholder organizations and to identify, and prioritize, strategies for the way ahead.

Focus group discussions were held with six stakeholder organizations including the Army Combat Development Board (ACDB), the Canadian Army Land Warfare Centre (CALWC), the Canadian Army Doctrine and Training Command (CADTC), the Director Land Requirements (DLR 5), the Director Soldier System Project Management (DSSPM), the Infantry School, Combat Training Centre Gagetown, and the Medical Group at 2 Field Ambulance.

The overwhelmingly consistent need of stakeholder organizations from the Burden Mitigation WBE is scientific evidence to support burden-related decisions. Stakeholders require scientific evidence to support and justify difficult decisions, valid measures and standards to control and shape the sources of burden, and knowledge and awareness of the effects and causes of burden, necessary to transform the enabling culture of overburdening in the Canadian Army. In reviewing the stakeholder needs for scientific evidence to fill gaps in knowledge and to support the development and implementation of solutions, several action streams are recommended.