SOLDIER SYSTEMS TECHNOLOGY ROADMAP

CAPSTONE REPORT AND ACTION PLAN

SUPPORTING THE FUTURE SOLDIER
SUPPORTING CANADIAN INDUSTRY

Government of Canada Gouvernement du Canada

Canada

SOLDIER SYSTEMS TECHNOLOGY ROADMAP

CAPSTONE REPORT AND ACTION PLAN

Abstract

The Soldier Systems Technology Roadmap Capstone Report and Action Plan captures and summarizes the findings of the Development Phase of the Soldier Systems Technology Roadmap (2011–2025) (SSTRM) initiative. The SSTRM is a groundbreaking industry-government collaboration focused on enhancing the operational effectiveness of the future Canadian soldier and the competitiveness of Canadian industry through open innovation. Led by the Department of National Defence (DND)—with participation from Army and Materiel branches and Defence Research and Development Canada (DRDC)—and Industry Canada (IC), the initiative enjoys the strong support of the Canadian Association of Defence and Security Industries (CADSI) and of Technopôle Defence and Security (TDS). Applying roadmapping principles and processes to Canadian Forces soldier modernization efforts, the initiative involves industry and academia collaboratively in a comprehensive knowledge-sharing platform to articulate future needs and identify capability gaps, related challenges and potential technology solutions for the Canadian soldier of the future. The report includes an Action Plan that highlights the key R&D priorities identified by the soldier systems community of interest and makes recommendations for next steps in the initiative to encourage industry, academia and government collaboration in bringing innovative solutions forward for use by the future Canadian soldier.

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Preface

It is with pride that we present the Soldier Systems Technology Roadmap (SSTRM) 2011–2025 Capstone Report and Action Plan.

The SSTRM is a groundbreaking industry-Government of Canada collaboration focused on enhancing the operational effectiveness of the future Canadian Soldier System and the competitiveness of Canadian industry through open innovation.

It aims to identify Canadian Army capability requirements and begin to align industry research and development (R&D) cycles with future Soldier System technology needs.

The SSTRM 2011–2025 Capstone Report and Action Plan serves as a guide for all future research, development and collaborative efforts to ensure the availability of the future Soldier System capabilities necessary to achieve the Canadian Army's vision and goals. Canadian Army staff, Government departments, industry and academia are strongly encouraged to use this reference document as a starting point to develop a high-level awareness about the various dimensions of Soldier System modernization.

Only through collaboration, improved focus and coherence across the Soldier System's community of interest will the future needs of our Canadian soldiers be addressed. By leveraging the Canadian defence industrial base's leadership and manufacturing capabilities, the imagination and scientific knowledge of our academics and the collaboration among all interested parties, we are confident that the Canadian Army' future Soldier System's requirements will be met in order to provide the Canadian Army with much needed tools to accomplish its demanding missions and tasks.

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Acknowledgements

On behalf of the SSTRM sponsor organizations, we would like to acknowledge the tremendous voluntary effort across the soldier systems community of interest that has provided the knowledge base to make this report possible. This spirit of collaboration and open innovation has been the hallmark of the SSTRM. Over the course of seven workshops, more than 1550 participants contributed their ideas to the vision for the SSTRM. Several hundred participants collaborated further through the Innovation, Collaboration and Exchange Environment (ICee) and Technical Sub-Committees (TSCs) to deepen this vision with detailed information on capability requirements, emerging technology solutions and expected technology readiness levels.

We would particularly like to thank the members of the SSTRM Executive Steering Committee and Technical Sub-Committees for their leadership and exceptional contribution of expertise and time. While the final content of this report is the responsibility of the Department of National Defence, the development of such a comprehensive roadmap would not have been possible without the diligence and dedication brought by the ESC and TSCs to the overall vision.

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Executive Summary

Setting the Stage

The Soldier Systems Technology Roadmap (2011–2025) (SSTRM) is a groundbreaking industry-government collaboration focused on enhancing the operational effectiveness of the future Canadian soldier and the competitiveness of Canadian industry through open innovation. Led by the Department of National Defence (DND)—with participation from Army and Materiel branches and Defence Research and Development Canada (DRDC)—and Industry Canada (IC), the initiative enjoys the strong support of the Canadian Association of Defence and Security Industries (CADSI) and of Technopôle Defence and Security (TDS).

The SSTRM project focuses on the technology needs of the soldier as the centre of a complex and integrated system of advanced technological systems. The soldier system incorporates anything related to the life and work of a ground force combatant including integration with other platforms (e.g. vehicles).

The initiative applies roadmapping principles and processes to Canadian Forces soldier modernization efforts, and involves industry and academia collaboratively in a comprehensive knowledge-sharing platform to identify capability gaps, related challenges and potential technology solutions for the future Canadian soldier.

By engaging Canadian industry and academia early in the capability development process, the SSTRM helps accelerate innovation within the soldier systems community of interest—both to position Canadian industry to compete in global markets and to support the future Canadian soldier with world-class capabilities and technologies.

Comprised of three phases—definition, development and implementation—the SSTRM has achieved notable success in bringing together Canadian and international business representatives and technical experts from multiple technology sectors across industry, government and academia to identify CF capability requirements and begin to align industry R&D cycles with CF future soldier technology needs.

In so doing, the SSTRM responds to the objectives of the *Canada First Defence Strategy*[1] *and its associated Defence Science and Technology Strategy*.[2] The *Canada First Defence Strategy* requires the CF, supported by DND, to deliver excellence at home, to be a strong and reliable partner in the defence of North America and to project leadership abroad. To successfully execute these missions, the CF needs to be a fully integrated, agile, multi-purpose and combat-capable force, possessing a range of military capabilities centred on personnel, equipment, readiness and infrastructure. Building and maintaining an adaptive and agile force capable of responding to the range of security challenges that Canada faces requires effective and integrated Force development (FD). FD encompasses concept development and R&D to provide capability delivery to operations. The soldier is a pillar of the CF ability to deliver on these tasks.

SSTRM Project Development Phase Strategic Partners

- Canadian Association of Defence and Security Industries (CADSI)
- Department of Foreign Affairs and International Trade (DFAIT)
- Canadian Forces
  - Director of Land Requirements (DLR)
- Department of National Defence (DND)
  - Director of Soldier System Program Management (DSSPM)
  - Defence Research and Development Canada (DRDC)
- Industry Canada (IC)
- National Research Council Canada (NRC)
- Public Works and Government Services Canada (PWGSC)

The human domain is the vital ground within the strategic domain . . .

Chief of Force Development

Worldwide Soldier Modernization Efforts

The SSTRM draws extensively on the North Atlantic Treaty Organization (NATO) soldier system definition and operational concept for its holistic framework. It also uses the five NATO soldier system capability areas (Survivability, Sustainability, Mobility, Lethality and C4I—Command, Control, Communications, Computer and Intelligence) to guide its work across the Canadian soldier capability areas.

The world stage now has a large number of nations providing systems for dismounted soldiers. This includes a growing number of countries outside of NATO and Partner for Peace (PfP) countries (e.g., Australia and Singapore). Most, if not all, of these nations use elements of the NATO defined soldier system capability areas.

The soldier systems worldwide market is quite robust. Major international prime contractors are bidding on programs in countries such as Australia and Singapore. NATO and PfP nations are also opening up soldier systems markets, led by Germany, Switzerland, France and Spain. Steady growth in this area is forecasted in a study conducted by VisionGain, with a total global market approaching $14 billion USD by 2019. A broad number of emerging nations are expected to seek to enable their soldiers and/or junior commanders with various system devices in the coming years.

1 Government of Canada. Canada First Defence Strategy. Ottawa: DND (2006).

2 Government of Canada. Defence S&T Strategy—Science and Technology for a Secure Canada. Ottawa: DND (2006).

Canadian Forces Soldier Systems Modernization Efforts

The Canadian Forces soldier system vision sees a networked dismounted soldier with vastly improved situational awareness and command execution, coupled with improved navigation and access to improved target acquisition and recognition capability. This configuration will optimize the five capability areas and enable the rapid aggregation of forces to effectively prosecute targets for overall improved tactical performance and ultimately, better operational effectiveness for the CF and its coalition partners.

Current technology contributes in enhancing soldier capabilities in the areas of energy and power, lethal and non-lethal effects, C4I and sensing, and survivability and sustainability. However, these capabilities still need to be further enhanced through emerged and emerging technologies in a concerted effort to improve systems integration and to better understand and accommodate the related human factor.

Through the SSTRM, the Canadian soldier systems community of interest has developed a detailed list of technology options having the potential to meet many of the CF future soldier's capability needs. However, the ultimate goal of Canadian soldier system efforts remains a wholly integrated soldier system that can best achieve the ideal "Hard Problem" equilibrium. This vision—coupled with the SSTRM's ongoing collaborative roadmapping effort—will enable the soldier systems community of interest to take emerging technologies and advance their maturity level such that they be considered for exploitation in soldier systems related programs.

What We Know

An important objective of the SSTRM is to identify the dismounted soldier's capability gaps and the technologies that are required to address those gaps. Chapters 5 to 10 of this report set out a logical sequence of information that links capability gaps in the six SSTRM technical domains—power and energy; weapons effects; command, control, communications, computer and intelligence (C4I); sensing; survivability/sustainability/mobility; and human and systems integration—to the R&D focus areas that could address those gaps.

The technical chapters are based on the knowledge exchange that took place at the SSTRM technical workshops, as well as on further discussion and analysis. Through these workshops, 20 "theme" areas were identified across the six technical domains. These themes provide a practical structure for discussing the technologies related to deficiencies in each of the technical domains.

Following the technical workshops, the knowledge exchange and collaboration was continued through the online Innovation, Collaboration and Exchange Environment (ICee) and the Technical Sub-Committees (TSCs). Participants included industry experts, academia, defence scientists and representatives from the "user" community—soldiers. This collaborative process of populating the templates occurred during the fall of 2010 and winter of 2011. The information gathered will continue to grow and be refined throughout the SSTRM Implementation Phase.

The vision and goals for each technical domain are summarized in the following sections.

Power and Energy

Power and energy on the dismounted soldier is a key technical domain with many associated challenges. It is a fundamental element of the recent digitization effort, which has become as essential as traditional soldier commodities such as food, water and ammunition. Electrical power must be provided for any of the electronic equipment to function. As soldier systems evolve to include new capabilities, the dependence on electricity will continue to grow.

Vision 2025

The SSTRM vision for the Power and Energy technical domain in 2025 is to provide the future networked soldier with self-sufficiency—without re-supplying for the mission duration— through increased energy efficiency, with the lowest acceptable added weight.

Overall System Goals for:

- **2015–2020**—soldier systems with sufficient energy storage capacity to operate through a 24-hour mission, and with the recharging or fuel re-supply to operate through a 72-hour mission.
- **2020–2025**—soldier systems capable of energy autonomy.

Weapons Effects

Weapons Effects (lethal and non-lethal) is the technical domain providing the firepower element of soldier systems. This technical domain covers the weapons platform, sighting and fire control system, and the weapon ammunition. Weapons effects can be optimized by addressing the various elements of the kill chain. The weapons system also includes the operator/user, sensors and other ancillaries that could be part of the weapon or the sighting system.

Vision 2025

The SSTRM vision for the Weapons Effects technical domain in 2025 is to provide an effective, portable and integrated weapons system platform for the soldier and the section. The platform provides scalable lethal and non-lethal effects against a variety of targets at the desired range/conditions (e.g., night and day, all-weather) while minimizing system physiological and cognitive burden.

Overall System Goals for:

- **2015–2020**—a weapons system that permits soldiers to accurately detect and identify enemy targets, accurately engage and effectively neutralize enemy targets (lethal—immediate incapacitation, and non-lethal—reversible incapacitation) with a minimum of ammunition. The weapon, ammunition and Weapon-Mounted Situational Awareness and Targeting Suite (WM-SATS) will be lighter in weight and bulk to improve soldier mobility. The weapons system will reduce the soldier training and skills retention burden.
- **2020–2025**—a weapons system that includes an advanced fire control system that will:
  - reduce operator deficiencies
  - significantly enhance target detection, recognition and tracking
  - provide assisted target engagement
  - permit the exchange of target information with other soldier systems and sensors
  - significantly reduce weight and optimize operator performance at all ranges
  - deliver effects tailored to the target (managed lethality weapons system concept)
  - possess embedded training features to facilitate operator training
  - offer tuneable ammunition

Command, Control, Communications, Computer and Intelligence (C41)

The Command, Control, Communications, Computer and Intelligence (C4I) technical domain encompasses a number of enabling elements that permit the combat soldier to efficiently execute the commander's intent and enhance interoperability. They also optimize the integration of people, processes and technologies for the sharing of information, decision-making and coordinated action. These enabling capabilities cover everything from military strategy and policy to information management, information assurance, system architecture, technology and security—all of which rely on a seamlessly integrated and network-enabled backbone.

Vision 2025

The SSTRM vision for the C4I technical domain in 2025 is to enable a combat soldier to obtain an accurate, relevant and timely understanding of the area of interest based on the Common Operating Picture (COP) through a fully integrated information and systems-based capability within the constraints generated by factors such as security, weight, volume, power and cognitive load. To ensure continued relevance, this system will be scalable.

Overall System Goals for:

- **2015–2020**—the networked enabled soldier will permit commanders to have improved command and control (planning, decision making, briefing, training and execution) over their area of interest. This seamless network will provide the soldier and commander with improved communications, decision-making aids, navigation and human-machine interface capabilities, thereby reducing cognitive burden while promoting better situational awareness.
- **2020–2025**—the autonomous and continuously networked enabled soldier will permit commanders to have optimized command and control (improved capability to train, collect, process, disseminate and exploit timely and accurate information and intelligence) across the spectrum of operations over their area of interest. This seamless, self-forming and self-healing ad-hoc network will allow for a multi-tier and opportunistic (i.e. any waveform, any channel, any medium available) communications platform for each soldier through COP and C4I assets regardless of environment. Increased situational awareness combined with autonomous information management, naturalized human interfacing, sensor integration and adaptive artificial intelligence will permit an increase in operational tempo (quicker to initiate/act/react/deploy).

Sensing

The Sensing technical domain feeds the command domain/function where decisions are made on which actions to take (e.g., exercise and fire power), and provides essential input into the generation of situational awareness. It combines a number of sensing tasks and technologies: passive and active sensors, as well the entire sensor system (the operator/user, sensors, sensor carrier, data communication system and computer system).

Vision 2025

The SSTRM vision for the Sensing technical domain in 2025 is a system that significantly improves individual, group and area sensing through a shared, intelligent and autonomous network to allow timely and efficient detection, recognition, identification and localization of objects of interest under all environmental conditions, across the whole spectrum of operations. This fusion of all the integrated sensing capability will bring the necessary knowledge to enable effective command, control and force protection while minimizing physiological and cognitive burden.

Overall System Goals for:

- **2015–2020**—an enhanced, lightweight system that reduces the burden of the sensor system, improves sensor performance and integration, and reduces operator workload.
- **2020–2025**—an adaptive, intelligent integrated sensor system that provides "plug and play" sensing capabilities with improved resolution, 360-degree extended coverage, a robust sensing network and a system that requires minimal operator workload.

Survivability, Sustainability and Mobility Technical Domain

The Survivability, Sustainability and Mobility technical domain addresses a number of issues related to soldier system survivability, sustainability and mobility, including personal protection.

Military activities and operations are intrinsically hazardous. Soldiers conducting full-spectrum operations must assume calculated risks every day, based on the significance of the mission, the operational requirement and opportunity. An assessment of the Future Security Environment suggests that future adversaries and the strategies, techniques, tactics and procedures and technological capabilities they will employ against the Canadian dismounted soldier may be diverse and wide-ranging. Opposition to a mission can come from traditional and emerging threats, as well as from environmental and occupational hazards. Soldier survivability against the diverse threats and hazards encountered in their operating environment is a crucial aspect of full-spectrum dominance and mission success.

Soldier survivability also closely relates to the Army of Tomorrow omni-dimensional shield functional concept that aims at providing force protection, survivability and freedom of action across the physical, human and informational planes for all hazards and threats, and at taking advantage of various enablers.

Vision 2025

The SSTRM vision for the Survivability, Sustainability and Mobility technical domain in 2025 is a system that enhances significantly soldier survivability, mobility and sustainability, and increases operational effectiveness by providing a lightweight, highly comfortable, mission configurable, fully integrated and interoperable, multi- functional system for all environment and weather conditions.

Overall System Goals for:

- **2015–2020**—a lightweight system that improves the balance between protection and performance, enhances functionality, comfort, personal protection, safety and mobility, and achieves better integration.
- **2020–2025**—an adaptive, intelligent integrated system that offers "plug and play" capabilities and "self" functions (e.g., self-repair). It allows the soldier to evade C4I detection through signature management, and to exploit an integrated and optimized survivability chain (with functions to avoid detection/identification and increase platform manoeuvrability, and the capability to defeat attack and enable self-repair).

Human and Systems Integration Technical Domain

The Human and Systems Integration technical domain covers human and systems integration as a key enabler linked to all the soldier system capabilities. Human Systems Integration (HSI) is a technical and management process that seeks to enhance total system effectiveness and minimize life-cycle costs throughout the entire life cycle of any socio-technical system. This is achieved by implementing the most effective balance of human integration processes from five human-centric areas—in concert with traditional systems-engineering and management processes—to optimize the integration of individuals and teams into socio-technical systems. These five HSI areas include human factors (HF) engineering, system safety, training, health hazards and personnel.

Vision 2025

The SSTRM vision for the Human and Systems Integration technical domain in 2025 is to significantly enhance soldier and team effectiveness and to minimize overall life-cycle costs by consistent and balanced implementation of HSI technical and management processes to optimize the integration of individuals and teams into the larger socio-technical soldier system across the five North Atlantic Treaty Organization (NATO) capability areas. This will be achieved through the application of human-centric processes in five domains: human factors engineering, system safety, personnel, training and health hazards.

Overall System Goals for:

- **2015–2020**
  - Quantify the gaps/deficiencies in task performance of the current soldier system.
  - Quantify the benefits and impact of HSI intervention across the five NATO capability areas and total system life-cycle cost.
  - Develop advanced human system interfaces for seamless integration with human characteristics, capabilities and needs.
  - Develop system integration architecture and interface guidelines and standards.
  - Develop/improve/disseminate affordable, usable HSI tools and processes to support effective human systems integration by and for the range of stakeholders.
  - Promulgate a Department of National Defence (DND) policy mandating the employment of HSI processes throughout the life cycle of all product acquisition and technology development projects having a soldier system element.
  - Institutionalize an Army service policy (including a handbook) and instruction to support the integration of HSI technical and managerial processes with the systems engineering process and life cycle management of soldier systems and their components.
  - Develop or adopt a handbook (including standards) and an instruction document for employing HSI technical and managerial processes in the product life cycle of soldier system components.
- **2020–2025**
  - Consistently implement an effective balance of HSI human-centric areas (i.e. human factors engineering, system safety, personnel, training, health hazards) and technical and management processes by institutionalizing HSI training and hiring HSI expertise.
  - Optimize integration of individuals and teams into the larger socio-technical soldier system across the five NATO capability areas.
  - Enhance and optimize physical, perceptual-cognitive, socio-psychological and system integration of soldier systems to meet training needs, operational demands and to defeat the threats of the Future Security Environment (FSE).
  - Provide designs with mature, deployable, operator-state and mission-phase adaptive (intelligent) interfaces and components of the soldier system.
  - Provide affordable, fully integrated, appropriately equipped, well-trained soldiers who are able to perform their tasks with minimum degradation under all conditions.
  - Train the entire soldier system infrastructure to use and maintain the systems.
  - Provide ubiquitous systems and processes that support human and systems integration.
  - Respond to secular trends in the physical, perceptual, cognitive and cultural characteristics of the soldier population in the design of future soldier systems.

What's Next?

Action Plan — R&D Priorities

The SSTRM 2011–2025 Action Plan is intended to engage a national collaborative effort to support the development of soldier system solutions for the Canadian soldier of the future. The broad analysis and efforts over the last two years have led to the identification of key R&D focus areas in the SSTRM's 20 themes, grouped into six technical domains. The Action Plan—located in Chapter 11—provides theme-by-theme snapshots of the SSTRM themes and the R&D priorities and gaps in technology standards that need to be addressed by the SSTRM community of interest.

Maintaining the principles of open innovation and open collaboration, members of the SSTRM community of interest are encouraged to pursue these opportunities through collaborative R&D and by leveraging public and private sector funding, infrastructure and networks of expertise. Individual researchers, companies and organizations are encouraged to pursue those R&D projects that provide the best fit with their own business plans and medium- to long-term goals.

The Way Forward

The SSTRM has built a broad network between industry, academia and government around the needs of the Canadian Forces soldier of the future. This kind of discussion between technology-based firms, academia and their future markets is fundamental to innovation. The technology solutions identified by the SSTRM, if successfully developed and implemented, will help position Canadian industry for success in global markets and increase the effectiveness of Canada's future dismounted ground soldiers in a variety of combat environments.

Recommendations

The SSTRM recommendations listed in the table below are directed to all members of the SSTRM community of interest, although specific recommendations call for leadership from some or all of the SSTRM partners. Some activities—such as the establishment of a project Management Office by the Department of National Defence (DND)—are already underway.

Recommendations for the SSTRM Implementation Phase

Recommendation	Impact	Description
Release & publicize the Capstone Report and Action Plan	Increased community of interest understanding and better integration of Canadian Forces systems-capability needs into Canadian and international industry-academia-government R&D plans.	SSTRM partners release the Capstone Report and Action Plan and encourage feedback from SSTRM community of interest through various channels including presentation at Army Outlook Day (CANSEC), publication on the Innovation, Collaboration and Exchange Environment (ICee) web platform and SSTRM web site, and distribution through participating industry associations.
Create SSTRM facilitation mechanism (MO)	Increased industry-academia-government collaboration on soldier systems R&D, with enhanced flow of innovative technology solutions to meet CF modernization requirements.	DND establish a MO to maintain ongoing SSTRM knowledge exchange and facilitate/coordinate/monitor R&D on potential technology solutions. IC will host and maintain the ICee knowledge exchange and information management tools, which will be administered by DRDC.
Identify timeframes/ sequencing for R&D priorities/standards	Improved sequencing of R&D to meet CF modernization requirements and early-to-market delivery of innovative technology solutions that enhance industry's competitive position in the global marketplace.	SSTRM partners convene a consultation process to determine the optimal sequencing of R&D priorities and recommended standards development. This process elicits an ongoing knowledge exchange within the SSTRM community of interest through technology networks, the ICee or workshops.
Encourage and support SSTRM community of interest in the pursuit of R&D and/or technical standards projects	Increased flow of innovative Canadian technology solutions to CF and global soldier systems markets.	SSTRM community of interest launches R&D projects and technical standards initiatives based on the capability gaps and technology solutions highlighted by the Capstone Report and Action Plan (and available in the ICee). Industry-academia-government research community members identify R&D projects and potential collaborations that best align with their R&D plans and business strategies. The SSTRM MO will link individual or collaborative research projects proposals with government innovation funding programs when requested, and will provide access to soldier systems subject-matter experts who can offer feedback on proposed technologies. Ongoing collaboration and feedback between the SSTRM community of interest and DND/DRDC is facilitated through the ICee and other mechanisms.

Recommendations for the SSTRM Implementation Phase

Recommendation	Impact	Description
Maintain SSTRM community of interest dialogue & ongoing roadmap updates	Increased innovation & global competitiveness among Canadian firms generating innovative products for soldier systems markets.	SSTRM community of interest continues its knowledge exchange and networking activities through a variety of means including the ICee, technology networks focused on key capability areas, annual workshops, and periodic updating of the roadmap.
Orient government innovation support programs to SSTRM objectives & capability gaps	Increased alignment of government innovation support for firms engaged in soldier systems R&D. Improved industry & academia understanding of how to access these programs.	The SSTRM MO maintains and improves communications channels with government innovation support programs across the country to keep program officials up-to-date with evolving CF soldier modernization capability requirements and potential SSTRM outputs. The MO also works with these programs to improve interagency linkages around soldier systems R&D and to encourage clear communication of the application process to the SSTRM community of interest.

Next Steps

Two core activities will underpin the success of the SSTRM Implementation Phase:

- **R&D Proposals**—increasing the flow of well-targeted private sector led R&D proposals that will generate technology solutions aimed at meeting the needs of the soldier of the future.
- **Knowledge Exchange and Roadmap Evergreening**—maintaining the knowledge exchange established during the Development Phase to keep the SSTRM community of interest updated on evolving soldier systems needs and technology solutions.

The SSTRM partners have agreed to collaborate on supporting these important Implementation Phase objectives, with an immediate focus on three key activities:

- Establishing a project Management Office (MO)
- Creating Soldier Systems Technology Networks as needed
- Continuing to "populate" the Innovation, Collaboration Exchange Environment (ICee) to enable technology watch

About the SSTRM Project Management Office

The SSTRM project Management Office—launched April 1, 2011 by DND—plays a central role in facilitating the SSTRM Implementation Phase and animating knowledge exchange within the Soldier Systems community of interest. Key functions include:

- Providing CF/DND/DRDC feedback on proposals for soldiers systems R&D.
- Helping stakeholders to prioritize R&D and assisting DND to bring certainty to future requirements (e.g., standards development in collaboration with the Canadian Standards Association).
- Creating a "clearing house" of ideas, capabilities and possible funding sources to facilitate collaboration among SSTRM participants.
- Facilitating possible sponsorship by CF/DND of relevant projects that align with future soldier systems needs.
- Communicating SSTRM R&D priorities to government innovation support programs and helping to align program priorities to SSTRM needs.
- Evergreening SSTRM activities through technology watch activities, R&D project monitoring and an annual workshop.

To contact the MO: SSTRM-CTSS@forces.gc.ca

The responsibility for developing a R&D proposal or offer based on the needs identified by the SSTRM will rest with industry and academia.

PART I: OVERVIEW

PART I: OVERVIEW

Chapter 1: Introduction

1.1 About this Report

This Capstone Report and Action Plan is a comprehensive document that includes the context, findings, conclusions and recommended action plan from the Development Phase of the Soldier Systems Technology Roadmap 2011–2025 (SSTRM) project. The report consists of three main parts:

- **Overview of the International and Canadian Environments**—A summary of the current soldier systems environments and the Canadian Forces soldier system capabilities (Chapters 1 to 3).
- **Technology Domains**—A comprehensive analysis of future CF soldier systems capability requirements and potential technology solutions (Chapter 4 to 10).
- **Action Plan**—Recommended actions to guide the soldier systems community of interest, including industry and academia, to meet the goals and objectives identified in the SSTRM to address the future Canadian soldier needs for operational effectiveness (Chapters 11 and 12).

The report draws together the results of the SSTRM project Development Phase's three main knowledge exchange and collaboration exercises. All three of the following activities were key steps in developing the report:

- **Workshops**—Seven workshops (one visioning and six technical) were held nationally, gathering industry, academia and government to explore and identify the key capability requirements, related challenges, potential technology options and R&D focus areas.
- **Online Collaboration**—Participants used the Innovation, Collaboration and Exchange Environment (ICee) to deepen and expand the knowledge base, and access and build communities of interest.
- **Expert Validation**—Experts on the SSTRM's Technical Sub-Committees (TSCs) provided in-depth analysis and helped identify top-level priorities.

SSTRM Project Development Phase Strategic Partners

- Canadian Association of Defence and Security Industries (CADSI)
- Department of Foreign Affairs and International Trade (DFAIT)
- Canadian Forces
  - Director of Land Requirements (DLR)
- Department of National Defence (DND)
  - Director of Soldier System Program Management (DSSPM)
  - Defence Research and Development Canada (DRDC)
- Industry Canada (IC)
- National Research Council Canada (NRC)
- Public Works and Government Services Canada (PWGSC)

The human domain is the vital ground within the strategic domain . . .

Chief of Force Development

1.2 Background

The SSTRM is a groundbreaking industry-government collaboration led by the Department of National Defence (DND) and Industry Canada (IC) that focuses on two complementary objectives: enhancing the operational effectiveness of the future Canadian soldier and the competitiveness of Canadian industry through open innovation.

The SSTRM approach is to understand how today's technology—and tomorrow's—might contribute to an enhanced soldier system that increases the capabilities of the individual soldier in the five North Atlantic Treaty Organization (NATO) soldier capability areas of Survivability, Sustainability, Mobility, Lethality and C4I—Command, Control, Communication, Computer and Intelligence.

The initiative applies roadmapping principles and processes to CF soldier modernization efforts, and involves industry, academia and government collaboratively in a comprehensive knowledge-sharing platform to identify capability gaps, related challenges and potential technology solutions for the future Canadian soldier.

In so doing, the SSTRM responds to the objectives of the *Canada First Defence Strategy* and its associated *Defence Science and Technology Strategy*.

The *Canada First Defence Strategy* requires the CF, supported by DND, the ability to deliver excellence at home, to be a strong and reliable partner in the defence of North America and to project leadership abroad. To successfully execute these missions, the CF needs to be a fully integrated, agile, multi-purpose and combat-capable force, possessing a range of military capabilities centred on personnel, equipment, readiness and infrastructure. Building and maintaining an adaptive and agile force capable of responding to the range of security challenges that Canada faces requires effective and integrated Force development (FD). FD encompasses concept development, research and development (R&D) to provide capability delivery to operations. The soldier is one of the pillars supporting the CF's ability to perform the tasks assigned to it.

The *Defence S&T Strategy* establishes the conditions to maximize the impact of the departmental S&T investments by ensuring that they are: aligned with priorities, properly harnessed to be a force multiplier and duly supportive of the defence institution and its core business processes. The strategy is intended to guide the appropriate positioning of those investments so that S&T informs and enables the stakeholders to respond to Canada's defence and security priorities where and when the CF and DND are expected to contribute. Specifically, the investments are expected to support decision-making as well as to anticipate, assess and advise on the implications of emerging and potentially disruptive S&T. It is also intended to help to assess mature technologies, their positioning and transitioning into service for the benefit of the CF and the department. The SSTRM contributes to the strategy through a collaborative innovation model, which aligns the interests of different groups of stakeholders around a common research and commercial objective.

By engaging Canadian industry and academia early in the capability development process, the SSTRM helps accelerate innovation within the soldier systems community of interest—both to position Canadian industry to compete in global markets and to support the future Canadian soldier with world-class capabilities and technologies.

1.3 Why a Technology Roadmap?

After initial experimentation with mind map methodologies, the CF soldier system experts recognized the need for a more comprehensive and structured approach that would enhance the CF's ability to identify and deliver effective soldier system capabilities for the dismounted soldier. Critical issues included a limited ability to identify technology readiness levels (TRLs) and complications arising from a lack of connection between industry, academia and government that might be generating complementary R&D and emerging technology solutions.

In 2008, IC agreed to bring its experience with industry to the soldier systems initiative—allowing DND and the broader soldier systems community of interest to drill deeper into soldier systems capabilities through a process known as technology roadmapping. This enabled companies of all sizes, academia and researchers in other government departments—both nationally and internationally—to explore soldier system requirements and propose technology solutions from across a wide variety of sectors.

1.4 What is Roadmapping?

Roadmapping is a collaborative process for developing innovative products and processes to meet future market demands. The process brings together stakeholders from across a particular industry sector—or group of sectors—to define a set of requirements and performance targets associated with projected market demands and to work collectively to determine how technology might best be used to meet those needs. The end product of technology roadmapping is a report—the roadmap.

Canada—and IC in particular—has considerable experience in roadmapping. Since 1995, IC has collaborated with various stakeholders to complete over 35 technology roadmaps.

The IC TRM process typically brings together industry, academia and government representatives in a series of workshops to identify knowledge barriers to competitiveness and to discuss ways to best meet future market demands. This knowledge exchange is driven by key questions relating to "why," "what," "how" and "when" market demands and technological changes might take place. The process takes into account the influences of capability pull and technology push and their impact on potential innovation (see Figure 1-1).

1.5 Aim

The aim of the SSTRM is to encourage the availability of exploitable technologies to address identified gaps to support the operational effectiveness of the future Canadian soldier.

1.6 Objectives

The objectives of the SSTRM are to provide a forum for stakeholder collaboration (industry, academia and government), to articulate client user requirements in the medium and long term, to improve CF/DND planning for Horizon 2 (10-15 years) and Horizon 1 (0-5 years) technology exploitation opportunities, and to provide S&T guidance to ensure relevance and enable capability development.

These objectives will support CF soldier modernization efforts and certain of its specific projects such as the Integrated Soldier Systems Project (ISSP); the Soldier Systems 2030 Project; the Future Combat Uniform and Footwear Project; the Sniper System Project; and the Small Arms Initiative with its three parts of Small Arms Modernization, Special Weapons and Ammunition, and Next Generation Small Arms; as well as provide guidance on future priorities for R&D related efforts in the soldier systems domain.

Roadmapping: Not a Procurement Activity

The SSTRM project is not part of DND or any other government department procurement process. It is a knowledge-sharing exercise that aims to generate a vision of the soldier of the future and the ways in which technology can enable that vision.

Adapted from Phaat, 2006

Figure 1-1: Roadmapping: Basic Frameworkt

In executing these objectives, the SSTRM brings Government of Canada defence capability planners together with researchers from the academia and industry sectors (both private and not-for-profit) from Canada and abroad to exchange knowledge on future Army key technical domains related to soldier systems modernization, so they can collaboratively explore potential solutions and technologies to solve the key capability deficiencies identified by the client user community.

By applying roadmapping principles in the area of soldier systems technology, the SSTRM project is designed to help industry, academia and government members of the soldier systems community of interest to:

- Better understand CF future capabilities requirements;
- Build a shared awareness of available and emerging soldier systems technologies;
- Raise the profile of relevant technologies and capabilities, and the organizations involved in researching and developing them;
- Identify potential partners and encourage networking and collaboration for future R&D and innovation in the area of soldier systems technology; and
- Position industry to take advantage of global market opportunities and enhance their competitiveness.

1.7 Scope

The SSTRM project focuses on the technology needs of the soldier as the centre of a complex and integrated system of advanced technological systems. The soldier system (see Figure 1-2) incorporates anything related to the life and work of a ground force combatant including integration with other platforms (e.g., vehicles).

The project includes three phases: definition, development and implementation. These consist of:

- **Definition Phase (2007–2008)**—Planning the overall project, adapting IC's roadmapping process to the soldier system environment and developing the Innovation, Collaboration and Exchange Environment (ICee) web-based platform. The SSTRM project is the first roadmap of such scope undertaken by the Government of Canada.
- **Development Phase (2009–2011)**—Fostering knowledge exchange among all stakeholders to build a comprehensive soldier systems technology roadmap to support CF soldier modernization efforts. The key deliverable for this phase is the Capstone Report with its Action Plan.
- **Implementation Phase (2011–2014)**—Implementation of the Action Plan by the soldier systems community of interest. Potential activity include formation of an integrated DND/IC team to act as a facilitator and catalyst to government, industry and academic engagement and collaboration in order to bring forward R&D proposals that will facilitate the availability of emerging or novel technologies identified in the roadmap. Proposals to address specific gaps will be considered and supported. Other implementation activities are expected to include an annual workshop and support and monitoring of R&D collaboration initiatives.

Operational Clothing Systems:
- Headwear System
- Handwear System
- Footwear System

Personal Protection Systems:
- Modular
- Multi-Threat
- Survivability

Load Carriage Systems

Individual Equipment

Weapon Systems and Ammunition:
- Lethal
- Non-Lethal

Power & Energy Systems:
- Harvesting & Recycling

C4I:
- Battle Management
- Soldier Network and Communication Suite
- Navigation System
- Sensor Suite

Integration of sub-systems considering human factors to attain a mission configurable, modular, interoperable soldier that achieves increased mission effectiveness

Figure 1-2: The Soldier System Capabilities

1.8 SSTRM Project Enablers and Governance

1.81 Stakeholders

The SSTRM project is a collaborative effort. Participation in the SSTRM activities is free, voluntary and open to Canadian and international manufacturing, service and technology-based companies of all sizes, and to researchers and other experts from academia, government and not-for-profit research organizations from Canada and around the world.

Within National Defence, three groups are involved:

- CF/Director of Land Requirements (DLR)
- Director of Soldier System Program Management (DSSPM), within the Assistant Deputy Minister Materiel Group (ADM Mat)
- Director, Science and Technology Land within Defence Research and Development Canada (DRDC), within the Assistant Deputy Minister Science and Technology Group (ADM S&T)

Within IC, there are two groups involved:

- Manufacturing and Resource Processing Industries Branch (which includes the Technology Roadmap Secretariat)
- Aerospace and Defence Marine Branch (ADMB)

Several other federal government departments and agencies contribute to the project as well, including Public Works and Government Services Canada (PWGSC), Foreign Affairs and International Trade Canada (DFAIT) and the National Research Council Canada (NRC). On the industry side, in addition to individual firms, the Canadian Association of Defence and Security Industries (CADSI) and Technopôle Defence and Security (TDS), two of Canada's leading defence associations, play a key role in the SSTRM project. Academia is also an important stakeholder and a number of universities from across the country have engaged in the workshops and networking opportunities (see Figure 1-3).

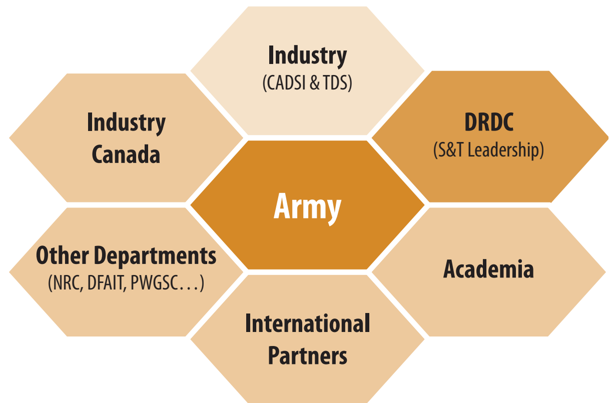

Figure 1-3: Stakeholders of the SSTRTM

1.8.2 Governance for the SSTRM Development Phase

Governance for the project has been achieved through a strong oversight structure and a rigorous set of principles, terms of reference and code of ethics, all of which fall within the current Government of Canada policy framework. All the governance documents related to the SSTRM project have been approved by Canada's Department of Justice. The SSTRM Development Phase has been governed by a Senior Review Committee (SRC), an Executive Steering Committee (ESC) and six Technical Sub-Committees (TSC) (a Technical Sub-Committee for each of the technical workshop areas) made up of government and industry, and in some cases, academia representatives.

1.8.3 Project Enablers

The SSTRM process incorporates a number of enablers to facilitate knowledge exchange and collaboration, including novel software tools and a series of workshops.

Workshops

The development phase included seven facilitated workshops to launch the knowledge exchange process on a series of interrelated technology domains and themes (see Table 1-1).

Table 1-1: The SSTRM Development Phase Workshops

Workshop		Date	Location
1.	Visioning	June 16–17, 2009	Gatineau, Québec
2.	Power/Energy and Sustainability	September 21–23, 2009	Vancouver, British Columbia
3.	Weapons Effects (Lethal and Non-Lethal)	November 24–26, 2009	Toronto, Ontario
4.	Command, Control, Communications, Computers and Intelligence (C4I)	March 9–10, 2010	Montréal, Québec
5.	Sensing	March 10–11, 2010	Montréal, Québec
6.	Survivability/Sustainability/Mobility	May 12–13/2010	Ottawa, Ontario
7.	Soldier Human and Systems Integration	September 21–22/2010	Gatineau, Québec

Each workshop included demonstrations by CF personnel, presentations by representatives of industry, government and academia, and working sessions during which participants collaborated to better understand soldier system capabilities and requirements and brainstormed on potential solutions and technologies to meet identified needs.

This exchange of knowledge was intended to help participants, and in the broader sense the community interest of the soldier systems modernization, to plan their investments in R & D to better address these new capability needs emerging from DND and the global defence markets. In turn, industry and academia were able to provide DND with information on their capabilities and possible alternative technologies, contributing to enhanced DND capability planning, and novel technology insertion and sequencing in time.

Over 1,550 participants from government, academia, companies and research organisation, be it national or international, attended the workshops. Detailed information was compiled in a proceedings document for each workshop. A workshop summary report was also prepared, which consolidates all the seven workshops' key outputs in a single document.[3]

All the content of the workshops (agendas, presentations and reports) is available on the ICee tool.

Software Tools

IC sponsored the development and the acquisition of a set of innovative software tools to support the project:

- **Web-Based Knowledge Management Tool**—A key enabler of the SSTRM project is the Innovation, Collaboration and Exchange Environment (ICee), a protected web-based collaboration tool comprising a database application and a wiki that are used to capture, share and collaborate on topics relevant to the future soldier systems. This technology knowledge base was used to build the roadmap.
- **Roadmapping Software**—Specialized softwares (e.g. Vision Strategist™ from Sopheon) were explored during the Development phase. This exploration highlighted the need for such a software in creating a comprehensive visual Roadmap that would structure and link all the elements of knowledge gathered through the SSTRM project.

1.9 Transition and Implementation

Release of the Capstone Report and Action Plan marks the transition from the SSTRM project's Development Phase to its Implementation Phase. SSTRM community of interest will be able to refer to the report for information on CF/DND future needs and also as a guide for proposed actions that could be taken to meet them.

The report also includes an Action Plan that describes the type of actions that are recommended in the short, medium and long term to the soldier systems community of interest to achieve the goals of the SSTRM project. The SSTRM project team becomes therefore the facilitators for the implementation of these recommended actions. The detailed Action Plan is provided in chapter 11.

3 Industry Canada. *SSTRM Workshop Summary Report*. Ottawa: Industry Canada (April 2011).

PART II: SETTING THE STAGE

PART II: SETTING THE STAGE

Chapter 2: Worldwide Soldier Systems Modernization Efforts

Canadian soldier systems modernization efforts cannot take place in isolation from our allies. Interoperability is a key concept in the North Atlantic Treaty Organization (NATO) doctrine. For the last 20 years, Canada has been a key contributor to this international effort through its military, scientific and engineering staff, as well as through significant industrial participation.

The Soldier Systems Technology Roadmap (2011–2025) draws extensively on the NATO soldier system definition and operational concept for its holistic framework. It also uses the five NATO soldier system capability areas (Survivability, Sustainability, Mobility, Lethality and C4I—Command, Control, Communications, Computer and Intelligence) to guide its work across the Canadian soldier capability areas.

The following chapter summarizes NATO soldier system modernization efforts and highlights some of the key influences on capability development, including the need for human factors and systems integration, verification and validation.

2.1 NATO Soldier System Modernization and Collaboration

While arguably the idea for a soldier system originated in science fiction[4], the first deliberate discussion on the topic in NATO circles occurred in the early 1990s. A mission requirements document on NATO soldier modernization was circulated in 1991, which defined the soldier system and five capabilities based on the timeless needs of all soldiers.[5] Imaginations were sparked by the U.S. Army Soldier Integrated Protective Ensemble (SIPE) Demonstration program in 1992, and a NATO Industrial Advisory Group (NIAG) study was requested. NIAG Sub-Group 48 was created and after study of the subject concluded that the NATO soldier's five capability areas could be substantially improved by the integration of technologies into a soldier system. The group also concluded that it was paramount that NATO managed development as a system, that a front-end analysis was needed to define the soldier system requirements, and that a standardization process for soldier systems be initiated to ensure effective and efficient system interoperability.[6]

A small working group (WG 3 on Soldier Modernization) within the NATO Armies Armaments Group (NAAG) spearheaded the work on soldier systems throughout the 1990s, establishing detailed NATO soldier system parameters[7] and an operational concept[8], as well as a holistic understanding of dismounted threats[9].

2.1.1 NATO Soldier System Concept

In 1991, the NATO Panel III on Close Combat — Infantry defined the Soldier System

"*. . . as those items and equipment that are worn, carried or consumed by the soldier, and those items carried for individual use.*"[10]

This was followed in 1993 by a broader description of the soldier system concept:

The future NATO Soldier System will be an integrated system composed of modular sub-systems to improve the soldier capabilities in the areas of: Survivability, Sustainability, Mobility, Lethality and C4I. For the purpose of this study, no soldier capability is considered more important than any other. The effort of the study shall be globally balanced in all areas and in the integration of various sub-systems into a Soldier System.[11]

2.1.2 NATO Soldier System Capabilities

By 1997, the WG 3 on Soldier Modernization established a detailed list of the five essential soldier system capabilities[12] and proposed a modular soldier system structure to identify components for potential standardization. These ideas have guided soldier system development across member nations, including Canada. Each capability is described in Table 2-1.[13]

4 Robert Heinlein, *Starship Troopers* (1959).
5 AC/225 (Panel III) D/316, *Mission Need Document on NATO Soldier Modernization* (27 May 91).
6 NIAG Sub-Group 48, *NIAG Prefeasibility Report on a Soldier Modernization Program* (AC/225 (P.III) WGE.3) D/3: September 94).
7 AC/225 (Panel III/WGE.3) D/m2, *Parameters of the Future NATO Soldier System* (18 May 93).
8 AC/225 (Panel III) D346, *Operational Concept for the NATO Dismounted Soldier*, 2nd Rev (14 February 96).
9 AC/225 (Panel III) D365, *Battlefield Threats and Hazards to the Dismounted Soldier System* (26 February 96).
10 AC/225 (Panel III) D/316, *Mission Need Document on NATO Soldier Modernization* (27 May 91).
11 AC/225 (Panel III/WGE.3) D/2, *Parameters of the Future NATO Soldier System* (18 May 93).
12 Ibid.
13 AC/225 (LG/3-WG/3) D6, *Approaches to NATO Soldier System Components* (04 September 97).

Table 2-1: NATO Soldier System Capabilities

NATO Soldier System Capabilities

Survivability

This capability enables the soldier to survive the threats he/she will encounter while on a mission. An extensive list of natural and man-made threats relevant to the soldier system is available in Appendix 1. A ground soldier should be able to respond to the following threats by:

Man-Made Threats

- Avoid detection (don't be seen).
- Deceive the enemy (defensive positions, mobility and counter measures).
- Detect threats.
- Receive and transmit information on threats identified.
- Prepare defensive positions (hasty or deliberate).
- Provide protection (blast, directed energy weapons, ballistic fragments, and nuclear/biological/chemical) (don't be killed).

Weather, Terrain, Animals & Insects

- Predict terrain and weather conditions.
- Monitor current terrain and weather conditions.
- Relay information on current terrain and weather conditions.
- Preserve human capabilities in all weather conditions.
- Provide protection (animal and insect threats).

Sustainability

This capability lengthens the time the soldier system can be effective on the battlefield. In order to sustain his/herself the soldier has to be able to:

- support physiological/physical functions and needs;
- support fighting capability;
- support equipment requirements (power, munitions, make repairs, decontamination);
- monitor health;
- administer first aid (including nuclear/biological/chemical);
- include embedded training; and
- minimize effects of stress.

Mobility

This capability extends the geographic sphere of influence of the soldier system. The main functions of the soldier system in this capability area, under all environmental conditions, by day or night, are to:

- orient;
- navigate;
- receive and provide information on the terrain;
- traverse on foot (across man-made and natural obstacles);
- carry his load while on the move; and
- mount / dismount vehicle.

Lethality

This capability is the soldier system's ability to incapacitate or destroy the enemy. An individual weapon, personal defence weapon or other weapon provides the soldier with lethality on the battlefield. To be lethal, the soldier may perform some or a number of functions:

- observe the battlefield and detect events occurring on the battlefield via visual and sensor inputs to the soldier system.
- recognize an event as a possible target.
- identify the target and classify the target as a valid target.
- relay and receive information on targets identified.
- acquire the target (aiming and ranging).
- evaluate the result of the engagement.
- engage the target (e.g., individual soldier).

Based on the information the soldier receives, he/she may or may not engage a target. If the soldier runs out of his/her basic load of ammunition, the cycle is suspended until resources are resupplied.

C4I

This capability provides the capacity to increase the tempo of operations, which may expand the battle-space and improve situational awareness of the soldier system. Intra-squad communication will enhance the effectiveness of the individual squad members and increase the squad's effectiveness. Inter-squad communication will enhance the effectiveness of higher-level units and enhance the squad leader's command and control of the soldier system. The main functions in this capability area are to:

- receive information visually, verbally and through sensors;
- process information;
- store information;
- present information; and
- distribute information.

Improved situational awareness will improve overall lethality, survivability, mobility and sustainability of the soldier system.

2.1.3 The Evolution to Land Capability Group 1 on Dismounted Soldiers

WG 3 gained in prominence post-2000, becoming Topical Group 1 on Soldier System Interoperability, as the NATO structure became convinced of the need to pursue standardization opportunities, coordinate national programs and explore the potential for adopting identical sub-systems or modules.[14] World events after 9/11 further compelled nations to pursue areas of common interest in the largest venue for such topics—now called Land Capability Group 1 on Dismounted Soldiers (LCG/1 structure is shown at Figure 2.1).

LCG/1 has a number of subordinate groups that address Small Arms Interchangeability, C4I/Architecture, Power, Weapons and Sensors, as well as Combat Clothing Integrated Equipment and Personal Protection at the soldier system level. Over the last 10 years, the team has shared considerable information, published many key soldier system documents and developed or updated the 38 NATO standardization agreements (STANAGs) for which they are responsible.

In 2010, NATO LCG/1 published a key interoperability document[15], which further refined the NATO soldier system capabilities, based on current operations, and identified the high priority interoperability issues for NATO dismounted forces. Drawing on the expertise in dismounted soldier systems provided by the Soldier Capability Assessment Group (SCAG), the report provides important guidance to LCG/1 and its sub-groups on identifying and prioritizing interoperability capabilities at the lowest tactical levels.

2.2 NATO Long-Term Capability Requirements

The NATO Long Term Capability Requirements[16] (LTCRs) were defined and published as a separate undertaking by the NATO Headquarters called Allied Command Transformation, and have influenced soldier system efforts across NATO. This program identifies 38 LTCRs and highlights two specific soldier-level capabilities, which remain challenges today: the need for Integrated Personal Protection and the need for Soldier Situational Awareness. Both of these LTCRs are lead by LCG/1.

2.2.1 Integrated Personal Protection (IPP)

Integrated Personal Protection is the capability of providing integrated personal protection from the wide range of threats faced in current and future operational theatres. These threats to the dismounted soldier are generally divided into 11 areas:

- Ballistics
- Fragmentation
- Flame, flash and heat
- Primary blast injuries[17]
- Laser
- Noise
- Non-ballistic threats
- Concealment
- Fratricide
- Environmental
- CBRN (Chemical, Biological, Radiological and Nuclear)

Efforts to counter all these threats on the battlefield are complicated by several major technological barriers—many of which are interrelated. Capability improvements in the short and medium term are, therefore, likely to be incremental.

LCG/1 and Sub-groups

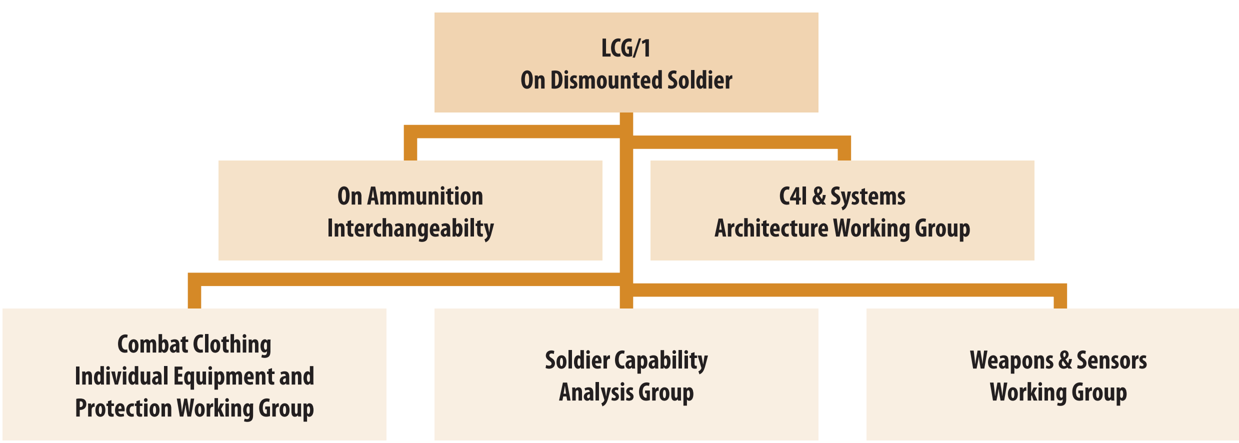

Figure 2-1: LCG/1 Structure

14 AC/225 (LG/3-WG/3) D/10, *Recommended Way Ahead for NATO Soldier Modernization* (20 January 2000).

15 PFP (NAAG-LCG/1) D (2010)0003, *NATO Infantry Squad Capabilities Development and Interoperability Issues Identification* (18 November 2010).

16 IMSM-0648-2008, *Long Term Capability Requirements* (LTCR) 2008 (10 November 2008).

17 http://www.bt.cdc.gov/masscasualties/explosions.asp

Among these barriers, human factors and integration, and more specifically soldier burden (overload/weight), are important considerations requiring significant attention:

- **Human Factors and Integration**—It is increasingly evident that human factors and equipment integration should be taken into account at every stage of personal protection equipment capability development. No single personal protection component can be assessed in isolation from other equipment or from the soldier responsible for its use. This should include "soft" factors such as user perception. Some human factors and integration issues are enduring in nature, while others are more nation or theatre specific and require separate assessment.
- **Overload/Weight**—The soldier as a system is already overloaded to a degree would not be acceptable for a vehicle or air platform, which is even less acceptable for a human. The solution to any capability gap for the dismounted soldier must be assessed against its impact on system burden, especially weight. The overarching focus for all LCG/1 work is to reduce the burden.

2.2.2 Soldier Situational Awareness (SA)

Soldier Situational Awareness (SA) is the capability of enhancing the SA of individual soldiers and increasing shared knowledge. This is accomplished through the seamless transfer of tactical information at the lowest tactical level. Through enhanced data interoperability, soldiers in a coalition environment will have improved command execution, target acquisition and situational awareness, which can also help to reduce fratricide.

Soldier SA Operational Requirements

Dismounted soldiers operate their equipment in dynamic and austere environments. As a result, the major operational requirements identified by LCG/1 for SA are:

- Equipment must be lightweight, compact and optimized to consume the absolute minimum of battery power.
- The system must be robust and situation display must be clear and easy to understand. The device(s) must be interoperable with other SA tools available, using NATO standard interfaces and protocols. The system must be able to operate for extended periods of time and automatically filter "need to know" information.
- The system should provide information on opposition forces, friendly forces neutral elements and non-combatant elements with a high enough level of accuracy and timeliness to enable targeting. The SA devices need enough communications bandwidth to transmit and receive various formats of information such as maps, hand drawn schematics, imagery, data, messages, and PNT updates (position / navigation / time) as well as sufficient power to transmit in all terrains over selected distances.

Standards

Significant progress has occurred in the development of a standard technological solution to share SA data among dismounted NATO soldiers across a force boundary. Standardized use of specific message sets, converted into a soldier variant of the common NATO data model, has been demonstrated through the exchange of command and control and SA information between Canada, Germany, Spain, the Netherlands and Slovakia, using prototypes of their respective soldier battle management system. This effort continues to advance significantly due to recent operations in Afghanistan, where forces at the end of the command chain interact frequently to deal with an all-pervasive threat.

2.2.3 Battlefield Combat ID

On current operations, all NATO nations have noted the excessive weight and power burden for dismounted soldiers, adding other devices becomes a major challenge. Adding a device or devices that provide seamless soldier level battlefield combat identification (BCID) is remaining a key challenge. This is not recognized as a separate LCTR but is embedded in various LCTRs. Soldier's individual combat identification is a required capability in NATO for coalition operations in order to avoid fratricide. Current documentation refers to the need for integrated solutions that do not add parasitic weight or system burden for the dismounted soldier.

Fratricide incidents at the soldier-to-soldier level remain a small percentage of the overall fratricide incidents in NATO or coalition operations. By contrast, air-to-ground and vehicle-to-vehicle incidents comprise the majority of fratricide incidents and are generally much more catastrophic than incidents involving small arms weapons utilized at the dismounted level. Systems and technologies developed for use on aircraft and vehicles are not suitable to the dismounted soldier system due to weight and power constraints. Thus soldier-level BCID systems need to be integrated into the whole soldier system suite and could consist of simple passive and active elements.

One potential part of the solution is Blue Force Tracking (BFT), through which combat identification, accessed by leaders at the company, platoon and squad / section levels are provided, enhancing their situational awareness of the adjacent units. BFT has been implemented by some nations. Ultimately, this information could be provided to the individual soldier through the implementation of national soldier system programs enabled through NATO coordination.

2.3 Soldier System Related S&T in NATO

A separate organization within the NATO structure is the NATO Research and Technology Organization (RTO). Its primary focus is to promote and conduct co-operative scientific research and exchange of technical information amongst 28 NATO nations and 38 NATO partners. The RTO encompasses over 3,000 scientists and engineers addressing the complete scope of defence technologies and operational domains.[18] Six subordinate panels of the RTO are responsible for coalition S&T efforts in a wide variety of domains from Human Factors and Medicine (HUM) to Applied Vehicle Technology (AVT), as well as the leadership of selected LTCRs. For example, the Information Systems Technology (IST) Panel—currently led by Canada—has the responsibility for the LTCR on language translator capabilities, and is closely linked with NATO soldier systems efforts. The Sensors & Electronics Technology (SET) and Systems Analysis and Studies (SAS) panels also conduct a number of soldier-related R&D task groups covering key aspects such as camouflage, power and electro-textiles.

18 http://www.rta.nato.int (Downloaded 18 March, 2011).

2.3.1 Weapons Systems Integration and Interoperability

A notable recent effort, sponsored by LCG/1, was the S&T work conducted under the Systems Concepts and Integration (SCI) Panel: SCI-178 Integration and Interoperability Issues for the Dismounted Soldier System Weapons Systems. This task group's objectives were to resolve three major soldier-level issues for assault weapons. Their work focused on:

- Determining an optimal methodology for attaching devices to infantry weapons and to draft a STANAG[19] as a NATO interoperability standard.
- Evaluating human factors considerations associated with modern infantry weapon systems and dismounted soldier systems composed of body armour, command and control capabilities, and head-borne systems.
- Investigating power management of weapon system accessories through centralized and decentralized power, and exploring methods to provide the power to the attached accessories.

2.3.2 Human Factors Standards for Weapons

The products of the SCI-178 Task Group include a draft STANAG proposed for ratification, reports and technical data from experiments and trials that provide informative human factors decision-making guidance for small arms of soldier modernization programs, and technical reports to provide trade studies and analysis in weapon subsystem power and data exchange methodologies. The suggested end-state would fill a gap in NATO infantry weapon system interoperability. It provides human factors design criteria for the integration of modern assault rifles with current body armour, and identifies opportunities for optimization of power and data on future infantry weapon system components. This highly successful five-year effort was recently recognized with the 2010 RTO Scientific Achievement Award.

2.4 Foreign Soldier Systems Modernization Efforts

2.4.1 International Soldier Systems Programs

The world stage now has a large number of nations providing systems for dismounted soldiers (see Table 2-2). This includes a growing number of countries outside of NATO and Partner for Peace (PfP) countries (e.g., Australia and Singapore). Most, if not all, of these nations use elements of the NATO defined soldier system capability areas of Survivability, Sustainability, Mobility, Lethality and C4I. They also regularly attend LCG/1 meetings. Training and human factors are key components of all the capabilities and are included as elements or considerations of most national programs.

The seminal event in the development of NATO soldier systems occurred in 2000 when the Netherlands hosted a key NATO conference, exhibition and field demonstration at their training area in Bergen Op Zoom. Nations such as the U.S. and France were spurred to further develop their programs, and Germany embarked on a deliberate path towards a soldier system program from almost a blank page. In fact, Germany was the first to field a soldier system in May 2004, and has had its Infantryman of the Future (IDZ) on operations in Afghanistan for over five years.[20]

Other Armed Forces have followed suit, most notably the United States Marine Corps (USMC) and the French Army. A key litmus test for the maturity of a soldier system is the soldier-to-soldier C4I components at the soldier level: the USMC has had all 27 regular infantry battalions equipped with Type 3 encrypted radios since 2006.21 The French Army is now fielding the FELIN22 from their Future Infantryman System programme to a regiment every 12 weeks, as well as teaching the use of the FELIN system in its military schoolhouses and addressing the key soldier-vehicle interfaces in a deliberate way. As of November 2009,

Table 2-2: World Stage—Soldier Systems

Country / Group	National Soldier System Programs	Dev	OEM	Fielded
Germany	IdZ BS – IdZ ES	Fielding, V2	Rheinmetall	Afghanistan Oct 2005
USMC	MERS	Main Project	No soldier system — waiting on US Army	NO
US Army	Nett Warrior	Ltd fielding Tech Demo	General Dynamics	Limited
UK	FIST		Thales	UOR Iraq Early 2008
France	FÉLIN	Fielding, V2	SAGEM	Summer 2012
Spain	COMFUT	Definition	EADS	NO
Switzerland	IMESS		EADS	NO
Italy	Soldato Futuro		Finmeccanica	NO
Australia	Land 125	Development	Elbit	NO
Belgium	BEST	Development		NO
Netherlands	VOSS	Development	Thales	NO
Sweden	MARKUS	Development		NO
Norway	NORMANS	Fielding	Thales	Limited

19 STANAG 4694 was developed by the SCI-178 Task Group and accepted by LCG/1. It has now been ratified by the NATO Standardization Agency.

20 http://www.army-technology.com/projects/idz/ (Downloaded 18 March 11).

21 USMC Type 3 Soldier Radio density is 704 per Infantry Battalion.

22 http://www.army-technology.com/projects/felin/ (Downloaded 18 March 11).

22,588 FÉLIN systems have been ordered. Other nations currently on operations in places like Afghanistan have fielded soldier C4I systems as urgent operational requirements, but still lack fully integrated solutions into their national C4I backbones. Table 2-2 provides a snapshot of progress assessed by the Chairman of LCG/1.

2.4.2 Soldier Systems Market Opportunities

The soldier systems worldwide market is quite robust. Major international prime contractors are bidding on programs in countries such as Australia and Singapore. NATO and Partner for Peace nations are also opening up soldier systems markets, led by Germany, Switzerland, France and Spain. Steady growth in this area is forecasted in a study conducted by Visiongain LTD[23], with a total global market exceeding $14 billion USD by 2019 (see Figure 2-2). A broad number of emerging nations are expected to enable their soldiers and/or junior commanders with various system devices in the coming years.

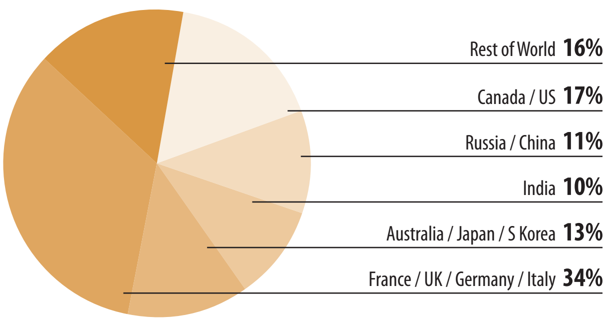

Figure 2-2: Global Soldier Systems Modernization Efforts and Markets
Source Note: Charts and estimates based on data from — Visiongain LTD (2009) "*Soldier Modernisation Market 2009-2019*" © Copyright 2009 by Visiongain LTD, London, UK

Market analysis (see Figure 2-3) of technologies required to meet the NATO soldier system capabilities, shows that the C4I capability has the largest potential market, both in Canada and abroad. The remaining four NATO capability areas are about equal in terms of sub-market breakdown.

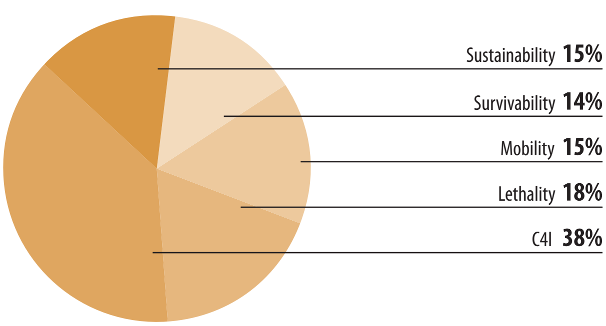

Figure 2-3: Soldier Systems Sub-Market Opportunities
Source Note: Charts and estimates based on data from — Visiongain LTD (2009) "*Soldier Modernisation Market 2009-2019*" © Copyright 2009 by Visiongain LTD, London, UK

2.5 Balancing the Five Soldier System Capabilities—"The Hard Problem"

World-wide soldier system modernization efforts have revealed what has become known as "the Hard Problem"—the need for continual vigilance in balancing the dismounted soldier's capabilities. This challenge has been described broadly in various early NATO documents and now, within Canada, as part of DND's S&T Functional Planning Guidance and Programme Convening Letter (February 2010). While there may be a series of "Hard Problems", the one that specifically impacts soldier systems relates to enhancing soldier survivability and effectiveness. The key to enhancement is the balancing of the five NATO capability areas while understanding that they are all interconnected and, thus, they all impact on each other. No single capability is more important than another, and the balance depends on what is being measured (weight, burden, cost, capability, etc.).

For example, as current technologies are applied to improve soldier survivability, the overall system weight increases: reducing mobility. The inclusion of additional C4I devices can have a similar impact on mobility, as can increases in ammunition load or responses to the need to carry more water on operations.

The soldier system can be viewed as a complex, interconnected web (see Figure 2-4). Thus—keeping "the Hard Problem" in mind—the international soldier system programs, including Canada's, are continually seeking solutions that enhance soldier survivability and performance by incorporating effective and efficient procedures as well as personal protection, communications and information exchange systems that are more user friendly, cost effective, lighter, smaller and highly energy efficient. At the same time, efforts are being made to balance these considerations with the needs of the other well-recognized soldier system capabilities.

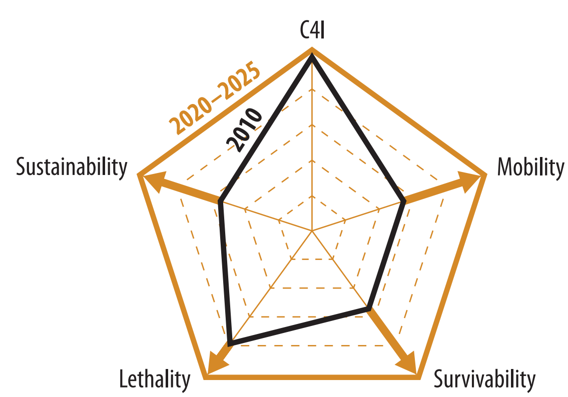

Figure 2-4: The Hard Problem—Balancing Soldier Effectiveness

23 Visiongain LTD, *Soldier Modernization Market 2009-2019* (London, UK: 2009).

Chapter 3: Canadian Soldier Systems Modernization Efforts

Canada's soldier system modernization efforts require a holistic approach that enhances soldier system capabilities across a wide range of technical domains. Canada's soldier system development efforts have not taken place in isolation from our North Atlantic Treaty Organization (NATO) partners or other Canadian Forces modernization efforts. Rather, the Canadian soldier system evolution has been a key component to overall NATO soldier capability development activities.

As with other nations, the Canadian soldier system development community understands that to be effective, soldier systems R&D needs to be well-integrated with activities in the broader science and technology (S&T) community, including those activities originating in industry, government and academia. Also interoperability within the CF, amongst NATO partners and across a variety of key multinational stakeholders (often referred to as JIMP—Joint, Interagency, Multinational and Public) is a key concept within the Army doctrine and plays an important part in the CF soldier modernization efforts.

The following chapter provides an overview of the CF current soldier systems baseline, the evolution of Canada's soldier system S&T methodology, and the key technological drivers that are expected to influence the evolution of Canada's soldier modernization efforts over the next 10 to 15 years. Furthermore, studies are now emerging on Army 2040 and the time horizons are shifting.

3.1 Canadian Adaptive Dispersed Operations

The contemporary CF soldier conducting land operations will operate within what is known as the Army of Tomorrow (2013-2021) and within a fluctuating future security environment. Global security threats are expected to continue to generate situations that will require the Canadian Land Force to support and act within coalition expeditionary activities in diverse locations where failing states have succumbed to insurgent pressure and internal political strife.[24]

The Canadian Army now understands and has articulated these activities as Adaptive Dispersed Operations (ADO). Figure 3-1 provides a representation of the capabilities expected of future ADO task forces.

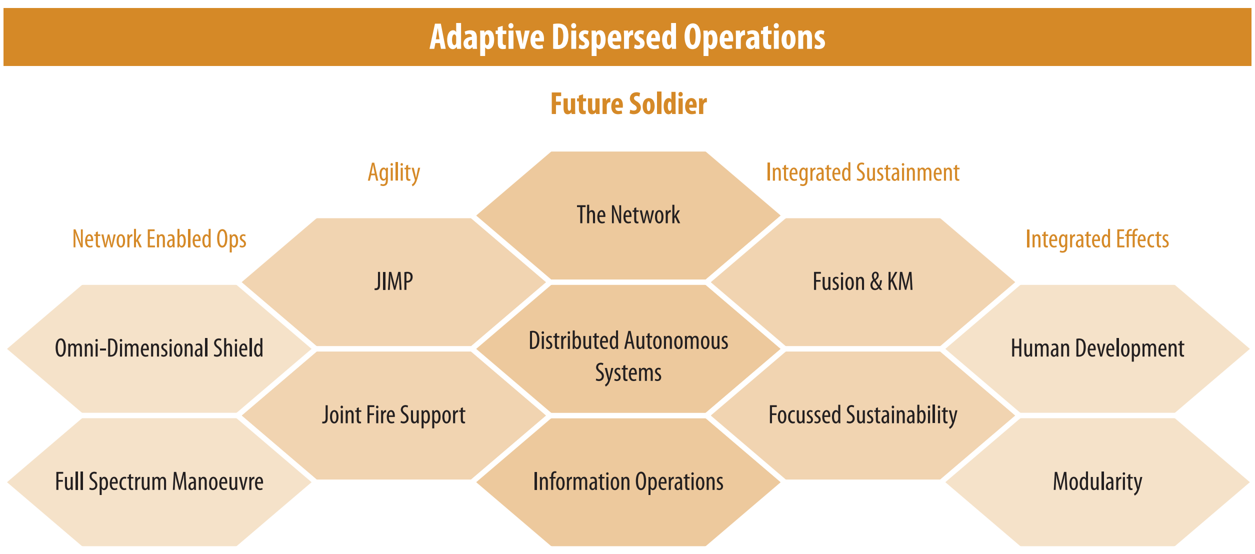

Figure 3-1: Adaptive Dispersed Operations Characteristics

Source: *Land Operations 2010: Adaptive Dispersed Operations—The Force Employment Concept for Canada's Army of Tomorrow*, Directorate Land Capability Development, DND

24 Directorate Land Capability Development, *Land Operations 2010: Adaptive Dispersed Operations—The Force Employment Concept for Canada's Army of Tomorrow* (Kingston, Ontario: Department of National Defence, 2007).

ADO is characterized by adaptable, networked and integrated manoeuvre forces that alternately disperse and re-assemble over extended distances in order to identify, influence and defeat a full spectrum of threats. Some of the fundamental tasks facing the soldier in ADO involve:

- responding to "developing" situations while dispersed and out-of-contact with the operational base/command;
- manoeuvring to positions of advantage;
- influencing and/or engaging an enemy that is beyond the range of weapons (either with lethal and non-lethal precision and area effects);
- destroying the enemy, if necessary, with precision and area fire;
- conducting, if necessary, close combat at the time and place of the unit/soldier's own choosing; and
- transitioning between operations without loss of focus or momentum.

ADO necessitates two key capabilities: 1) all-pervasive, network-enabled operations, and 2) situational awareness. In the digital age, the sharing pertinent and timely information—via voice and data—is of paramount concern in order to reduce the time involved in operational and tactical planning and execution, and also to assist in the transition between missions or tasks.[25]

Future soldier systems R&D should be aligned to deliver integrated capabilities that harness the potential of networked technologies in order to improve situational awareness, target acquisition, handover and prosecution, as well as to increase the efficiency of command execution, shield and sustain activities.[26] The SSTRM's technical domains encompass many, if not most, of these areas.

3.2 Canadian Soldier System Vision

The Canadian soldier system vision sees a networked dismounted soldier with vastly improved situational awareness and command execution, coupled with improved navigation and access to improved target acquisition and recognition capability. This configuration will optimize the five capability areas and enable the rapid aggregation of forces to effectively prosecute targets for overall improved tactical performance and ultimately, better operational effectiveness for the CF and its coalition partners.

3.3 Canadian Soldier System Baseline

Today's Canadian soldier is trained and equipped to conduct a full spectrum of operations—both domestic and international—as part of a coalition. For the past 15 years, CF research, equipment procurement and training has focussed on providing soldier system capabilities to the close combat soldier—both in mounted and dismounted roles—to improve tactical performance on operations such as Afghanistan where infantrymen are involved in ADO.

3.3.1 Equipping the Basic Soldier System

The centre of the contemporary Canadian soldier system is a world-class trained Canadian soldier, equipped through the Clothe the Soldier (CTS) program (see Figure 3-2) and the earlier Small Arms Replacement Project (SARP), while benefiting from considerable human factors research. Clothe The Soldier has provided the uniform, footwear and PPE for Land Force soldiers, sailors and aircrew for both training and operations since 2001. At the same time, SARP fielded the baseline weapon fleet, which has been modernized incrementally and has provided significant lethal effects during combat operations for the past 10 years. Additional improvements have been achieved through miscellaneous requirement procurement, Urgent Operation Requirements (UOR), "buy and try" activities and S&T efforts (see Figure 3-3).

CLOTHE THE SOLDIER
HABILLEZ LE SOLDAT

Figure 3-2: Clothe the Soldier Program Logo

Figure 3-3: Soldier System Evolution Model
Source: Integrated Soldier System Project, Director Land Requirements, DND

25 Ibid.
26 Ibid.

Some of these incremental improvements to the soldier system include:

• **Communications**—The personal role radio—distributed to each soldier—has provided the dismounted tactical commander with superior command execution and situational awareness, plus an enhanced ability to communicate more effectively with subordinates. Tactical commanders are also enabled with secure communications to vehicles (the mother ship) and operations centres via dismounted Land Command support system (LCSS) radios.[27]

• **Situational Awareness**—Coupled with improved communications, today's soldier has a range of tools to assist with situational awareness, including Global Positioning Systems (GPS), combat identification devices and improved surveillance, target acquisition, and night observation (STANO) goggles and weapon sights.[28]

• **CADPAT™**— During the past 15 years, CF soldiers have been equipped with two distinctive Canadian computer-generated digital camouflage patterns in their clothing—Canadian Disruptive Pattern Trade Mark (CADPAT™) Temperate Woodland and CADPAT™ Arid Regions. While vastly superior to the previous monochromatic OG107 green colour in both the visual and near infrared band, this choice does create the challenge of multiple versions of soldier equipment.[29]

The result is a baseline soldier system, which the CF has on operations today.

3.3.2 Current Soldier System Capability Gaps

Current combat operations in Afghanistan together with other peace support and humanitarian assistance activities performed by the Army (Disaster Assistance Response Team (DART), United Nations Military Observers (UNMO), and Operation PODIUM for the 2010 Olympic Games) indicate a trend away from symmetrical operations and tasks. The demands of these adaptive dispersed operations highlight the deficiencies of the present soldier system and demonstrate the need for effective capability planning to maximize the potential of the individual soldier as a system (see Figure 3-4).

C4I
- Lacks effective network-enabled command at fire team, section and platoon for full spectrum ops in complex terrain
- Lacks light weight comms and electronic aids linked to TCCCS backbone
- LAV dismounted warfighter lacks support provided when mounted
- Lacks BCID and connectivity to sensor info
- No linkage to ISTAR

Lethality
- Lacks ability to harness info-age technology to effect better command execution, target acquisition and Situational Awareness at the lowest level
- Lacks connectivity for precise effects-based weapons engagement

Mobility
- Lacks Situational Awareness info sharing and navigation aids for complex terrain

Survivability
- Lacks an integrated threat protection against blast, fragmentation, CBRN, etc.

Sustainability
- C4I, Lethality, Mobility and Survivability solutions must incorporate adjustments to the carriage of combat supplies for operations over extended periods
- Weight, power, space budgets

Figure 3-4: Key ADO Capability Deficiencies of the Contemporary Soldier System
Source: Integrated Soldier System Project, Director Land Requirements, DND 2009

27 Konsberg Defence and Aerospace, White Paper on Soldier Radio for Dismounted and Mounted Soldiers, Document M100301 (January 2010).

28 Statement of Requirement—Integrated Soldier System Project, Director Land Requirements, Department of National Defence, March 2011.

29 *Jane's Defence Weekly* (13 September 2000).

3.4 Canadian Soldier System S&T Evolution

Canada's Defence S&T Strategy—led by Defence Research and Development Canada (DRDC)—helps link DND's S&T investments with its capabilities planning. While Canada's soldier system community of interest includes industry, academia and a range of government research organizations, DRDC plays a key role in fostering the S&T necessary to guide effective capability planning.

Under the strategy, DRDC's S&T investments are expected to contribute to and support decision-making. This S&T anticipates, assesses and advises on the implications of emerging and potentially disruptive technology. A better positioning and transition of these technologies will benefit the CF.

3.4.1 Why not What—Asking the Right Question

The current approach to soldier system S&T in Canada grew out of the 1995 Integrated Protective Clothing and Equipment (IPCE) Technical Demonstration (TD). Although IPCE was ultimately deemed unsuccessful, Canadian soldier system experts learned several key lessons, which were applied to subsequent S&T efforts, including asking the right questions of soldier capabilities. Instead of looking at the "what" of soldiers' tasks, it became evident that the more scientific and effective approach is to ask "how" do soldiers perform their various tasks and "why" would technology be used to assist?

The world-class Soldier Information Requirements (SIREQ) Technology Demonstration Project (TDP) applied this improved capability and requirement methodology, focusing on revolutionary (vs. evolutionary) changes to command execution, target acquisition and situational awareness at the lowest tactical level. SIREQ then provided both tactical and enabling human factors research for the development of the Integrated Soldier System Project (ISSP) and a host of other subsequent TDPs. Research findings from these projects were then applied to efforts relating to personal protective equipment; Soldier Integrated Helmet System (SIHS) and Modular Multi-Threat Protective Headwear System (AMMPHS) TDPs; power and energy, Advanced Soldier Adaptive Power (ASAP) TDP and improved lethal effects; Soldier Integrated Precision Effects (SIPES) TDP. Figure 3-5 amply highlights the transition to "Why not What?" and the evolution of timely, focussed operational S&T in order to deliver the right soldier capability at the right time.

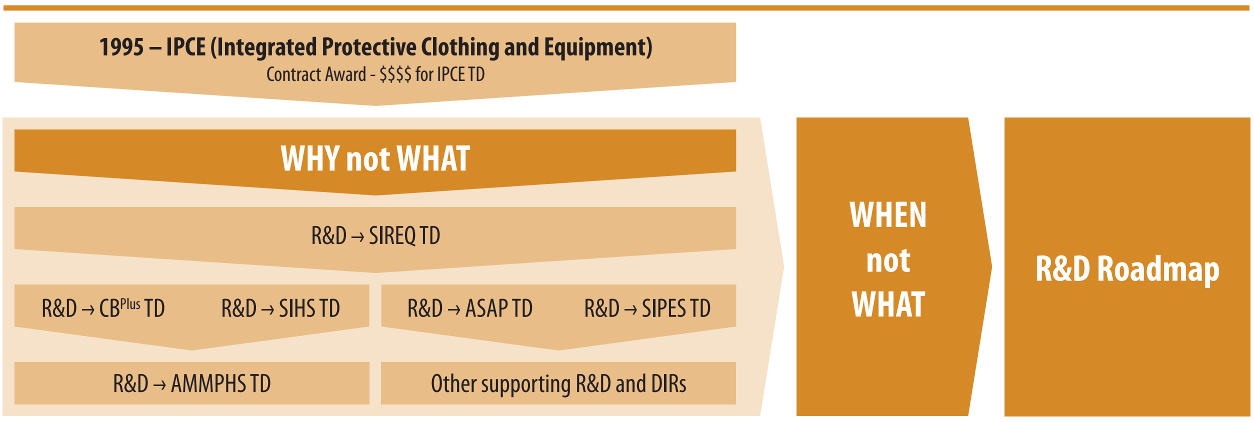

Figure 3-5: Soldier System S&T Evolution 1995 to Present

3.4.2 From the Mindmap to a Roadmap

Building on the success of these S&T activities, the need to effectively map multiple efforts in order to deliver soldier system capability became not only evident but a priority. "When" technology would be ready was actually a more pressing question than "What" technology. Thus a mind-map of future capabilities evolved into the Soldier Systems Technology Roadmap 2011-2025 (SSTRM).

Effective capability planning and S&T stewardship for proper capability delivery and sequencing are now understood to be key aspects to delivering the Army's Future Family of Land Combat Systems of which the Future Soldier System and Future Direct Fire Capability are a part.

Although S&T efforts and capability delivery are somewhat linear procurement activities, the presence of a system roadmap enables key soldier system stakeholders to have a strategic understanding of which soldier capabilities are deficient, which activities are ongoing to bridge these capability gaps, and how these various activities might be aligned.

3.5 Canadian Soldier System Technology Domains

The Army is currently pursuing several modernization programs and initiatives to deliver the Future Family of Land Combat Systems. These activities include the continued evolution of the Canadian soldier of today into a more tactically capable and strategically relevant system—the Future Soldier System.

As previously described, the Canadian program has benefited from being an early and significant contributor to NATO's soldier system initiatives. Efforts to address the first Canadian soldier system deficiency—approved in November 1988—have continuously evolved, with current efforts to modernize close combat soldiers focusing on developing more capable and modern sub-systems that emphasize integration within the domains of:

- Power and Energy;
- Weapons Effects (lethal and non-lethal);
- C4I;
- Sensing;
- Survivability/Mobility/Sustainability; and
- Human and Systems Integration.

These domains map well against the five NATO Soldier System Capabilities (see Table 3-1).

Table 3-1: SSTRM Technical Domains vs. NATO Soldier System Capability Areas

SSTRM Technical Domains	**NATO Soldier System Capability Areas**				
	Survivability	Lethality	Mobility	C4I	Sustainability
Power and Energy					
Weapons Effects (Lethal and non lethal)					
C4I					
Sensing					
Survivability / Mobility / Sustainability (Clothing, Load Carriage, Mobility, Personal Protection)					
Human and System Integration					

Colour code: enabler directly related indirectly related

Work across the six technical domains includes both external S&T partners and interdepartmental efforts to provide improved capability to the Canadian soldier in the near-term and to initiate focussed research and development (R&D) that will enable sequencing of future capabilities in Horizon 2 (5–10 years) and Horizon 3 (10–15 years).

With technological development and evolution cycles growing ever shorter (the communications industry now delivers networked applications and software in six-month product evolution cycles) the Army's present and future capability initiatives will rely closely on integrated research, development and acquisition cycles. Present and future initiatives such as the Integrated Soldier System Project, Small Arms Modernization, Close Combat Modular Fighting Rig and the Future Combat Uniform/Footwear program will profit from these cycles. These should be interspersed with iterative contributions sought from representative sample of soldiers exercising the capabilities being integrated. The ability to develop leading-edge, highly capable, well-integrated and usable systems requires the application of sound engineering principles and careful trials with users, taking account both controlled and uncontrolled (with training and running operation vignettes) parameters.

The following section describes some of the key capability challenges where the CF is focusing its S&T efforts through DRDC and acquisitions efforts through the Materiel branch (ADM Mat).

3.5.1 Power and Energy

The dismounted Canadian soldier, like his contemporaries, is heavily dependent on power and energy for enabling tactical improvement. Body and weapon-mounted sensors, dismounted C4I capabilities and position/time/navigation assets all require portable electrical power. Despite the fact that many of these capabilities share the same power form factor—the AA cell battery—there remain issues with soldier power carriage and sustainment. An early S&T Defence Industrial Research Program (DIRP) with Angstrom Power highlighted the use of alternate power sources using strategic fuels. As a result, the current soldier system power modernization effort within DND is DRDC's key initiative: the Army-sponsored Advanced Soldier Adaptive Power Technology Demonstration (ASAP-TD) project.

ASAP-TD's goals are to determine baseline soldier power and energy usage, research suitable soldier power solutions, distribution schemes, and bring the most suitable capabilities to Technology Readiness Level (TRL) 6. The program has investigated soldier power consumption and the cost and sustainment of soldier power, and is conducting trials on a soldier devices power consumption cue card. The latter is intended to assist today's close combatant with power management and to lessen soldier and sustainment burden. ASAP is also investigating novel power solutions, including power unit recharging, energy harvesting and soldier power-assistance, to name a few.[30]

30 http://pubs.drdc-rddc.gc.ca/pubdocs/asap (Downloaded 22 March 11).

3.5.2 Weapons Effects (Lethal and Non-Lethal)

The Army benefits from an impressive arsenal of dismounted soldier effect systems. Though this array of systems is predominantly lethal, both evolving threats and the need to reduce the risk of collateral damage are driving increased R&D and other efforts to strengthen non-lethal effect capability. To date, small arms technology development (delivery systems and munitions) has not progressed as fast as other areas (such as C4I) towards Horizon 1. Forecast operational requirement for Horizon 2 and Horizon 3 will require further materials innovation and evolving effect capabilities.

The Army is currently sponsoring several domestic dismounted soldier effects modernization efforts as well as collaborations with its NATO and American, British, Canadian, Australian and New Zealand (ABCA) partners. The following are just a few examples of the range of current domestic lethal and non-lethal activities underway, including R&D programs, urgent operational requirements, miscellaneous requirements ("buy and try's") and capability projects, many with supporting S&T:

- **Soldier Integrated Precision Effects System (SIPES)**—The objective of the SIPES program conducted by DRDC is to demonstrate the viability, utility and usability of integrated novel small arms-related lethal and less-than-lethal technologies for future, lightweight, small calibre weapons systems that will address current capability deficiencies. This R&D initiative also provides data to concurrent small arms modernization, sense and C4I capability projects.
- **Company Area Suppression Weapon (CASW)**—The CASW system will soon be delivered to the Army after several years of development. This state-of-the art capability involves integrated laser range finder (LRF) technology, target acquisition and prosecution computing for precise engagement solutions via a ballistic computer and smart munitions.
- **Non-Lethal LASER Dazzler**—This recently delivered capability is both an example of a modern effect and also a technological/capability gateway for further non-lethal effects and capabilities such as electromagnetic pulse weapons (EMP) and further optical/audio exploitation platforms.
- **Small Arms Modernization (SAM)**—The initial cycle of the soldier system effects modernization project is to improve and upgrade the existing small arms fleet within the 2011–2013 timeframe. This will include improved weapon platforms, accessories and sighting units.
- **Special Weapons and Ammunition Project**—This follow-on activity to SAM seeks to provide several enhanced dismounted effects capabilities for 2012-2018. The key capability gaps being addressed include the provision of small unit sharp shooters (marksmen), a personal defence weapon (replacing pistols), an improved small structure breaching capability and boarding party solution for the Navy. The project also aims to replace the current dismounted area suppression capability (M203 Grenade launcher).
- **R&D for the Next Generation Small Arms Project**—The third phase of the dismounted effects modernization effort seeks to provide solutions for the future field force beyond 2021. Enhanced capabilities to be investigated are improved munitions with better effects, precision and weight-savings, and effectively integrated dismounted solutions incorporating power, lethality, target detection, location, prosecution and handoff (PNT) that reduce the soldier's burden and improve tactical effectiveness. A significant S&T effort is being planned.

3.5.3 Command, Control, Communicate, Computer and Intelligence (C4I)

Dismounted C4I capabilities will soon see significant advances through the Integrated Soldier System Project (ISSP). ISSP aims to deliver integrated, dismounted PNT, digital data and voice communications, battle management software, audio and visual display for improved tactical soldier and small unit situational awareness, navigation, sensor and lethality capabilities. Technical specifications and Statement of Requirements for the project are based on extensive integrated C4I research conducted as part of the Soldier Information Requirements Technology (SIREQ) TDP project.

Figure 3-6: ISSP Logo

ISSP is programmed to achieve the following goals over three cycles:

- **Cycle 1**—deliver a basic solution (2014–2016) to close combat soldiers in operational task forces (see Figure 3-7)
- **Cycle 2**—deliver capability upgrades to the baseline capability (2016–18)
- **Cycle 3**—deliver and field a fully integrated dismounted C4I capability

Figure 3-7: Concept of Capability Delivery for ISSP Cycle 1 and Cycle 2

3.5.4 Sensing

As with many of its allies, the CF relies heavily on its soldiers as a primary sense asset. A major focus of the Army's sense modernization effort is ensuring that the entire sense paradigm is integrated and linked with the complete C4I effort. Reaching this level of integration will be key to simplifying and quickening the shooter-sensor cycle, increasing the effectiveness of target detection, acquisition, hand-over and, ultimately, to enabling prosecution with the correct effect.

For this reason, vision sensor evolution has been a defining feature of the Army's sense modernization activities. The Army's Unit Surveillance, Target Acquisition, Night Observation (STANO) capital project has delivered and is currently delivering a plethora of observation devices to the field force for operations and training. These new off-the-shelf capabilities include:

- Improved Night Vision Goggles (AN-PVS-14 MNVG, AN-PVS-504 NVG)
- Soldier laser aiming devices
- Improved hand-held LRF and thermal imagers (CORAL C and C-RC)
- A variety of soldier thermal weapon sights.

Combat Identification (CID) is another priority modernization effort for the Army. For example, the Land Force's collaboration with its international partners includes a Battle Combat Identification (BCID) "Way Ahead" paper, promoting various NATO Standardization Agreements (STANAGs) and a soldier trial of passive Infrared Combat Identification (IR CID) capability.

The integration of sensors to the dismounted soldier network and the sharing of "sensed" information are paramount. Ideally, integration would include not only weapon and handheld optical sensors, but other sensors available to close combat soldiers such as unmanned air vehicles, unmanned ground sensors and, potentially, robot mounted sensors.

3.5.5 Survivability/Mobility/Sustainability

Survivability is a key soldier capability. The heaviest burden of a dismounted close combatant's equipment is the personal protective equipment (PPE). Through the Clothe the Soldier (CTS) program—supported by strong S&T—Canadian soldiers currently enjoy world-class PPE. However, this equipment continues to require updating in response to ongoing changes in soldier threats globally—including blast weapons, direct fire, fragmentation, CBRN, blunt trauma and environmental risks—and technological advances in materials (see Appendix 1 for a list of current threats by priority, based on a recent update by the Integrated Soldier System Project). Mobility is a key factor in a soldier's survivability; however as increased protection capabilities (through PPE) are supplied to the soldier, dismounted mobility is reduced by the additional weight and bulk of the items worn (see Figure 3-8). The addition of more PPE to the soldier's load also increases the sustainment load (food, water, spare parts) required to keep dismounted soldiers combat effective.

CANADIAN SOLDIER SYSTEMS MODERNISATION EFFORTS

Figure 3-8: Dismounted Close Combat Soldier on Operations in Afghanistan

In an effort to improve on the current level of dismounted soldier protection—including specific coverage, mobility and sustainment issues—the Army is sponsoring several domestic modernization efforts as well as collaborating with its partners in NATO and the ABCA Armies' Program. The following are just a few examples of current domestic activities, including S&T programs, urgent operational requirements, miscellaneous requirements ("buy and try's") and capability projects:

- **Soldier Integrated Headwear System (SIHS)**—This DRDC TDP initiative has provided key data for the current and continued evolution of an integrated headwear solution that aims to provide protection, C4I and sensor interoperability, potential future uniform interoperability and in-depth human/system integration (see Figure 3-9).[31]
- **CB Plus**—This DRDC S&T TDP initiative investigated short-term CBRN protection capability in an everyday soldier garment. The aim was to develop a lightweight, low profile, fully functional protective combat uniform (CBplus) that provides whole-body protection to the combatant against toxic hazards, for the 10 to 15 year timeframe. The functionality and system level protection performance under various chemical and biological exposure scenarios and environmental conditions was also tested.[32]
- **Advanced Modular Multi-Threat Protective Headwear System (AMMPHS)**—The goal of this DRDC TDP sub-project is to develop a fully protective prototype of a modular integrated protective headwear system to improve mounted and dismounted soldier survivability against multiple battlefield threats based on the SIHS design concepts. It will also identify and demonstrate upgrades for the in-service combat helmet to increase protection of the nape, mandible and neck based on the SIHS design concepts and to examine alternate ballistic protection solutions for helmets and body armour.[33]
- **Intelligent Textiles**—This S&T Defence Industrial Research Program (DIR) initiative seeks to incorporate power and data distribution into the soldiers' garments. The potential weight savings, multi-use capability and advances in power distribution of this technology could have a positive impact on protection, sustainment and mobility.

Figure 3-9: Headwear Concepts Derived From the SIHS TDP Integrated Soldier System Project, DRDC 2005

Key ongoing acquisition efforts include:

- **Soldier's Helmet Mid-life Upgrade**—This project is making improvements to the retention and pad systems to provide better stability and thermal management.
- **Ballistic Protection Mid-life Upgrade**—This capability seeks to provide improved direct small arms fire protection with the same mass as the current in-service ballistic plates.

31 Soldier Integrated Headware System, Defence Research and Development Canada (2005–2011).
32 Defence Research and Development Canada, *Annual Report* (March 2007).
33 Advanced Modular Multi-Threat Protective Headwear System, Defence Research and Development Canada (March 2010).

- **Land Operations Temperate Combat Boot**—One of the final CTS items, this capability has been developed through a highly iterative process. It has undergone thorough "trials" and is now based on a performance specification rather than a purely technical version.
- **Close Combat Modular Fighting Rig**—Recent operations have demonstrated that the current in-service load carriage used by Canadian close combat soldiers has insufficient capacity for immediate combat consumables and cannot be adequately tailored for specific roles, tasks and missions. As a result, a better-integrated, modular load carriage solution is being pursued that will feature increased capacity and flexibility.
- **Hybrid Shirt**—Improvements have been made to the combat shirt worn under PPE. By using a stretchable wicking material for the torso, and including pockets on the fire retardant sleeves, the dismounted soldier has a far more comfortable and useful garment to wear for the next decade, as a minimum.
- **Ballistic (Sand, Wind, Dust) Goggle**—Building on the success and utility of CTS ballistic eyewear, this initiative is currently putting solutions for this visual protection capability through trials. In addition to providing tremendous ballistic and debris protection and lens resistance to abrasion, this solution offers excellent comfort and thermal management. These benefits have been achieved through extensive human and system integration design and testing.
- **Combat Vehicle Crew Modular Helmet**—Utilizing lightweight bicycle helmet technology mated with current ballistic protection solutions, this capability provides a baseline modular helmet for future dismounted development.
- **Sniper System Project**—This project intends to deliver a baseline capability set to Canadian Army snipers by 2015. This set will include improved sniper task specific load carriage and PPE systems, as well as improved lethality through C4I and position, navigate and time (PNT) solutions.
- **Future Combat Uniform and Footwear (FCUF) Project**—This project intends to deliver integrated combat uniforms and improved footwear systems.

3.5.6 Human and Systems Integration

For more than 15 years, the CF soldier modernization effort has embraced the need for significant S&T efforts, particularly in the human factors and system integration domain. This was primarily executed by DRDC Toronto and industry human factors consultants under the sponsorship of the Land Requirements staff. Early on, this involved projects such as an anthropomorphic survey of users of a load carriage simulation suite of tools and, then, rapidly adapting to the need for Unforecasted Operational Requirements (UOR) acquisitions such as the personal role radio and night vision equipment. This has now led to this inclusion of more deliberate system-level analysis. Very few items have been fielded without the benefit of user trials or some level of human factors study. This is why the Canadian soldier enjoys leading-edge weapons and equipment.

3.6 Balancing Canadian Technical Domains—Have Map, Will Travel

The CF soldier modernization effort aims to achieve the appropriate equilibrium for "the Hard Problem"—including a constant effort to balance the soldier capabilities and technical domains.

Current technology has provided enhanced soldier capabilities in the areas of energy and power, lethal and non-lethal effects, C4I and sensing, and survivability and sustainability. These capabilities have been further enhanced by a concerted effort to improve systems integration and to better understand and accommodate human performance factors.

Through the SSTRM, the Canadian soldier systems community of interest has developed a detailed list of technology solutions across all of these technology domains to meet many of the CF future soldier's expected capability needs. However, the ultimate goal of Canadian soldier system efforts remains a wholly integrated soldier system that can best achieve the ideal "Hard Problem" equilibrium. This vision—coupled with the SSTRM's ongoing collaborative roadmapping effort—will enable the soldier system community to take emerging ideas and bring them to technology readiness levels that are ripe for soldier system exploitation.

PART III: WHAT WE KNOW

PART III: WHAT WE KNOW

Technical Domains: Capability Deficiencies, Vision, Goals, Drivers, Enabling/Emerging Technologies and R&D Focus Areas

Chapter 4: Guide to the Technical Domain Chapters

An important objective of the SSTRM is to identify the dismounted soldier's capability gaps and the technologies that are required to address those gaps. The following six chapters of this Capstone Report and Action Plan set out a logical sequence of information that links capability gaps in the six SSTRM technical domains—power and energy; weapons effects; command, control, communicate, computer and intelligence (C4I); sensing; survivability/sustainability/mobility; and human and systems integration—to the R&D focus areas that will address those gaps.

4.1 How the Technical Chapters Were Developed

The technical chapters of this Capstone Report and Action Plan are based on the knowledge exchange that took place at the SSTRM technical workshops, as well as on further discussion and analysis. Through these workshops, technology "theme" areas were identified for each of the six technical domains. These themes, which are further discussed in the individual reports from each technical workshop, provide a practical structure for discussing the technologies related to deficiencies in each of the technical domains.

Following the technical workshops, the knowledge exchange and collaboration was continued through the online Innovation, Collaboration and Exchange Environment (ICee) and the Technical Sub-Committees (TSCs). The theme structures for each technical domain were embedded into the ICee tool to enable further discussion and the addition of pertinent information by the respective TSCs and other experts. The ICee was organized as a series of templates to capture the information in a common structure and format.

The TSCs developed their information and populated the templates using different approaches: some held face-to-face working sessions; some delegated the tasks to content experts; and some employed a mix of both approaches. Each TSC chose an approach that was the most efficient and effective for completing its templates. Participants included industry experts, academia, defence scientists and representatives from the "user" community—soldiers.

The templates were developed iteratively, allowing contributors to add content based on input from others. This collaborative process of populating the templates occurred during the fall of 2010 and winter of 2011. The information gathered will continue to grow and be refined throughout the SSTRM Implementation Phase, which is to begin April 1, 2011.

The templates from the ICee provide the backbone for the technical chapters of this Capstone Report and Action Plan.

4.2 About the Technical Domain Chapters

Each of the technical domain chapters includes the following components:

- **Introduction to the Technical Domain**—The initial capability requirements of the North Atlantic Treaty Organization (NATO) soldier—Survivability, Sustainability, Mobility, Lethality and C4I—were further refined during the SSTRM Development Phase and provided the framework for the six technical domains of the overall SSTRM project.
- **Deficiencies and Gaps**—During the SSTRM workshop demonstrations and discussions, and through subsequent discussions by the TSCs, the capability deficiencies as they relate to the dismounted soldier were identified, and the gaps between current and desired capability were identified.

This analysis took into consideration the current status of soldier systems and related technologies, which was used as the baseline for improvement. These gaps were then characterized as high-, medium- and low-priority (see Table 4-1).

Table 4-1: Priority Setting Criteria

Priority	Criterion
High-priority gap	Any item or feature of a given capability or the lack of a capability that has a very significant negative impact on soldier operational effectiveness and his ability to conduct his mission and tasks with success
Medium-priority gap	Any item or feature that has a more significant negative impact on soldier operational effectiveness
Low-priority gap	Any item or feature that has a significant negative impact on soldier operational effectiveness

- **Vision for the Technical Domain**—setting a desired state for the domain for the year 2025. This work began at the technical workshops and was further refined by the respective TSCs.
- **Overall System Goals for the domain**—with two time horizons: 2015 to 2020 (near term) and 2020 to 2025 (far term). The near-term goals are categorized as incremental improvements on existing systems, the far term goals are characterized as revolutionary. The discussions on system goals were introduced at the SSTRM technical workshops, and these statements were further refined by the TSCs.
- **Key drivers for the domain and its themes**—these were presented and discussed during the SSTRM workshops, and further refined by the TSCs afterwards.

This background information on each technical domain provides the foundation for the discussion of the individual "themes" identified through the SSTRM workshops. In the upcoming technical chapters, each of these themes is discussed according to the four-step structure seen in Figure 4-1.

Theme Title

1. Theme Objective: The specific change that has to occur within this theme area in order to contribute to the technical domain's overall system goal and to address the identified gaps.

2. Technical Challenges and Requirements: The technology problem that needs to be overcome to achieve the objective, including a description of the technical requirement.

3. Enabling Technologies: The specific technology areas that need to be adjusted and improved to overcome the challenges. Some of these are traditional technology areas and some are emerging technologies.

4. Research and Development Focus Areas: This involves describing the specific areas of R&D that need to be pursued within the enabling technology. The discussion may include a description of known research efforts in this area.

Figure 4-1: Structure of SSTRM Theme Discussion

4.3 Understanding the Relationship Between Capability Gaps and Technology Progress

The following graphic was used within the SSTRM to explain the relationship between the soldier's current capability gap and how progress in targeted technology areas will address those gaps (see Figure 4-3).

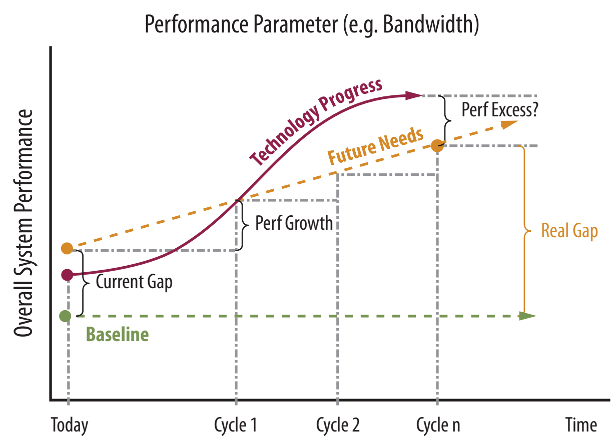

Figure 4-2: Functional Objective and Technical Challenge

The red dotted line illustrates how the soldier's needs will continue to grow over time. The three coloured dots on the left, representing the situation today (the baseline), show the current gap between what the soldier has and what he/she needs, as well as what can be achieved today with known technology.

As technology progresses over time—the solid blue curve—it overtakes the soldier's actual need, thereby providing an opportunity to fully meet those needs.

The graphic illustrates that the soldier's needs can be met or exceeded by choosing the right technologies to develop.

The discussion in the following technical chapters is intended to improve decision-making about technology development, so that the soldier's needs can be fully met as quickly as possible.

4.4 About the Technical Domain Chapter Annexes

The information on each technical domain and theme presented in the following chapters is supplemented by additional information and analysis—contained in annexes to the respective technical domain chapters. These annexes reflect information developed and compiled by the TSCs based on the results from the SSTRM technical workshops and on additional discussions with DND and DRDC. The presentation of this information follows a common structure as follows:

• ***Annex A: Technical Domain Deficiencies***—provides additional information on the general deficiencies affecting the domain and the relationship between the deficiencies and the themes identified within the domain.

• ***Annex B: Technical Domain Drivers/Constraints***—provides a list of the technical domain's main drivers and constraints, which are the most significant factors influencing technology options. An example of a driver is "the continued need for reduced weight," and an example of a constraint is "limited availability of electrical power." Often times, a driver and a constraint are opposite sides of the same coin.

• ***Annex C and subsequent technical domain chapter annexes***—present detailed information and analyses for each theme identified by the TSCs under their technical domain. This includes, for each theme:

- **Operational challenges**—the key characteristics or performance parameters that need to be improved for the theme. These are supplemented with assessments of the importance, or priority, of that challenge to the soldier, and of what would be required operationally to address those challenges, within five years and within ten years.
- **Enabling and emerging technologies**—the technologies needing development to address the operational challenges. Information on each of these technologies includes its current Technology Readiness Level (TRL), the year it would achieve TRL level 7, the strengths and weaknesses of the technology, the current critical barriers (or gaps) affecting the development of that technology, and recommended actions (see Table 4-3).
- **Proposed R&D focus areas**—derived from the analysis of the enabling and emerging technologies. The R&D focus areas are intended to be broad domains of research, rather than specific research projects although they could inspire the initiation of R&D projects. They could address challenges or standard gaps. Each R&D focus area is assigned a priority order (see section 4.4.3).

4.4.1 Definitions of Technology Readiness Levels

Technology Readiness Level (TRL) is a common measure used to assess the maturity of evolving technologies. The TRL framework is used by DND and DRDC, and was a useful reference tool throughout the SSTRM. Table 4-2 provides abridged definitions for TRL levels 1 through 9.

Table 4-2: Technology Readiness Level Definitions[34]

Technology Readiness Levels (TRLs)
1. Basic principles observed and reported
2. Technology concept and/or application formulated
3. Analytical and experimental critical function and/or characteristic proof of concept
4. Component and/or breadboard validation in laboratory environment
5. Component and/or breadboard validation in relevant environment
6. System/subsystem model or prototype demonstration in a relevant environment
7. System prototype demonstration in an operational environment
8. Actual system completed and qualified through test and demonstration
9. Actual system proven through successful mission operations

TRLs are given for most of the technologies identified in the Emerging/Enabling technology tables presented in the technical annexes to the technical chapters. Also, expected date for TRL 7 level, a key point for transition in future acquisition projects, as well as the recommended action on that technology (e.g., invest, transition, leverage, assess, etc.) are also indicated. High TRL technologies (TRL 7–9) would be potential candidates for incremental improvements in the near term (2011–2017), while low TRL technologies (TRL 1–6) would be mature for potential transition or insertion in the longer term (2017–2025), depending on technology-specific improvement time and effort invested.

4.4.2 How the "Recommended Actions" Were Determined

Each technology has been assigned a recommended action by their TSC. The recommended action takes into account all the above information about the technology and also the current knowledge of related R&D efforts already underway in Canada and other countries. A catalogue of known R&D efforts for each theme is included as Appendix 2 to the Capstone Report and Action Plan.

34 Department of National Defence, *Defence Acquisition Guidebook* (2006).

Table 4-3 lists the recommended action categories, and the underlying rationale for assigning each one:

Table 4-3: Recommended Action Categories

Action	Rationale
Monitor	Technologies or technology areas where *technology watch* is recommended. These are often technologies that are being developed actively by other organizations and/or countries, and where it would not make sense to pursue further development until more is known about their progress and potential.
Assess	Technologies or technology areas where it would be worthwhile to critically assess the state of the art of those technologies to better understand their performance information against Canada's requirements.
Leverage	Technologies or technology areas where non-DND Canadian organizations are already achieving some R&D success and could accelerate development through new collaborations with other Canadian or international R&D performers.
Invest	Technologies or technology areas where DND should consider starting or continuing R&D efforts because they have a significant potential to address the operational challenges.
Transition	Technologies or technology areas that have reached TRL 7 and have a high potential to address the stated operational challenges. These technologies could be considered for a transition to engineering development and commercialization, which would involve final technology development and integration into other soldier systems.

4.4.3 Proposed R&D Focus Areas

The analysis of each theme and its technologies generated a range of possible R&D focus areas. To help guide future R&D decision making, each proposed R&D focus area has been assigned a "priority order" by the TSC. Priority rankings are based on the soldier's urgency to address the operational challenge; how quickly the desired result can be achieved; and, the logical order within other related R&D efforts. These priority orders are based on the knowledge of TSC members and other experts participating in the discussions, and other information available from DRDC and DND.

This logical sequence of related information is intended to help guide decisions on which specific technology areas and technologies should be pursued, and when, in order to address the dismounted soldier's operational needs as quickly as possible.

4.5 Technical Domains and Their Themes

The following chapters are presented according to the following structure of technical domains and themes within each domain (see Table 4-4: SSTRM Technical Domains and Themes) and these highly detailed chapters with rich content can be found on the attached CD or the SSTRM website.

Table 4-4: SSTRM Technical Domains and Themes

Chapter 5: Power and Energy	Theme 1: Power Generation (Fuel Cells and Energy Harvesting)
	Theme 2: Power Sources (Storage)
	Theme 3: Power and Data Distribution
	Theme 4: Distributed Power Management
Chapter 6: Weapons Effects	Theme 5: Weapons Platform (Launching System)
	Theme 6: Ammunition (Lethal and Non-Lethal)
	Theme 7: Weapon-Mounted Situational Awareness and Targeting Suite
Chapter 7: Command, Control, Communications, Computer, Intelligence (C4I)	Theme 8: Command and Control
	Theme 9: Communications
	Theme 10: Computer
	Theme 11: Intelligence
Chapter 8: Sensing	Theme 12: Personal Sensing (Body-Worn)
	Theme 13: Weapons-Mounted Sensing
	Theme 14: Crew-Served and Hand-Held Sensing
	Theme 15: Unattended Area Sensing
Chapter 9: Survivability/ Sustainability/ Mobility	Theme 16: Operational Clothing, Load Carriage and Mobility
	Theme 17: Personal Protection
Chapter 10: Human and Systems Integration	Theme 18: Physical Integration on the Soldier
	Theme 19: Perceptual-Cognitive Integration on the Soldier
	Theme 20: System Architecture and Interoperability

Chapter 5: Power and Energy

5.1 Introduction

Power and energy on the dismounted soldier is a key technical domain with many associated challenges and an enabler for all 5 NATO soldier systems capabilities. It is being addressed first in the SSTRM as it is a fundamental element of the recent digitization effort, which has become as essential as soldier's combat supplies such as food, water and ammunition. Electrical power must be provided for any of the electronic equipment to function. As soldier systems evolve to include new capabilities, the dependence on electrical power will continue to grow. The introduction of enhanced C4I and sensing capabilities at the soldier level will allow the soldier to be more aware of his or her surroundings and to collaborate effectively with other soldiers. This will also generate more data that will need to be processed and shared, requiring even more electrical power. The generation, storage, distribution, management and use of greater electrical power must be provided and integrated in such a way as to minimize the overall weight and bulk of the soldier's equipment. These aspects of power provide the foundation for the four Power and Energy technical domain themes identified below.

- Theme 1: Power Generation (Fuel Cells and Energy Harvesting)
- Theme 2: Power Sources (Storage)
- Theme 3: Power and Data Distribution
- Theme 4: Distributed Power Management
- Technical Domain Deficiencies

5.2 Technical Domain Deficiencies

A total of 16 important deficiencies were identified in the Power and Energy technical domain. More information on these deficiencies is provided in Annex A to Chapter 5. The deficiencies are the following:

Standardization	No common power management communication protocol
	No common in-situ power generation communication protocol
	No independent electro-textile characterization and testing
Power management	Need to reduce intrinsic energy consumption of devices
	No standard power management schemes or policies
Power sources (storage devices, specifically batteries)	Secondary batteries lag behind primary batteries in energy density
	Batteries in general have poor performance at low temperature
	No standard for "state of health" definition or communication interface
	As the energy density of sources increases, their intrinsic safety mechanisms must be enhanced to meet the increased dangers of catastrophic failures.
In-situ power generation	Lack of Concept of Operations (CONOPS) or Concept of Employment (CONEMP) for group recharging and on-the-move recharging
	Lack of CONOPS or CONEMP for fuel storage and recharge (e.g., for fuel consuming devices such as fuel cells)
	Poor performance of air-breather power generation devices in the operational environment due to contaminants that are present
	Complexity and cost of new technologies limiting or hindering their acceptance
Power and data distribution	Lack of evaluation and characterization of electromagnetic susceptibility and interference performance
	Lack of suitable electro-textile connectors
	Connector form, fit and function not adapted to human usage (body worn); military-grade connectors mating cycle number (connection-disconnection) is too low for soldiers' daily usage.

5.3 Power and Energy Vision 2025

The SSTRM vision of the Power and Energy technical domain is to **provide the future networked soldier with self-sufficiency—without re-supplying for the mission duration— through increased energy efficiency, with the lowest acceptable added weight**.

5.4 Overall System Goals (2015–2020, 2020–2025)

This overall vision for the Power and Energy technical domain is broken down in specific goals for the medium and the long term. The specific goal for 2015–2020 is to provide soldier systems with sufficient energy storage capacity to operate through a 24-hour mission, and with recharging or fuel re-supply, to operate through a 72-hour mission.

For the 2020–2025 timeframe, the overall goal is for the soldier system to achieve energy autonomy.

The overall system goals are presented in Table 5-1.

Table 5-1: Overall Power and Energy Technical Domain Goals

2015–2020 (Incremental Improvement)	2020–2025 (Revolutionary Change/Improvement)
Managed power demand through low-power technologies and better power management schemes	Adiabatic computing used where possible—reducing power consumption of devices by 75% to 80%
Improved energy storage in batteries through improved materials and techniques	Semi-fuel cells in use with air-metal batteries and nano-scaffolding to augment surface area
Centralized power management to control power consumption	Decentralized power management scheme in place, with power usage simulation to produce a power management policy
Energy harvesting available to soldier on operations (producing 25% of requirements)	Energy harvesting providing at least 50% of required power while lowering the overall weight of power on the soldier by 25%
Improved efficiency of fuel cells by 25%—providing 25% of year-round soldier power requirements (by recharge or direct power)	Multi-fuel fuel cells using strategic hydrocarbon fuel and hydrogen in refillable, high-density cartridges —providing 50% of year-round soldier power requirements (by recharge or direct power)
Soldier power and data infrastructure integrated to its clothing for power and data distribution	Infrastructure with common connectors, common interfaces and common protocols
Soldiers need only one set of batteries for a 24-hour period	Soldier is completely independent from the logistics chain for power and is autonomous from a power standpoint

5.5 Technical Domain Specific Drivers

Eight drivers were identified in this technical domain. Since "reduced weight" is a common driver across all technical domains, it is not included in this list. The drivers that are specific to power and energy are:

- energy density, power density;
- safety (human and of information);
- voltage, current;
- wide temperature performance;
- wearability;
- mobility/transportability;
- usability; and
- ruggedness.

The four Power and Energy technical domain themes are summarized below and presented in greater detail in Annexes C, D, E and F to this chapter.

5.6 Theme 1: Power Generation (Fuel Cells and Energy Harvesting)

5.6.1 Scope

In-situ power generation involves the capability to generate electrical power in the field by two approaches: getting power from logistic fuels or getting power by exploiting the environment. In-situ power covers many emerging technologies such as micro fuel cells, diesel micro thermoelectric generators or diesel micro rotating electrical generator sets. For the SSTRM, the scope of in-situ power generation is limited to the two most promising areas (sub-themes) in the mid-term: fuel cells and energy harvesting.

5.6.2 Objectives

The objective for the In-Situ Power Generation theme is to provide—by fuel cells or energy harvesting—the necessary power to sustain the soldier's mission while minimizing the inherent size, weight and bulk.

5.6.3 Related Challenges and Requirements

The SSTRM participants identified a number of key performance parameters to be improved. The challenges were clustered into two broad deficiency groupings: fuel cells and energy harvesting solutions. For a full list of the critical challenges, see Annex C to F to Chapter 5, which provides mid-term (2015–2020) and long-term (2020–2025) performance targets.

The fuel cell performance parameters that need to be improved are:

- fuel cells must respond to the different power needs of dismounted soldiers, from 1W to 40W;
- support up to eight hours of continuous operation;
- 40 percent net system efficiency;
- system water-submersible;
- start-up of less than five minutes at -15°C; and
- spill-proof recharge and usage.

The energy harvesting performance parameters that need to be improved are:

- efficiency of up to 40 percent;
- weight and bulk < 1.5 Kg and 1 L;
- less than 50db of noise level; and
- up to 40 percent of daily required power.

A list of detailed challenges and requirements is provided in Table C-1 to Annex C to this chapter.

5.6.4 Enabling and Emerging Technologies

Nine enabling and emerging technologies that could address a number of specific deficiencies in the in-situ power generation theme were identified. These potential solutions are detailed in Table C-2 of Annex C to this chapter.

The enabling and emerging technologies for fuel cells include:

- conventional plate and frame fuel cell at small scale;
- novel architecture proton exchange membrane (PEM) fuel cell;
- micro reformation;
- hydrogen generation;
- micro-scale balance of plant; and
- high-temperature systems (e.g. reformation or solid oxide cells).

The enabling and emerging technologies for energy harvesting include:

- solar, wind, hydro;
- pyroelectric, piezoelectric and thermoelectric materials; and
- electromechanical energy harvesters.

5.6.5 Proposed R&D Focus Areas

For in-situ power generation, six Research and Development (R&D) focus areas are proposed. These are listed below.

- Alkaline fuel cells
- Reversible hydrogen storage
- Biomechanical and electromechanical energy harvesters
- Micro-reformation with micro balance of plant
- Multi-junction quantum dot photovoltaic cell
- Thermoelectric material improvement

The needs and opportunities related to each R&D focus areas are presented in Table C-3 of Annex C to this chapter.

5.7 Theme 2: Power Sources (Storage)

5.7.1 Scope

This theme covers primary batteries and secondary batteries (rechargeable). Soldier systems rely on portable electrical energy, e.g. batteries, to power its devices. The soldier system's power consumption has grown tremendously, and novel soldier systems will require significant increases in electrical power in the future. The increased of weight and volume of the energy storage devices is directly proportional to the increased in energy demand of the new capabilities required by the soldier. For batteries, the energy density (measured as watt-hours/kilogram) determines the amount of energy stored in a given mass.

The demands on the soldier's power system may vary by a factor of 10 times in power draw. For example, demand could change from a nominal constant load of 5 watts to a peak demand above 50 watts for short periods (seconds or minutes of time). As well, storage requirements are affected by a very demanding soldier environment, such as a very wide range of operating temperatures.

5.7.2 Objective

For the Power Sources theme, the key objective is to optimize:

- Runtime (optimize mission profiles)—i.e. increase energy storage through improve energy density.
- Form, fit and function of energy storage device (wearable).
- Appropriate power/data interface standards to permit smart power management.

The significant weight, bulk and cost of shipping batteries to the field make advanced storage options essential. The capacity optimization of battery, in terms energy storage calls for the improvements of several battery components (e.g. cell materials, electrolytes). It is important to include improved battery recharging methods (such as more efficient or versatile charging algorithms) as well as integration of storage in a hybrid power system that could include energy production and harvesting. Figure 5-1 shows the future direction of technology development for batteries for electric vehicles (EV).

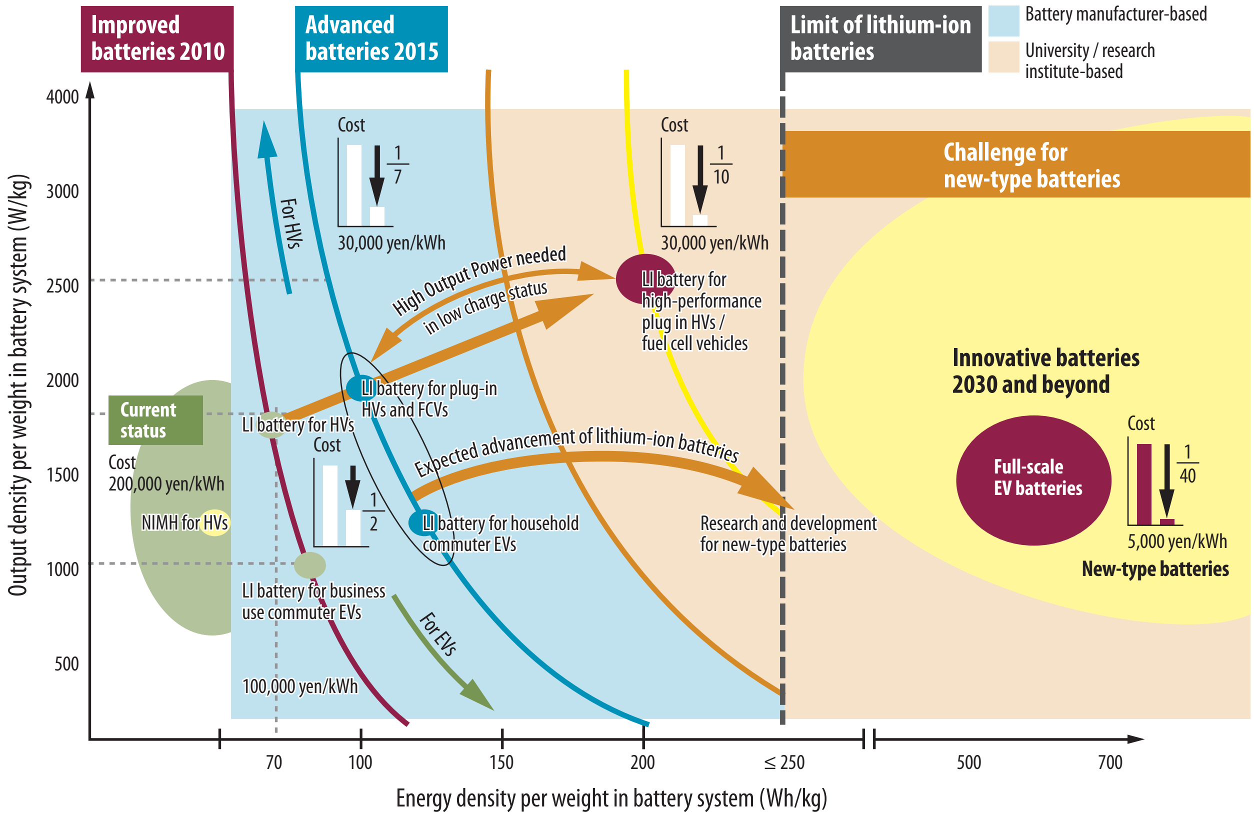

Figure 5-1: The Future Direction of Vehicle Battery Technology Development
Source: Japan Minister of Economy Trade and Industry, 2006

This is the traditional Ragone plot of power density versus energy density targets that need to be achieved for the EV market. The diagram for soldier power would be very similar with the same three development targets for batteries, which include improvement, advancement and innovation.

5.7.3 Related Challenges and Requirements

There are several challenges and requirements for electrical energy storage for the future soldier system. These are discussed further in Table D-1 of Annex D to this chapter. They relate to the following:

- Improved Standardised data interfaces (a better SMB)
- Fast charge capability, rechargeable at greater than 3C rates
- Energy density >300 Wh/kg
- Should function -40°C to +50°C
- Military guidelines for personnel's health and safety
- Conformable power sources
- Service life durability—primary batteries: 5-year minimum storage life, rechargeable batteries: cycle life >300

5.7.4 Enabling and Emerging Technologies

Six enabling and emerging technologies that could address a number of specific deficiencies in the Power Storage theme were identified. These are listed as follows:

- Lithium-air for primary
- Lithium/CFx for primary
- Nickel-Zinc (aqueous, rechargeable) for secondary
- Lithium-ion for secondary
- Nano-battery
- Ultra capacitor

These potential solutions are detailed in Table D-2 of Annex D to this chapter.

5.7.5 Proposed R&D Focus Areas

Five proposed R&D focus areas were identified, which concentrate on battery technologies that could address specific soldier systems requirements and the high priority deficiencies. The following R&D focus areas are proposed:

- Novel high-capacity rechargeable battery
- Intrinsic safety through designs
- Li battery with improved cold-weather power density
- Improved charge rate and power density
- Power sources integration

Of the proposed R&D efforts, many are aimed at improving the overall power and energy densities of batteries. However, the highest priority area is to improve especially the low-temperature range performance characteristics and primarily for rechargeable batteries.

5.8 Theme 3: Power and Data Distribution

5.8.1 Scope

The Power and Data Distribution theme includes transport mediums such as novel electronic harness technologies and connectics. These systems allow the interconnections of the soldier's system devices, including power generation, power storage components and power consuming devices.

This theme also involves the unification and integration of power and data transport mediums and the related connectics. The design of such a wearable soldier infrastructure is also closely related to the Human and System Integration technical domain (see Chapter 10).

The integration of the cabling into the fabrics of garments with novel transport mediums, such as conductive textiles, requires a new approach to design and integration.

5.8.2 Objectives

The objective of this theme is to have a totally cable-free backbone integrated into the soldier's operational clothing system, into which devices can be plugged, hot-swapped, reconfigured and scaled on the fly. The system needs to be adaptable to the soldier's mission.

5.8.3 Related Challenges and Requirements

Six challenges and requirements related to the Power and Data Distribution theme were identified and are listed below. Detailed information is provided in Table E-1 of Annex E to this chapter.

- Electromagnetic compatibility of e-textiles to United States Military Standard (MIL-STD) 461E or equivalent, without compromising fabric qualities that provide light weight, low-profile, flexibility and wearability
- Environmental compatibility of e-textiles to MIL-STD 810, without compromising fabric qualities and usability, durability and cleaning
- Connector standards and solutions that are compatible with e-textiles and garments and comply with MIL-STDs
- E-textile backbone electrical architectures that include fast data capacity, modularity and scalability, damage tolerance and redundancy
- Connectors with form factors that meet soldier needs
- Many competing architectural solutions

An overall challenge is to define and develop the architectural concept that will offer electrical and signal distribution, modularity and scalability, and layering of the garment to survive damage. This infrastructure needs to be integrated in the garment and also needs to accept a diversity of devices offering a range of capabilities that the soldier would choose for a specific mission.

5.8.4 Enabling and Emerging Technologies

Overall, for new transport mediums, many technologies exist and are promising to address the identified challenges. However, for connectors, no production design exists that could be easily attached to a fabric structure. Six enabling and emerging technologies that could address a number of specific deficiencies in the Power and Data Distribution theme were identified. They are:

- Electro-textile shielding;
- Environmental protection of e-textiles;
- Fast data transmission through e-textiles;
- Connectors for e-textiles;
- Connector physical characteristics; and
- Connector electrical characteristics.

Details about these enabling/emerging technologies are provided in Table E-2 of Annex E to this chapter.

5.8.5 Proposed R&D Focus Areas

Fundamentally, a common power and data exchange backbone is needed, with an appropriate overall architecture linking the three soldier system physical sub-systems: the head, where most of the senses are located; the torso, where the power, computing power and communication equipment normally resides; and the weapon, where the effectors and some sensors are situated. The following five R&D focus areas are proposed:

- Power and data distribution test standards
- Novel transport mediums
- Soldier system connectors
- Power and data distribution infrastructure
- Wireless power and data transmission

A detailed list of R&D needs and opportunities is available in Table E-3 of Annex E to this chapter.

5.9 Theme 4: Distributed Power Management

5.9.1 Scope

The Distributed Power Management theme includes the management system that controls battery charging among distributed storage elements; provides monitoring of battery health and system power demand; and performs energy re-allocation to maximize system availability. Optimized distributed power management helps minimize overall power demand, which in turn can lower the soldier's weight load.

5.9.2 Objectives

The objective of this theme is to intelligently manage power at all levels of the system in a manner transparent to the soldier, allowing for a defined level of mission-specific customization by the soldier and the overall reduction of power demand.

5.9.3 Related Challenges and Requirements

The overall challenge for the dismounted soldier is to be frugal in his or her energy consumption to allow for longer power availability. Six challenges and requirements related to the Distributed Power Management theme were identified and are listed below.

- Reduce power/energy demand of individual soldier system devices (e.g., C4I, sensing)
- Energy-efficient clocking design and synchronization mechanism to permit the implementation of adiabatic computing
- Power/energy architecture standards
- Distributed power management system
- Power management policies
- Power-aware smart devices

Detailed information is provided in Table F-1 of Annex F to this chapter.

5.9.4 Enabling and Emerging Technologies

Distributed power management is realized through a combination of software, hardware and architecture technologies. The optimum power management architecture starts with the design of software and hardware components that are assembled to produce devices that are power aware. The power manager is more often than not a software application. This application, in its more simplistic description, is composed of three modules: a module that observes the system and gathers power demand and consumption information; a module that analyses and forecasts what will be the next state of the system under observation, and at what time that state change should take place; and, finally, a command module that will respond to the forecast and change the state of the system.

Six enabling and emerging technologies that could address a number of specific deficiencies in the Distributed Power Management theme were identified. They are:

- Adiabatic processing;
- Power consumption of individual hardware components (e.g., chips) and devices (e.g., GPS, radio);
- Power-aware software components (e.g., library) and software applications (e.g., Battle Management System, communication stack);
- Power-management control protocol;
- Simulation; and
- Distributed dynamic power management.

These potential solutions are detailed in Table F-2 of Annex F to this chapter.

5.9.5 Potential R&D Focus Areas

Five proposed R&D focus areas were identified for the Distributed Power Management theme. These are listed below:

- Adiabatic computing
- Dynamic power management
- Predictive mission power planning
- Power sources and soldier devices simulation models
- Power-aware components

A detailed list of R&D development needs and opportunities is available in Table F-3 of Annex F to this chapter.

Annex A: Power/Energy Deficiencies

Table A-1: Power/Energy Deficiencies

Deficiency	Rank	Description
Lack of standardisation	High	There is a need to create power/energy standards in the realm of dismounted soldier systems, to guide industry and government
	High	There is a need for a system on the soldier to federate all power consumption and manage power. To do this, each device on the soldier would need to use the same language to allow for the "command and control" of energy demand at the device level
	High	In-situ power generation lacks the ability to query the power controller for status in a standardised manner (i.e. no SMBus-like capability)
	High	There is no accepted way to test electro-textiles for EMI/EMC, electrical characteristics, usability, wearability, or to validate the behaviour of e-textiles when transporting power and exchanging data
Lack of power management and power demand management	High	With the high cost of battery power, there is a need to lower power demand through active power management
	High	There is a need to define a common power management scheme in such a manner that all federated devices on the soldier can work together in a way that lowers power demand

Deficiency	Rank	Description
Deficiencies in power source (storage) capabilities	High	A battery communication interface is needed to enforce the SMBus industrial standard. The SMBus v 1.1 is the generally accepted interface for high-density batteries, but vendors can add their own functionalities. Energy harvesting systems do not communicate with power sources at all
	High	Energy density in batteries needs to improve significantly to meet soldiers' requirements. The number of electronic devices on the soldier will increase with time, and so will power demand. Also, the amount of information/data exchange will increase, and the need for its processing will require more power.
	High	Batteries have a limited capability in cold weather, whereas soldiers will likely be operating in Canada's North.
	High	As energy density of power sources increases, so does the danger related to these devices. There is a need to improve the safety of batteries as they react to perforation, overcharging, over-current, and high temperatures.
Lack of understanding of in-situ generation, including safety for fuel cell utilization	High	The Concept of Operations needs to be defined for in-situ power generation. Will fuel cells be used as power sources for individual devices or systems? Will fuels cells be used as power sources for charging stations on the move?
	High	Fuel safety will become a concern with the introduction of in-situ generation, since fuel for fuel cells can be toxic to humans and there needs to be a safe system for recharging and replenishment in the field
	High	Fuel cells add a new level of complexity and, therefore, cost.
	High	Fuel storage and recharge for fuel cells and micro-generation can be problematic: there is no easy way to store efficiently on a soldier high energy fuels like hydrogen.
	Medium	The efficiency of fuel cells is around the same as that of a combustion engine, and they also produce heat and a detectable scent as a by-product.
Lack of architecture and standard capabilities in power and data distribution, especially using electro-textiles	High	Electro-textiles can be sensitive to the harsh environment encountered by the soldiers: any tear or wear can create entry points for humidity creating short-circuits or gaps in connectivity.
	High	With respect to EMI-EMC, electro-textiles need to be protected from external interference and, at the same time, limit to a minimum the emission of signals.
	High	There is no practical way to interconnect e-textiles to the external world, so new connectors need to be developed that are simple and inexpensive.
Lack of energy harvesting at the soldier level	Medium	There is no effective way to harvest or scavenge and distribute energy efficiently.
Lack of energy consumption knowledge for mission planning	Medium	There is no easy way to estimate the power consumption for a specific mission. There is a need to predict power consumption and to generate a power consumption policy for a soldier-level power management engine.
Lack of power source standardisation	Medium	There are too many types of power sources (i.e. batteries) and power source interfaces in the current soldier system, whereas there needs to be a "class" of main batteries and interfaces.
Lack of proper connectors for the soldier	Medium	In general, the form factor of connectors is not designed with the human body in mind, and the number of mating cycles in the majority of connectors does not meet military standards (which may require thousand of cycles during its lifetime).
Deficiencies in electro-textile application in multilayered garments (3-D)	Medium	E-textiles are, by their nature, a 2-D construction of fabrics, and there is a need to extend them to a 3-D product (i.e. going from one clothing layer to the other).

Annex B: Drivers

Table B-1: Power and Energy Drivers/Constraints

Drivers/Constraints	Implications
Energy density, power density	The weight and bulk of energy storage limits the useful load that can be carried by the soldier, and will be reduced to practical limits
Safety, ruggedness	Fire, electrical shock, chemical spill, overheating
Voltage, current	Quality of power (reliability), low-noise signature, electromagnetic pulse, vibrations, etc.
Wide temperature performance	From -40°C to +65°C for both the charging and discharge of batteries, and for fuel cells
Wearability	The energy storage, sourcing, and power management within the soldier systems
Mobility/transportability	Must have the least possible impact to user ergonomics and mobility
Usability	Seamless package, so as not to create a cognitive load for the user

Annex C: Theme 1: Power Generation (Fuel Cells and Energy Harvesting)

Annex C includes the following three tables:

- Table C-1: Challenges/Requirements
- Table C-2: Enabling/Emerging Technologies
- Table C-3: Proposed R&D Focus Areas

Table C-1: Challenges/Requirements

Challenges	Priority	Requirements	
		2015–2020 (Horizon 2)	2020–2025 (Horizon 3)
Fuel Cells: Power Level			
High Power and Energy Systems Three power-level paradigms emerge: 1. High power central source for powering multiple devices: 20 W to 40 W system 2. Low power distributed source for powering or recharging individual soldier systems and more power-hungry individual devices: 5 to 10 W system 3. Very low power distributed source for powering or recharging individual devices: 1 to 5 W system All three paradigms need to be developed to TRL 4 or better so that "on board power architecture" can select the better of the three when needed Quantitative performance parameters are helpful as comparative measures, but more important are considerations for the integration of these devices into soldier systems (i.e. devices need to be wearable and mountable to soldier kit)	High	TRL 4 demonstrated 20 to 40 W system; package in <1.5 litre 5 to 10 W system; package in <0.75 litre 1 to 5 W system; package in <0.1 litre System includes fuel cartridge System weight should achieve parity with best battery alternative, defined as weight required to complete mission (fuel cell plus required fuel cartridges)	TRL 7 demonstrated 20 to 40 W system; package in <1.0 litre 5 to 10 W system; package in <0.5 litre 1 to 5 W system; package in <0.075 litre

Challenges	Priority	Requirements	
		2015–2020 (Horizon 2)	2020–2025 (Horizon 3)
Fuel Cells: Efficiency Improvement			
High energy-density fuel cartridges Fuel cartridges should be sufficient to support 8 hours of continuous operation of the fuel cell system (e.g., 150 to 250 W-h for high power system, 40 to 80 W-h for low power system)	High	500 W-h/l for complete cartridge 300 W-h/kg for complete cartridge This could be lower in the case of micro-fuel cells: in the order of 250 W-h/kg Demonstration of scalable production capability for fuel Demonstration of safe disposal of spent fuel	>1000 W-h/l for complete cartridge >600 W-h/kg for complete cartridge This could be lower in the case of micro-fuel cells: in the order of 500 W-h/kg Compliance with IEC 62282.6
System efficiency — heat production	High	>40% net system efficiency (accounting for all system losses including fuel cell efficiency, fuel utilization, venting, power conversion)	>50% net system efficiency (accounting for all system losses including fuel cell efficiency, fuel utilization, venting, power conversion)
Fuel Cells: Usability			
Air breathing apparatus	Medium	System submersible in water: operation can stop when immersed but must recover when air access returned	System modified to allow operation under water with addition of auxiliary oxidant source
Extreme temperature Start-up at low temperature and humidity	High	Should be able to start in less than 5 minutes in -15°C	Functioning over all soldier acceptable environments
Soldier proof	Medium	Resistant to soldier activities	
Safety	High	Spill proof recharge Spill proof usage	Spill proof all the time, no danger resulting in perforation and no dangerous by-products
Energy Harvesting			
Efficiency	High	For electromechanical devices: in the order of 40% For PVC (solar) foldable panel: at 30% efficiency For thermoelectric devices: efficiency < 15%	For electromechanical devices: in the order of 50% For PVC (solar) foldable panel: at 50% efficiency For thermoelectric devices: efficiency < 25%
Weight and bulk	High	For electromechanical devices: > 1 kg and 1 litre For PVC: a volume of 10x10x5 cm at 0.5 kg For thermoelectric devices: less than a 1 mm thick	For electromechanical devices: > 0.75 kg and 0.75 litre For PVC: a volume of 10x10X5 cm at 0.5 kg For thermoelectric devices: less than a 0.5 mm thick
Usability (including stealth and dual use)	High	Less than 50db of noise level	Less than 50db of noise level
Power output	High	For electromechanical: 40% of the daily required power For PVC (solar) foldable panel: up to 33% of the daily required power in good condition For thermoelectric devices: 5% of the daily required power	For electromechanical: 50% of the daily required power For PVC (solar) foldable panel: up to 100% of the daily required power in good condition For thermoelectric devices: 10% of the daily required power

Table C-2: Enabling/Emerging Technologies

Technology	TRL (1–9)	Year for TRL 7	Strength (S)/ Weakness (W)	Critical Barriers/Gaps	TSC Recommended Action
Fuel Cells:					
Conventional plate and frame fuel cell at small scale	5	2020	S: Leverages from more mature automotive technology W: Typically requires expensive and complex balance of plant components	• Low system power density, high system complexity, tends to be heavy	Invest (Rationale: Look for very low cost and lighter weight alternatives)
Novel architecture PEM fuel cell	4	2025	S: Overall high power density W: Generally low reliance on additional balance of plant	• Costs higher in small volumes • Lower maturity due to lack of leverage from large scale applications	Monitor/assess (Rationale: Keep abreast of consumer level product developments based on this technology)
Micro reformation	5	2025	S: Potential to merge benefits of "logistic fuels" for supply side with "hydrogen operation" for power generation W: Added complexity, added volume & weight, added parasitic losses	• Robust and simple reformer systems have not been demonstrated	Monitor/assess (Rationale: Keep up with reformation technologies: 1) methanol reformers 2) butane reformers 3) other fuel reformers (e.g., formic acid, alcohols))
Hydrogen generation	4 to 6	2025+	S: Potential to generate hydrogen from chemical sources, high energy density cartridges with relatively simple generation apparatus W: Chemical feedstock materials can be dangerous and potentially toxic to soldiers, to generate H2 through hydrolysis requirements for water, reduce energy density	• Chemical feedstock materials need to be scrutinized to ensure they can be synthesized in volume at reasonable cost • System compliance with health and safety standards is essential	Assess
Micro-scale balance of plant	5	2020	S: Enabling technology for the more complex systems, balance of plant includes pressure regulators, valves, blowers, cooling apparatus, and sensors as required to enable the more complex (i.e. higher power) systems W: Micro scale technology tends to be expensive and at prototype stages only	• MEMS technologies tend to be very expensive • Relatively little MEMS work is focused on fuel cell specific applications due to small market and slow adoption of fuel cell technology	Assess (Rationale: Possibly try to stimulate university / industry research develop appropriate MEMS technologies for portable fuel cells)
High temperature systems	5	2025	S: Potential for use with very high energy density fuels such as butane, propane W: Challenges with thermal cycling, potentially long start-up times, potentially ill-suited for dynamic duty cycle of soldier system		Monitor

Technology	TRL (1–9)	Year for TRL 7	Strength (S)/ Weakness (W)	Critical Barriers/Gaps	TSC Recommended Action
Harvesting					
Solar, wind, hydro	9	Now	S: Solar offers the best availability of the three natural harvestable energies W: For solar, very poor efficiency of about 20% in the best of conditions, hydro is not readily available even in very small, free current turbines exist, but good efficiency of about 70%, for wind the efficiency has a theoretical maximum efficiency of 0.593 (59.3%) Betz's law	• For solar producible multi-junction quantum dot photovoltaic cell, with high efficiency	Invest
Pyroelectric, piezoelectric and thermoelectric materials	4	2025	S: Can be used in material or in device that are subject good temperature delta W: All of them have a poor efficiency, the thermoelectric seems to offer the best opportunity, due to poor efficiency need large harvester and therefore bulk and weight	• Need better efficiency and a rugged harvester	Invest
Electromechanical energy harvester	6	2015	S: The devices exploiting human biomechanics offer the best opportunity, best efficiency, and the best sustained power output, two possible avenues of R&D: 1) devices that exploit human biomechanical to generate energy, 2) devices that need direct human energy expenditure, such as a crank generator	• Weight • Noise • Comfort	Invest

Table C-3: Proposed R&D Focus Areas

R&D Focus Areas	Scope/Description (Needs and Opportunities)	Priority Order (1, 2, 3)
Alkaline fuel cells	Due to new understanding and technologies, alkaline fuel cells at the forefront of R&D. They have the potential to reduce fuel cell costs and broaden opportunities for alternative fuels relative to conventional PEM fuel cells by avoiding the use of exotic catalyser	3
Reversible hydrogen storage	An alternative to the disposable fuel cartridge approach, requires complete system integration approach with possible base generation of hydrogen to support rapid device refuelling	3
Biomechanical and electromechanical energy harvesters	In recent years, efforts have been done in the field of active energy harvesting using human power and environmental effect and the investment is starting to provide acceptable ROI	1
Micro-reformation with micro balance of plant	If micro-reformation were to become commercialized, it could assist in the acceptance of fuel cell technologies. This would open the door to using hydrocarbon-based fuel in fuel cells. By achieving this in a micro-format (MEMS) with a balance of plant in the same technology, it would open the door to multiple-fuel fuel cells.	2
Multi-junction quantum dot photovoltaic cell	Using quantum dots capabilities in a multi-junction photovoltaic cell that would harness the largest part of the solar spectrum from infrared up to ultraviolet to provide the best efficiency	1
Thermoelectric material improvement	Thermoelectric materials are a promising small scale harvesting technology and work needs to be done to produce materials that are lightweight and have higher performances than what is available now: a desired efficiency of at least 25%	2

Annex D: Theme 2: Power Sources (Storage)

Annex D includes the following tables:

- Table D-1: Challenges/Requirements
- Table D-2: Enabling/Emerging Technologies
- Table D-3: Proposed R&D Focus Areas

Table D-1: Challenges/Requirements

Challenges	Priority	Requirements	
		2015–2020 (Horizon 2)	2015–2020 (Horizon 2)
Data interface	High	The form factor and power/data interface must be standardised	Common standard
Rechargeable format (high efficiency)	High	Rechargeable at greater than C3 rates (>90% columbic efficiency)	Rechargeable at greater than C rates (>95% efficiency)
Energy density	High	>300 W-h/kg	>500 W-h/kg
The environment (temperature, humidity)	High	Should function -40°C to +50°C	Must function through full military environment
General safety	High	Military safety evaluation guidelines	Military safety evaluation guidelines
Conformable power sources	Medium	Remove 'brick' format	Complete conformability (soldier system ensemble)
Fast charge (replacement) capability	Medium	Reduce logistics to one spare battery	Fast charge (<30 min) (no spare energy storage required)

Challenges	Priority	Requirements	
		2015–2020 (Horizon 2)	2015–2020 (Horizon 2)
Service life durability	Medium	Primary batteries — storage life a minimum 5 years Rechargeable batteries — cycle life: # of charges/ discharges >300	Primary batteries — storage life up to 10 years Rechargeable batteries — cycle life: # of charges/ discharges >500

Table D-2: Enabling/Emerging Technologies

Technology	TRL (1–9)	Year for TRL 7	Strength (S)/Weakness (W)	Critical Barriers/Gaps	TSC Recommended Action
1. Li-air (primary)	3	2018	S: High energy density W: Cost/ primary (disposable) system	• Reactivity of Li • Issues of metal air systems	Leverage
2. Li/CFx (primary)	7	2013	S: High energy density W: Cost/ primary (disposable) system	• Wide temperature performance • Improve rate capability • Reduce resistance for higher rates and scale-up to D-size	Leverage
3. Ni-Zn (aqueous, rechargeable)	7 8 (AA format)	2013	S: Safety of aqueous system, low cost W: Cycle life	• Wide temperature performance • Improve rate capability	Leverage
4. Li-ion (secondary)	9	Now	S: Good energy density W: Susceptibility to catastrophic failure, poor cold weather performance	• Wide temperature performance • Improve rate capability • Improve energy density, new materials for positive and negative electrodes, gel-polymer & non-flammable electrolytes	Invest
5. Nano- battery	1–2	2020–25	S: High surface area (rate), high energy density W: (none identified)	• Heterogeneous side reactions (parasitic energy loss)	Monitor
6. Ultracapacitor	5–6	2015–20	S: High rate power output W: Poor energy density vs. battery	• High self-discharge • Low & linearly falling discharge voltage	Leverage

Table D-3: Proposed R&D Focus Areas

R&D Focus Areas	Scope/Description (Needs and Opportunities)	Priority Order (1, 2, 3)
Novel high capacity rechargeable battery Safe designs	Chemistries that exceed 200 W-h/kg energy density (short term) >300 W-h/kg longer term Energy linked to weight (via energy density) Improve rate capability Improve energy density • New materials for positive and negative electrodes, gel-polymer & non-flammable electrolytes Safe designs/concepts for battery packs	3 (Based on cost limitation, will not be undertaken by commercial sector)
Li battery that has improved cold-weather power density	Energy density decreases sharply below -10 °C Wide temperature performance Improve rate capability	1 (Will not be undertaken by commercial sector)

R&D Focus Areas	Scope/Description (Needs and Opportunities)	Priority Order (1, 2, 3)
Improved charge rate and power density	Fast charging better power density reducing size/weight of main battery	2
Power sources integration	Energy storage and power sources part of power/data architecture Proper integration required	3 (Part of overall soldier system architecture)

Annex E: Theme 3: Power and Data Distribution

Annex E includes the following tables:

- Table E-1: Challenges/Requirements
- Table E-2: Enabling/Emerging Technologies
- Table E-3: Proposed R&D Focus Areas

Table E-1: Challenges/Requirements

Challenges	Priority	Requirements	
		2015–2020 (Horizon 2)	2020–2025 (Horizon 3)
Improve and/or assure electromagnetic compatibility of e-textiles to MIL-STD 461E or equivalent, using screening materials over yarns/fabrics/interconnects, without compromising fabric qualities of light weight, low profile, flexibility and wearability	High	MIL-STD 461E compliance with e-textile "sandwich" thickness < 2.5 mm	MIL-STD 461E compliance with e-textile "sandwich" thickness < 1.0 mm
Improve and/or assure environmental compatibility of e-textiles to MIL-STD 810, using coatings, finishes, laminations and garment design, without compromising fabric qualities and usability, such as durability and cleaning	High	MIL-STD 810 compliance with e-textile "sandwich" thickness < 2.5 mm	MIL-STD 810 compliance with e-textile "sandwich" thickness < 1.0 mm
In line with Theme 2, develop connector standards and solutions that are compatible with e-textiles and garments. Similar drivers to fabrics, namely environment, EMC, fast data capacity, plus human factors and usability	High	MIL-STD 461E and MIL-STD 810 compliant connector, using pigtail cables for backwards compatibility	Streamlining manufacture and ramping volumes for cost efficiency Connectors adopted within devices to remove pigtail cables
In line with Theme 1, determine and develop e-textile backbone electrical architectures, to include fast data capacity, modularity and scalability, damage tolerance and redundancy	Medium	USB2.0 (480 Mbit/s) data speeds on one-dimensional e-textile "ribbons"	USB2.0 on two-dimensional e-textile backplanes, USB3.0 (4 Gbit/s) data speeds on "ribbon"
Connector form factors for soldier's needs	High	Meet all quantified soldier's parameters	International acceptance
Many competing architectural solutions	High	Accepted architecture	Standardised architecture

Table E-2: Enabling/Emerging Technologies

Technology	TRL (1–9)	Year for TRL 7	Strength (S)/Weakness (W)	Critical Barriers/Gaps	TSC Recommended Action
Electro-textile shielding	5	2013	S: Integrated wiring harness within e-textile can have overall shield applied that outperforms piecemeal shielding W: Shielding (as per MIL-STD-461 EMI\EMC)	• Problems associated with shielding individual conductor strands, which is also at odds with achieving differential coupling	Invest (Rationale: An electro-textile that is susceptible to be disrupted by RF nearby or is leaking or emitting internal processing will not gain acceptance)
Environmental protection of e-textiles	5	2013	S: Plasma activated coating shows great promise, breathable micro-porous membranes have proven effective in commercial products W: (none identified)	• Application of multifunctional coatings (e.g., shielding/ waterproofing/ abrasion resistance)	Invest (Current environmental protections for textiles can be unnecessarily bulky and heavy)
Fast data transmission through e-textiles	6	2014	S: Well-understood signal integrity domain W: parallel data paths within two-dimensional e-textile must all be terminated with characteristic impedance to avoid internal reflections	• Terminating or disconnecting single-ended transmission line stubs • Achieving dielectric stand-offs for shield without making fabric "sandwich" too thick and inflexible	Invest (Rationale: Current e-textiles are capable of slow (<12 Mbit/s) data transmission, good for 90% of current demands, but real-time video data to/from displays and sensors will require faster rates)
Connectors for e-textiles	3	2013	S: USB (1.1 and 2.0) rapidly becoming de-facto industry standard, connector technologies for flexi-circuits can be leveraged W: No COTS connectors are available for wearables or e-textiles	• Defined electrical and data standards • New paradigm of connector geometry required for unique human factors requirements (e.g., single handed, gloved, blind, wet mate of connectors anchored to the body)	Invest (Rationale: MOTS connectors generally a point-of-failure for systems, particularly unsatisfactory when soldier-borne, regards human factors and environment)
Connector(s) physical characteristics	3	2015	S: (none identified) W: No adapted connectors	• Normal connectors not adapted: human integration (form factors), electro-textile, soldier environment	Invest (Rationale: To have data and power transiting across devices taking into account the human integration)
Connector(s) electrical characteristics	3	2015	S: (none identified) W: The parameters are not defined: data speed, impedance, voltage, power, etc.	• Need to standardize	Invest (Rationale: To have data and power transiting across devices taking into account the human integration)

Table E-3: Proposed R&D Focus Areas

R&D Focus Areas	Scope/Description (Needs and Opportunities)	Priority Order (1, 2, 3)
Power and data distribution test standards	Standard test methodologies for: • Electromagnetic (EMI/EMC/EMS) • Human system integration (usability, wearability, safety evaluation)	1
Novel transport mediums development	E-textile Fibre optics Dual (e-textile for power and fibre-optics for data) Skin conductance	3
Soldier system connectors	Design, develop and/or assess a family of novel connectors optimized for soldier system (i.e. based on a human centric design approach) These connectors should fulfill all the requirements identified such as being electrically and mechanically versatile for different transmission standards They should be certified for hazardous environment and the soldier's environment	2
Power and data distribution infrastructure	Development and demonstration of the power and data backbone: integration of novel transport mediums and soldier system connectors with the electronic devices	1
Wireless power/data transmission	Inductive technologies: • Improved efficiency • Improved bandwidth and throughput • Undetectable signature in close proximity • Very close proximity activation and de-activation • Integration with fabrics	3

Annex F: Theme 4: Distributed Power Management

Annex F includes the following tables:

- Table F-1: Challenges/Requirements
- Table F-2: Enabling/Emerging Technologies
- Table F-3: Proposed R&D Focus Areas

Table F-1: Challenges/Requirements

Challenges	Priority	Requirements	
		2015–2020 (Horizon 2)	2015–2020 (Horizon 2)
Reduce overall power/energy demand from soldier systems consuming devices (e.g., C4I, sensing)	High	-25%	-50%
Find a solution for a highly energy-efficient clocking design and synchronization mechanisms to permit the implementation of adiabatic computing	High		100% of the processing components in system are of this technology
Power/energy architecture standards	High	Initial definition of standards	Optimized architecture standards

Challenges	Priority	Requirements	
		2015–2020 (Horizon 2)	2015–2020 (Horizon 2)
Distributed power management system	High	Implementation of "power manager" in the basic soldier systems devices (such as computer, display, radio, GPS, etc.), each with its own power usage policies, uploaded from a computer	Implementation of a "distributed power management" scheme on all information processing devices, with the power usage policies generated and provided by predictive mission power planning
Power management policies	High	Specific power usage policies implemented (day and night)	Optimized mission specific power usage policy implementation
Power aware smart devices	Medium	60% of devices are power aware	100% of devices are power aware

Table F-2: Enabling/Emerging Technologies

Technology	TRL (1–9)	Year for TRL 7	Strength (S)/Weakness (W)	Critical Barriers/Gaps	TSC Recommended Action
Adiabatic processing	2	2025 (optimistic)	S: Can reduce processing power requirements by 90% W: Currently very little hardware exists	• Implementation of µComputer architectures in reversible logic structures, and its successful commercialization • Power management is most easily realized through power reduction, computation requirements will only increase over time	Invest
Hardware components (e.g., chips) and devices (e.g., GPS, radio)	6–7	2015	S: (none identified) W: Not used as much as it should be used but missing the power manager to orchestrate the entire concept	• Cost, availability, architecture to benefit from this technology • The availability power aware design tools and their usage in industry • Smart components that can interact with other component and power manager	Invest
Power aware software components (e.g., library) and software applications (e.g., BMS, communication stack)	6–7	2015	S: (none identified) W: Not used as much as it should be used, a question of knowledge of the capability and missing the power manager to orchestrate the entire concept	• Application or software component specifying their power requirements that would be orchestrated by a power manager	Invest
Power management control protocol	8	Now	S: (none identified) W: Not wholly adopted by industry and not secured communication	• Cost • Software aware applications not there yet • Based on I2C which is suitable for internal communications, suitable on a device, but not between devices • Need to push this or similar language and protocols on a different transport medium like IEEE 802.3 and develop a secured version of it	Invest

Technology	TRL (1–9)	Year for TRL 7	Strength (S)/Weakness (W)	Critical Barriers/Gaps	TSC Recommended Action
Simulation	7	Now	S: The processing power now available makes simulation an available technology in many areas or domains W: Need different components to make it work: the simulation engine, the power processing directly available, consumption model of devices, power source models	• This can be applied to soldier systems design to understand soldier power usage • It can be applied directly in dismounted commander battlefield planning tools to predict the power usage of troops	Leverage
Dynamic power management (distributed)	7–8	2015	S: Not used as much as it should be used, a question of knowledge of the capability W: Added complexity, need to have a distributed capability to manage power	• Technology needs to be adapted to soldier systems and needs more data onpower cycle, usage, timing, to be able to create a data corpus • Power management software to use a learning capability to predict when to save power or not • An architectural standard must be defined to permit future development	Invest

Table F-3: Proposed R&D Focus Areas

R&D Focus Areas	Scope/Description (Needs and Opportunities)	Priority Order (1, 2, 3)
Power reduction technologies: adiabatic computing	Review of adiabatic computing for feasibility and applicability	1
Dynamic power management	Power management secure network language: • Develop and standardise a DPM secure network language to exchange data on power consumption, power demand, batteries health, DC-to-DC control, power usage policies distributions, and secure protocols DPM scheme: • To work in soldier systems, the DPM needs a power management secure network language	1
Predictive mission power planning tool	Need to create a simulation engine that will generate the power usage policies needed to manage the power, based on the planned operations and the configuration of participating soldiers	2
Power sources and soldier devices simulation models	The models would be used with the power management policies and soldier device models	2
Power aware components	Hardware and software • The design, development and demonstration of power aware components that follow the PMBus architecture and configured to communicate with a PMBus controller. Companies that are starting to develop and offer components with this capacity With respect to software, there are very few instances where these principles have been implemented	3

Chapter 6: Weapons Effects (Lethal and Non-Lethal)

6.1 Introduction

Weapons effects (lethal and non-lethal) are the technical domain providing the firepower element of soldier systems and directly relates to the NATO soldier systems capability of Lethality. This technical domain covers the weapons platform, sighting and fire control system and the weapon ammunition. Weapon effects can be optimized by addressing the various elements of the kill chain, which are the opposite ones of the survivability chain (See Chapter 9 (Survivability/Sustainability/Mobility).

For the purpose of this discussion, the weapons system also includes the operator or user, sensors and other ancillaries that could be part of the weapon or the sighting system. Within the weapons technical workshop a number of themes were explored:

- Theme 5: Weapons Platform (Launching System)
- Theme 6: Ammunition (Lethal and Non-Lethal)
- Theme 7: Weapon-Mounted Situational Awareness and Targeting Suite (WM-SATS)

The weapons effects system is depicted below in Figure 6-1.

Figure 6-1: Depiction of the Weapons Effects System

6.2 Technical Domain Deficiencies

A total of 37 general deficiencies were identified in the Weapons technical domain. The deficiency priorities are detailed in Annex A to Chapter 6. Fourteen deficiencies were identified as being high priority:

1. Human system integration
2. Training burden and limitations (lack of realism)
3. Variable accuracy—human error budget (stress, tiredness, weapon handling, etc.)
4. Excessive weight, size (affects mobility)
6. Excessive noise (signature and human factors (HF))
6. Excessive maintenance and logistics
7. Mismatch between weapon and sensors
8. Insufficient capability to understand target intent, with the case being delay, deny access or immobilize target (in the non-lethal sense) at long enough range. (Use-of-force concept as applied at long range). Target can be personnel or material
9 Lack of multiple effects in a single platform
10. Excessive contamination
11. Mismatch between ammunition and researched effects
12. Lack of seamless transition (from short to long range)
13. Mismatch between weapon and sensing capability (e.g. range differential, for identification vs. engagement)
14. Time to engage

The deficiencies were clustered around weight, human factors, system integration, incapacitation effectiveness and material/system properties. Improvements in all areas are required.

6.3 Weapons Effects Vision 2025

The SSTRM vision of the weapons effects technical domain in 2025 is **an effective, portable and integrated weapons system platform for the soldier and the section which provides scalable lethal and non-lethal effects, against a variety of targets at the desired range/conditions (night and day, all weather) while minimizing system physiological and cognitive burden.**

6.4 Overall System Goals (2015–2020, 2020–2025)

In order to achieve the capability vision, near-term and far-term goals have been identified. While the near-term (2015–2020) goals can be categorized as incremental improvements on existing systems, the far-term (2020–2025) goals are characterized as revolutionary.

The goal for the 2015–2020 timeframe is a weapon system that permits soldiers to accurately detect and identify enemy targets, accurately engage and effectively neutralize enemy targets (lethal—immediate incapacitation and non-lethal reversible incapacitation) with a minimum of ammunition. The weapon, ammunition and WM-SATS shall be lighter in weight and bulk to improve soldier mobility. The weapons system shall reduce the soldier training and skills retention burden.

The goal for the 2020–2025 timeframe is to provide a weapon system that includes an advanced fire control system (AFCS), which will help the soldier in significantly enhancing target detection, recognition and Identification. And in order to compensate for the operator deficiencies, the AFCS will also provide for enhanced tracking and ultimately assist in target engagement. The system shall permit the exchange of target information with other soldier systems and sensors. The weapon system shall be significantly lighter in weight and optimized for operator performance at all ranges. The system will be able to deliver effects tailored to the target (managed lethality weapons system concept). The system will possess embedded training features to facilitate operator training. Future ammunition shall be tuneable to provide a capability in lethality. The overall system goals are outlined in Table 6-1.

Table 6-1: Overall Weapons Effects Technical Domain Goals

2015–2020 (Incremental Improvement)	2020–2025 (Revolutionary Change/Improvement)
Enhanced target detection by the use of emerging sensors	Significantly enhanced target detection by the use of fused sensors, links to soldier systems sensors, e.g. Unattended Air Vehicles (UAVs), automatic target detection, automatic target recognition and automatic target tracking sub-systems
Improved accuracy by the incorporation of miniaturized sensors, laser range finders, sight, etc.	Significantly improved accuracy via the use of operator feedback systems, semi-automatic engagement systems, etc., (e.g. integrated fire control systems)
Enhanced lethal and non-lethal target effects	Tuneable effect system
Reduction in system weight, improved soldier mobility	Significant reduction in system weight with improved performance
Improved training (reduced training burden) (skill acquisition and retention)	Built-in feedback and training system

6.5 Technical Domain Specific Drivers

Twenty technology drivers in this technical domain were identified. Eleven of the drivers were common across the SSTRM technical domains. Detailed below are the nine unique drivers in this technical domain. ROE and collateral effects have been grouped as one driver due to commonality of theme. The drivers/constraints included the following (see Chapter 6, Annex B for a full description):

- Spectrum of capabilities required
- Variable engagement distances
- Operator in the loop
- Rules of engagement/minimize collateral effects
- Target effects (enemy protection)
- State of knowledge
- Durability
- Modularity

The three Weapons Effects domain themes will be summarized below and discussed in greater detail in Annexes C, D and E.

6.6 Theme 5: Weapons Platform (Launching System)

6.6.1 Scope

The weapons platform is the electro-mechanical device used as an anti-personnel device for combat and self-defence as well as a pointing device for surveillance and includes the power, the data and mechanical or attachment (rail) interfaces. The weapons platform may include a rifle subsystem, fragmentation subsystem and non-lethal subsystem. The ammunitions and WM-SATS (including the Fire Control System (FCS)), including various sensors and illuminators, are covered in Theme 2 and Theme 3 respectively. Anti-material systems such as mortars and anti-tank weapons are not part of this scope.

6.6.2 Objective

The objective of this theme is to develop a portable and integrated weapons system for the soldier and the section, which will increase weapon effectiveness, provide scalable lethal and non-lethal effects against a variety of targets (e.g. protected and unprotected personnel, material) at the desired range, in the different conditions (night & day) while minimizing system physiological and cognitive burden.

6.6.3 Related Challenges and Requirements

Nineteen key performance parameters to be improved were identified. The challenges were clustered around four broad deficiency groupings: operator limitations, weight, power, integrated non-lethal capabilities, and improved performance. For a full list of the critical challenges see Table C-1 of Annex C to this chapter, which provides mid-term (2015–2020) and long-term (2020–2025) performance targets.

Key Mid-term Challenges and Requirements:
- 25 percent reduction in integrated platform weight;
- Identification and quantification of all operator induced errors;
- 100 percent improvement in accuracy (bursting and conventional);
- 30db reduction in noise signature;
- Improved non-lethal capabilities.

Key Long-term Challenges and Requirements:
- 50 percent reduction in integrated platform weight;
- Built-in training;
- Compensation for operator induced errors;
- 100 percent increase in effective range and 200 percent improvement in accuracy;
- Integrated lethal and non-lethal effects.

6.6.4 Enabling and Emerging Technologies

Seventeen enabling and emerging technologies that could address a number of specific deficiencies in the Weapon Platform theme were identified. These potential solutions are detailed in Table C-2 of Annex C to this chapter.

Based on this review, emerging near-term solutions to fill the performance gaps in the Weapons Platform theme were relatively limited. Potential technologies that may provide near-term solutions to the performance gaps include:

- Programmable airburst fragmentation ammunition;
- Case-telescoped weapons (Lightweight Small Arms Technologies Light Machine Gun (LSAT LMG));
- Modular bull-pup and conventional weapons;
- Less-than-lethal systems.

A large number of revolutionary technologies were identified that may resolve deficiencies in the weapons launcher area. The majority of these technologies revolve around the processes and applications of nano-technology. Nano-materials include carbon-based nano-materials, nano-composites, nano-ceramics, nano-coatings, etc. Nanotechnology has the promise of customizing and reducing weapon weight, providing improved durability, reduced fouling, etc. Research suggests that caseless ammunitions could provide significant weight reductions. Potential far-term weapon launcher solutions to the performance gaps include:

- carbon-based nano-materials (e.g. particles and carbon nano-tubes) for improved strength, electrical energy storage, insulation, semiconducting and conducting properties;
- nano-fibres and nano-fibrils for improved fabric strength, polymer reinforcement and lighter materials;
- nano-ceramics for improved abrasion resistance and chemical protection;
- nano-coatings for lubrication and reduced fouling;
- composite over-wrapped barrels for weight reduction;
- integrated sound suppressors;
- caseless ammunitions; and
- extended range electro-stun weapons.

6.6.5 Proposed R&D Focus Areas

Eighteen potential R&D focus areas were identified. These R&D needs and opportunities could address generic weapon launcher deficiencies (e.g. human factors) as well as specific sub-system needs (e.g. improved barrel materials). These identify R&D needs and opportunities that cluster around the following areas:

- Weight reduction
- Advanced material properties
- Improved integration and design
- Human system integration
- Non-lethal technology

A detailed list of R&D needs and opportunities is available in Table C-3 of Annex C to Chapter 6.

6.7 Theme 6: Ammunition (Lethal and Non-Lethal)

6.7.1 Scope

The ammunition system is the term applied to munitions delivered by the weapons system. Ammunition types include, but are not limited to, high-velocity projectiles (e.g. 5.56mm bullets), low-velocity non-lethal projectiles, and fragmenting ammunition, as well as non-kinetic, non-lethal munitions such as conductive energy devices, chemicals (e.g. odorants and calmatives), electromagnetic technologies (e.g. High Power Microwave (HPM), lasers) and acoustics.

6.7.2 Objective

The objective of the Ammunition theme is to improve the incapacitation effects of weapons systems at all engagement ranges. The Canadian soldier needs ammunition with the following qualities:

- Manages lethality, i.e. tunes terminal effects from lethal to non-lethal effects;
- Reduces weight and volume, (but provides similar performance);
- Provides robust and reliable case-less and case-telescoping ammunition (required for future advanced weapons);
- Offers extended-range non-lethal ammunition that allows the soldier to effectively and safely neutralize combatants without resorting to deadly force;
- Provides quantifiable physiological and psychological effects of all potential lethal and non-lethal ammunition and response devices to permit effective options analysis for future acquisition.

6.7.3 Related Challenges and Requirements

Twenty-one key performance parameters to be improved were identified. They pointed to deficiencies that were clustered around improving the technical performance of conventional ammunition (reducing weight and bulk; improving accuracy, range and incapacitation effects; providing programmable bursting munitions) and improving non-lethal ammunition. A total of 10 high priority ammunition deficiencies were identified. For a full list of the critical challenges see Table D-1 of Annex D to Chapter 6.

Key Mid-term Challenges and Requirements:

- Quantification of non-lethal ammunition effectiveness
- Increased behind-barrier effectiveness (kinetic and air bursting)
- Programmable bursting ammunition
- Improved lethal and non-lethal effects
- Reduction in ammunition bulk and weight
- Reduced environmental footprint

Key Long-term Challenges and Requirements:

- Tuneable effect ammunition
- Significant improvement in ammunition incapacitation effects
- Significantly improved effective range
- Guided ammunition

6.7.4 Enabling and Emerging Technologies

Twenty-one emerging technologies have been identified as applicable to the Ammunition theme.

Based on this review, a number of emerging near-term solutions to gaps in the ammunition theme were identified. A number of the proposed technologies and processes identified in the workshop have already been evaluated by other forces (e.g. 25 and 40mm air bursting fragmentation rounds, case-telescoped ammunition). Potential technologies that may provide near-term solutions to the performance gaps include:

- Case-telescoped ammunition;
- Lighter weight case materials (stainless steel);
- Intermediate calibre rounds (6.5 and 6.8mm);
- Frangible rounds, blind-to-barrier ammunition;
- Short-range training ammunition;
- Programmable, air bursting ammunition; and
- Improved range non-lethal ammunition.

A small number of revolutionary technologies were identified that may resolve deficiencies in the conventional ammunition area. These technologies include caseless ammunition, micro-electromechanical systems for guided munitions, novel propellants, novel propellant igniter electronics/approaches (e.g. laser), etc. Development of revolutionary non-lethal technologies/devices was not identified. Potential far-term technology solutions to the performance gaps include:

- Plastic and aluminum-based cases for case-telescoped ammunition;
- Novel igniter electronics;
- Improved trace;
- Programmable fragmentation weapons;
- Miniature killer drones.

6.7.5 Proposed R&D Focus Areas

Seventeen proposed R&D focus areas were identified and are clustered around the following areas:

- Cased ammunition
- Case-telescoped ammunition
- Case-less ammunition
- Improved understanding of incapacitation effects
- Programmable bursting ammunition
- Non-lethal technologies

A detailed list of R&D needs and opportunities is available in Table D-3 of Annex D to Chapter 6.

6.8 Theme 7: Weapon-Mounted Situational Awareness and Targeting Suite

6.8.1 Scope

For the purposes of this discussion, the Weapon-Mounted Situational Awareness and Targeting Suite is the electro-mechanical device used to accurately aim a weapon for target engagement and point for surveillance, target designation and battle management purposes. Fire control systems include a suite of sensors to accurately detect targets, determine ranges and 3-D (three dimensional) coordinates, compute firing solutions, etc. These fire control systems also include data links to associated soldier systems and the mounting interfaces to the weapon. It should be noted that the sensors integral to the WM-SATS are discussed under the Sensing technical domain (Weapon Sensors theme).

6.8.2 Objective

The Canadian soldier needs to be able to accurately engage point and area targets using a common WM-SATS. The WM-SATS shall possess the following characteristics:

- Weapon-independent device capable of providing ballistic and surveillance solutions for all section and platoon weapons.
- Integrated miniature laser range finder, GPS, directional heading, inclination, rotational sensor, fused sensor, accelerometer, etc.
- Compact lightweight form factor.
- Seamless transition from close quarters to far target engagements.
- Enhanced sensors to allow effective target engagements at all ranges and in all lighting conditions.
- Significantly improved operator accuracy against moving targets, partially exposed targets and those in defilade.
- Integration with the digital soldier system allowing the engagement and hand-off/share of non-line-of-sight targets and improved through-sight situational awareness.
- Semi-autonomous target detection, identification and engagement.

6.8.3 Related Challenges and Requirements

Seventeen key performance parameters to be improved were identified. The deficiencies were clustered around weight reduction, improved accuracy, integration and improved sensing. A total of 14 high priorities were identified by the Weapons Effects TSC. For a full list of the critical challenges see Table E-1 of Annex E to Chapter 9.

Key Mid-term Challenges and Requirements:

- Increased accuracy at all ranges
- Integration with the soldier system
- Reduced weight and bulk of WM-SATS
- Improved target detection sensors
- Ballistic computation for bursting munitions
- Programmable bursting ammunition

Key Long-term Challenges and Requirements:

- 50 percent reduction in WM-SATS weight and bulk
- Integrated with fully fused electro-optical (EO) and other type of sensors
- Semi-autonomous target detection, identification and engagement capability
- Integrated weapon orientation and target localization with soldier systems suite
- Automatic boresight: Zeroing automatically the weapon to shoot

6.8.4 Enabling and Emerging Technologies

Twenty-one emerging technologies that could provide improvements in the Weapon-Mounted Situational Awareness and Targeting Suite theme were identified. These solutions have the potential to close the observed gaps and are detailed in Table E-2 of Annex E to Chapter 9.

Based on this review, a number of emerging near-term solutions to gaps in the WM-SATS theme were identified. A number of the proposed technologies and processes identified in the workshop have already been evaluated by other forces (e.g. advanced electro-optical sensors, miniature laser range finders). Potential technologies that may provide near-term solutions to the performance gaps include:

- high density pixel sensors (pixel pitch <25 microns);
- short Wave Infra Red (SWIR) sensors;
- high resolution displays;
- miniature laser finders;
- integrated fire control systems; and
- dual role optic sights.

A small number of revolutionary technologies were identified that may resolve deficiencies in the WM-SATS area. Potential far-term technology solutions to the performance gaps include:

- multiband sensors;
- novel detector materials;
- micropore multi-channel plates;
- miniaturized sensors;
- chip-level automatic target detection, recognition and identification capabilities; and
- assisted target engagement.

6.8.5 Proposed R&D Focus Areas

Eighteen proposed R&D focus areas were identified and are clustered around the following areas:

- Requirements definition
- Human system integration
- Battlefield management system integration
- Assisted engagement and decision support
- Integration
- Sensors

A detailed list of R&D needs and opportunities is available in Table E-3 of Annex E to Chapter 6.

Annex A: Weapons Effects Deficiencies

Table A-1: Weapons Effects Deficiencies

RANK (High/Medium/Low)	Theme 5: Weapons Platform (Launching System)	Theme 6: Ammunition (Lethal and Non-Lethal)	Theme 7: Weapon-Mounted Situational Awareness and Targeting Suite
High	Human system integration		
High	Training burden and limitations (insufficient realism)		
Medium	Usage burden		
High	Variable accuracy – Human error budget (stress, tiredness, weapon handling, etc.)		
High	Excessive weight, size (affects mobility)	N/A	N/A
Medium	Integration – insufficient balance and stability (Ergonomics)	N/A	N/A
High	Excessive noise (signature and HF)	N/A	N/A
High	Excessive maintenance	N/A	N/A
High	Excessive logistics	N/A	N/A
Low	Insufficient breaching round	N/A	N/A

RANK (High/Medium/Low)	Theme 5: Weapons Platform (Launching System)	Theme 6: Ammunition (Lethal and Non-Lethal)	Theme 7: Weapon-Mounted Situational Awareness and Targeting Suite
High	Mismatch between weapon and sensors	N/A	N/A
Low	Usability and commonality on all the weapon, for example firearm safety catch (see NATO RTO)	N/A	N/A
Medium	Lack of interoperability	N/A	N/A
Medium	Unable to use weapon system and ammo at all levels of escalation and de-escalation of force purposes (force proportional to the target resistance) (use of force concept)		
High	Insufficient capability to verify target intent, delay, deny access or immobilize target (in the non-lethal sense) at long enough range. (Use of force concept as to be applied at range) Target can be personnel or material		
Medium	Unable to tailor effects on the target (either personnel or material) in terms of volume affected, time of onset of effects, duration of effects, and amplitude of effects on a variety of targets (managed lethality)		
Medium	Lack of integration		Lack of integration of power and data (battery change, info exploitation etc.)
High	Lack of multiple effect in a single platform		N/A
Medium	N/A	Excessive weight and volume, awareness of the state of ammunition	N/A
Medium	N/A	Insufficient effects, i.e.: capability to defeat targets (unprotected, protected and behind barriers, breaching)	N/A
Low	N/A	Insufficient effect measurement	N/A
High	N/A	Excessive contamination	N/A
Low	N/A	Insufficient door/gate breaching round	N/A
High	N/A	Mismatch between ammo and desired effects	N/A
Low	N/A	Ergonomics – Bullet counts, magazine reload, weapon reload	N/A
Medium	N/A	Ammunition: Flight stability, flight time, flight path, etc.	N/A
Medium	N/A	Inadequate incapacitation (variable performance), over the range (defilade behind barriers)	N/A
Medium		Insufficient capability to immediately neutralize or incapacitate targets without causing permanent injury, death or gross physical destruction	N/A
High	N/A	N/A	Lack of seamless transition (from short to long range)
Medium	N/A	N/A	Excessive power demand
Medium	N/A	N/A	No link with network (lack of target hand-off/share)

RANK (High/Medium/Low)	Theme 5: Weapons Platform (Launching System)	Theme 6: Ammunition (Lethal and Non-Lethal)	Theme 7: Weapon-Mounted Situational Awareness and Targeting Suite
High	N/A	N/A	Mismatch between weapon and sensing capability (i.e.: range differential, for identification vs. engagement)
Medium	N/A	N/A	Cognitive load to assemble all the data/information and turn it into awareness
Medium	N/A	N/A	Deficient target detection, recognition and identification under all conditions (night)
High	N/A	N/A	Time to engage

Annex B: Drivers

Table B-1: Weapons Effects Drivers/Constraints

Drivers/Constraints	Implications
Need a spectrum of capabilities	Need a system that provides immediate incapacitation with either irreversible effects (lethal) or reversible effects (non-lethal)
MOUT Operations, require very short, reactive engagements. Rural operations require longer range engagements > 400 m	Need to be able to incapacitate targets at a variety of ranges 0 to > 400 m. Need to be able to engage targets instinctively.
Operator in the loop	The operator is the biggest source of error in the current system. Training on the current system is excessive, future systems must reduce training burden.
Ergonomics	The operator is the limiting factor and better weapon design and improved interfaces will improve performance
State of knowledge	Research must be undertaken to quantify operator error and development of systems to compensate for errors. The efficacy of carbon-wrapped barrels, nano-coatings, caseless propellant mixes, novel materials etc. must be determined. Wounding capability, reversibility of effects and effectiveness of non-lethal systems must be determined in different environment against a variety of targets.
State of technology, disruptive technologies	Need higher resolution/resolving sensors in smaller, lighter and less bulky packages. LWIR, SWIR, NVD systems. The application of nanotechnology will improve weapon materials and designs.
Rules Of Engagement (ROEs), terminal effects – laws of war, civil use of force	Future systems must comply with the Hague, Geneva conventions etc.
Minimize collateral effects	Future systems must be highly accurate and provide the appropriate application of required effects
Weight	Reduce weight of system – note weight reductions in weapon and ammunition may be offset by weight increases in WM-SATS.
Bulk	Future systems must be smaller to optimize soldier mobility and weapon handling performance
Power (portable energy- temperature, weight)	Future weapon systems will require centralized power sources to operate the fire control and ammunition ignition system. Future power sources must have greater power density.
Robustness	Future weapon systems – launcher, ammunition and fire control systems must be robust to withstand operational handling
Cost	The future weapon system must not be cost prohibitive.

Drivers/Constraints	Implications
Environmental effects	Future ammunition, materials, manufacturing processes, etc. must not be environmentally hazardous
Target effect (enemy protection)	Future weapon systems must be capable of defeating protected and unprotected opponents (behind barriers and or while wearing ballistic protection)
Access to US technology	ITAR restriction may limit the use of US research, technology, etc. for Canadian projects
IP rights	Development of future weapon, ammunition and WM-SATS will require the proper management of IP rights
R&D capability in Canada (barrier)	Canada has limited R&D capabilities in this area
Integration in Soldier Systems	Future weapon systems must link through a soldier network for access to other sensors, IFF information, etc. Need a system to assess hand-off, data exchange, etc. Soldier systems could also provide centralized or auxiliary power, perform data computation, etc.
Modularity and interoperability	Future weapons systems must be modular and interoperable with a fleet of weapons and sensors. Systems must be interoperable with our allies.

Annex C: Theme 5: Weapons Platform (Launching System)

Annex C includes the following three tables:

- Table C-1: Challenges/Requirements
- Table C-2: Enabling/Emerging Technologies
- Table C-3: Proposed R&D Focus Areas

Table C-1: Challenges/Requirements

Challenges	Priority	Requirements	
		2015–2020 (Horizon 2)	2020–2025 (Horizon 3)
Shooter error sources identification	High	To quantify shooter error budget using instrumented weapons and target	Increase accuracy by compensating for shooter error
Improved accuracy under operational stress	High	+100% performance improvement in combat situation (average soldier)	+200% performance improvement in combat situation (average soldier)
Anxiety/fatigue coping (operator limitations)	Medium	Better understand poor shooting performance and the contribution of factors such as anxiety and fatigue	Compensate for /ameliorate anxiety/fatigue (whole body and localized) effects and poor shooting techniques (flinching, breathing, etc.)
Training optimization	High	Optimize the training tools and techniques ("train faster, retain longer")	Built-in training
Reduced weapons platform weight	High	Integration of accessories (reduced number, weight and power requirements) Improved materials (barrel/(sub)components - lighter weights) Improved modularity (reconfigurable for mission/tasks) -25% weight	Optimal integration of accessories Case-telescoped and caseless ammunition-based weapons -50% weight
Enhanced weapon balance	Medium	Optimized centre of gravity of the weapon (design)	Optimized centre of gravity of the weapon (design)
Distribution of power and data	Medium	Functional powered/data rail with remotely powered accessories	Fully networked weapon (with whole SS) (full stream video transmission - see C4I)

Challenges	Priority	Requirements	
		2015–2020 (Horizon 2)	2020–2025 (Horizon 3)
Reduced power weight and increased power use efficiency for an autonomy of 72 hrs	Medium	Increased power density, central/rechargeable power source for the weapon system, reduced power weight -50% power usage	Continuous improvement of efficiency and reduction of weight -75% power usage (see Power/Energy and Sustainability)
Improved weapon design (ergonomics)	Low	Improved weapon design for balance, ergonomics, controls, displays	Fully optimized weapon balance, ergonomics, controls, displays
Reduced failure and mainte-nance	Low	Improved materials (barrel/(sub) components - lighter weights) (coating)	Embedded logistic and system monitoring sensors
Integrated lethal and non-lethal system (variable effects) on the assault rifle	Medium	Modular	Fully integrated non-lethal capability into the weapon system (e.g. one platform, many barrels)
Shooting performance at extended ranges (assault rifle, kinetic)	Medium	Range 0 to 400 m (lethal) Range 0 to 100 m (non-lethal)	Range 0 to 800 m (lethal) Range 0 to 200 m (non-lethal)
Improved non direct line-of-sight fragmentation weapon system performance (airburst dismounted capability)	High	+100% improved accuracy and range against targets in open (15 m x 2.5 m)	+200% improved accuracy and range against targets behind walls, behind corners, in trench (7.5 m x 1.25 m), windows, etc.
Stand-alone non-lethal system performance	Medium	Immediately (within 1 sec) disable target at range from 0-100 m. The effect must be reversible.	Immediately (within 1 sec) disable target at range from 0–500 m. The effect must be reversible.
Reduced felt recoil for fragmentation and sniper platform	Medium	Mitigate recoil effect	Manage
Increased accuracy for fire in automatic mode due to recoil management	Medium	To quantify and assess for better understanding of the parameters	Reduction 80% in dispersion for five rounds burst
Increased firing rate of fragmentation rounds	Medium		Semi-automatic fire of at least three rounds
Reduced noise level and signature	High	-30 dB reduction Modular suppressors	No hearing damage due to weapon Fully integrated suppressors for automatic rifles
Reduced flash signature (all weapons)	Medium	N/A	Invisible to future C4I suite

Table C-2: Enabling/Emerging Technologies

Technology	TRL (1–9)	Year for TRL 7	Strength (S)/Weakness (W)	Critical Barriers/Gaps	TSC Recommended Action
Nanocoating and nanolubricants for barrels and mechanism components	4–7	2012	S: Reduced friction (bullet and mechanism), reduced fouling, replace toxic chrome coatings W: Increased manufacturing complexity and capital equipment expense	• Coating process that provides good bonding and uniform thickness characteristics to small diameter (5.56mm) barrels • These are multi-application type technologies where industrial development has not centred on small arms (SIPES and Small Arms SOR Development Program)	Leverage/invest
Composite overwrapped barrel	4–7	2016	S: Lighter weapon platform W: Potential fragility to impact loading	• Need to attain high heat transfer rates, melting of the resin for high rates of fire. Determine how to apply phosphate (or other alternative) protective finish Colt Canada –under development & test) • Composite materials offer a wide choice of materials and the ability to tailor the mechanical properties to suit the mechanical and heat loading on the barrel	Assess/leverage
Super alloys	3	2015	S: Increased strength, weapon weight reduction & possibly eliminate hard chrome requirement W: Limited potential in terms of weight reduction	• Low volume material production, high material cost, compensate for work hardening during deep hole drilling and need to prove forgeability quality. Colt Canada – evaluate several candidate materials for barrels • Industrial applications will drive the development of new super alloys. New materials can be evaluated as they come available on the market.	Monitor/assess
Integral suppressed weapon barrel: Innovation Plus	5	2012	S: Reduction of hearing loss, alternate operational approach to suppression W: Velocity loss, weight, fouling	• USMC is looking at this technology (SIPES and Small Arms SOR Development Program)	Assess/leverage
Power cell (see Power/ Energy and Sustainability)	4–5	Level 1: 2011 Level 2: 2016	W: Can become chemically inert in cold weather operation, cannot be charged in cold weather operation, battery density needs to be increased to reduce size/weight and improve operational endurance	• Level 1 – Operate in minus 32ºC environment • Level 2 – Operate in minus 54ºC environment to match weapon requirement • Desire 6 hour operation at 5 watt continuous load • DND/Colt Canada & NATO are reviewing this technology for small arms power rails and data systems	Monitor/assess

Technology	TRL (1–9)	Year for TRL 7	Strength (S)/Weakness (W)	Critical Barriers/Gaps	TSC Recommended Action
Man portable rail or coil gun	3	2018	S: Potential for tailored lethality (variable muzzle energies), high muzzle velocities for lethal applications W: Power requirement	• Generation or transportation of lightweight electrical power • There is a need to fully understand the potential of this technology. Insufficient open literature information exists	Invest
Modular bullpup rifles: e.g. FN 2000, ST Kinetics SAR 21, Daewoo K11	9	2010	S: SOTA bullpup with under slung grenade launcher W: Modular system and not integrated	• No significant technical barriers, rather troop acceptance and training are potential barriers given the unusual placement of magazine • State of the art bullpup designs	Assess
Airburst launchers: e.g. H&K XM25, Daewoo K11, Denel Neopup, IMI MPRS, ST Kinetics LV ABMS	7-9	2010	S: Useful against targets in defilade, 20 and 25 mm versions have increased range and accuracy W: High recoil for 20 and 25 mm version	• Ranging accuracy, optimizing calibre for effectiveness, managing felt recoil • Significantly mature variations of this technology exists (SIPES and Small Arms SOR Development Program)	Assess/invest
Dual calibre air-burst weapon: e.g. Daewoo K11, H&K XM29	7-9	2010	S: Combined air-bursting and 5.56 capability W: Weight	• Weight is a significant issue that can only be overcome by a change in paradigm (i.e. stacked rounds à la Metal Storm) • Technology exists that will provide contextualization, but not an ultimate solution to the challenges (SIPES and Small Arms SOR Development Program)	Assess/invest
Cased-telescope weapons (LSAT LMG (IAR))	7	2011	S: Significantly reduced weapon system weight W: Non legacy ammunition form requiring new mechanism	• Requires final development of ammunition • Significant investment by US LSAT program	Monitor
Cased telescope (LSAT AR)	5	2011	S: Significantly reduced weapon system weight W: Non legacy ammunition form requiring new mechanism	• Requires final development of ammunition • The US version does not take advantage of electronic ignition technologies (SIPES and Small Arms SOR Development Program)	Leverage
Caseless LMG (LSAT (IAR))	5	2011	S: Significantly reduced weapon system weight W: Non legacy ammunition form requiring new mechanism, mechanism sealing, cook-off	• Chamber sealing, thermal management • Significant investment by US LSAT program	Monitor
Caseless (LSAT AR)	3	2012	S: Significantly reduced weapon system weight W: Non legacy ammunition form requiring new mechanism, mechanism sealing, cook-off	• Chamber sealing, thermal management • US development is concentrated on ammunition. No work is presently being done on the AR (small arms)	Leverage

Technology	TRL (1–9)	Year for TRL 7	Strength (S)/Weakness (W)	Critical Barriers/Gaps	TSC Recommended Action
Visual warning (e.g. Laser Dazzler)	9	2011	S: Effective W: Risk of permanent eye damage	• The technology is very effective; however, some commercial systems are still too heavy. Research is needed to miniaturize and do better power management • This system could be improved by merging many functions: optical sight, laser designation, laser target marker, range finding and visual warning. A multi-functional laser system would be low TRL (3–4)	Assess
Laser guidance high voltage discharge	3	2020		• Low TRL • Effectiveness/weight ratio • First large-scale demo FY11–12	Invest
High Power Weapon (HPW)	9	2011	S: Effective against vehicle W: Heavy and bulky	• Optimize efficiency of system, miniaturize existing systems • Current system can be mounted at the back of a vehicle and are said to be effective	Invest
Electric incapacitation device	7	2011	S: Reversible incapacitation W: Energy demands, size, bulk, range	• Range to be increased • Power source • To be used as an electro muscular incapacitation device or for vehicle stopping	Monitor

Table C-3: Proposed R&D Focus Areas

R&D Focus Areas	Scope/Description (Needs and Opportunities)	Priority Order (1, 2, 3)
Weight reduction	Case-telescoped electronic ammunition weapons • New feeding and extraction mechanism, weapon electronic architecture Caseless ammunition weapons • New mechanism, sealing (new breach design), thermal management (cook-off), feeding and extraction (unfired) Optimization (applied to all Weapons Effects themes) • Overall system optimization (includes calibre, bullet nature, pressure profile, etc.)	2
Advanced material development	Advanced material studies • Define the performance parameters directed towards replacing current materials with new commercially available materials in assault weapons • Define the parameters for advanced coatings and their processing technologies for assault rifle component performance. Assess potential material and coating technologies from the perspective of reduced weight and friction and improved thermal resistance and fatigue life	2

R&D Focus Areas	Scope/Description (Needs and Opportunities)	Priority Order (1, 2, 3)
Improved integration and design	Electronically initiated primers • Electrode design and interface with the ammunition Electronic ignition • Provide capability for the firing of rounds based on an electronic impulse from the ATC/ATE system. Main options include electromechanical mechanism combined with percussion primer rounds and fully electronic system, requiring an electronically initiated primer on the part of the ammunition and an electronic ignition system on the weapon. Various primer options need to be explored including traditional type bridge wire to semi-conductor circuits. The main challenge is to ensure protection against EMC/EMP type events, resulting in either unwanted discharge or destruction of the weapon ignition circuit. Electrode design and interface with the ammunition. Power/data rail • Integration with Soldier Systems/C4I/WM-SATS, interface with accessories Improved integrated weapon design • Optimize weapon effectiveness, weight and balance • Alternative calibre • Novel materials – Overwrapped barrels – Super alloys – Coatings, etc. – Ceramic coatings – barrel/mechanism – Nano coatings • Technologies – Recoil/recoil management – Suppressors • Configurations – Conventional – Bullpup Improved accuracy (see Human and System Integration) • Rate of fire management for accuracy Better ergonomics/compatibility/human factors in weapon design • Investigate design requirements and novel weapon design concepts for the physical design of the weapon, alternative means and methods of supporting and stabilizing the weapon, and the design and integration of control interfaces for weapon function, communications, weapon-borne ancillary devices, and a future computerized soldier system Optimize muzzle velocity for weapon length • Identify optimum barrel length Combat electrical power demand modeling (links to Power/Energy and Sustainability) • Parametric analysis of future capabilities • Examine the system power demands and estimate the contribution such power consumption provides toward mission success • Estimation of systemic power demands (based on device profiles) to develop optimized power delivery systems in light of the desired outcomes	1

R&D Focus Areas	Scope/Description (Needs and Opportunities)	Priority Order (1, 2, 3)
Improved integration and design	Weapon system dynamic analysis • Increase understanding of the weapon physics processes in small arms weapons systems as a risk reduction task • Characterize the strengths and weaknesses of a representative set of existing weapons to serve as a reference data set • Assess potential new weapons concepts from the perspective of constraints imposed by weight, configuration and dynamic process Laser technologies • Increase knowledge of feasibility of having an all integrated, multi-functional laser device (LRF, designator, IFF) for small arms and a portable flash laser capability for multiple targeting • Review various state-of-the-art laser range finders, laser target designators and laser-RF based IFF technologies, while focusing on the laser source, optics, and electronics and determining if it is feasible to integrate the three capabilities into a single device for small arms • Determine if a portable unit using flash laser technology can be realized for small arms leading to multiple targeting capabilities	1
Non-lethal technologies	Non-lethal (scalable lethality). Investigate compliance and incapacitation technologies • Directed Energy Weapon – Investigate acoustic devices to warn, disrupt communications, annoy target – Understand effects on human beings, increase effective range of current devices – HPW: better understand how to disrupt electronic material, investigate effects on humans – Blunt impact devices: Maximize pain level while reduce injurious and lethal effects • Constant Energy Weapon (at target) – Investigate launcher with variable velocity at muzzle • Variable air pressure • Partial ignition of cartridge and electronic ignition • Variable size vent in breach/barrel • Variable barrel length – Fire control system to determine range and adjust projectile velocity • Improved Dazzler – Technology watch and continuous investigation of dazzler technology – Going beyond Dazzler: investigate other capabilities of lasers (heating, breaking windows, etc.) • Calmatives – Review effects of current calmatives and design new molecules so that they can be safe in small and large doses – Safe dose-response curve development • Psychological response of target to non-lethal technologies: Individual and group • Modeling of non-lethal technologies with groups/individuals • Integration of technologies on platform	3

R&D Focus Areas	Scope/Description (Needs and Opportunities)	Priority Order (1, 2, 3)
Human system integration	Better ergonomics/compatibility/physical design aspects • Investigate the effect of weapon weight, bulk, balance, and length on soldier mobility, access to confined spaces, and target engagement performance • Determine the extent to which different points of support and stabilization contribute to shooting error and target engagement performance • Assess/develop novel support/stabilization designs Investigate the design, placement, and orientation of controls on the weapon Weapon system recoil, thermal management and signature analysis • Increase understanding of the weapon physics processes in small arms weapons systems as a risk reduction task • Characterize the strengths and weaknesses of a representative set of existing weapons to serve as a reference data set Assess potential new weapons concepts from the perspective of constraints imposed by weight, configuration, recoil, thermal management, and signature Human accuracy (see Human and System Integration) • Increase understanding and knowledge of the factors affecting shooting performance from a rifleman's perspective • Develop error budgets for static and dynamic (shooting on the move) rifleman performance at distant and close-in targets Human Factors of Armed Combat • Increase understanding and knowledge of the human factors affecting performance in armed combat • Build knowledge about what is required for shooters to fully engage human targets, what the current situation is, and how performance can best be optimized either through the provision of training or technological supports Lessons Learned • Collect, analyze and understand the lessons learned based on the most recent conflict in Afghanistan – SAM, SWA and NGSA should be included Training Modernization • Increase understanding and knowledge of the effectiveness of current small arms training systems • Use the strengths and weaknesses of in-service methods to guide the development and testing of alternative training programs and new training support tools • Investigate the utility of using embedded training systems; shooter feedback system etc. • Explore factors affecting skill acquisition, required degree of over-learning, required skill elements, methods of testing for initial learning and retention, conditions of retrieval, instructional strategies and training methods as well as individual differences	1

Annex D: Theme 6: Ammunition (Lethal and Non-Lethal)

Annex D includes the following tables:

- Table D-1: Challenges/Requirements
- Table D-2: Enabling/Emerging Technologies
- Table D-3: Proposed R&D Focus Areas

Table D-1: Challenges/Requirements

Challenges	Priority	Requirements	
		2015–2020 (Horizon 2)	2020–2025 (Horizon 3)
Tunable effects from non-lethal to lethal	Medium	One weapon with ammo for non-lethal and ammo for lethal Integration of a suite on non-lethal technologies on one platform	One weapon with one ammo for lethal and non-lethal Selectable (scalable) lethality, physiological/psychological effects
Reduced bulk (length)	High	-10%	-25%
Increased lethal effective range – assault rifle	Low	Range 0 to 800 m (lethal effects)	Range 0 to 1000 m (lethal effects)
Increased lethal effective range – sniper rifle	Low	Range 0 to 2000 m (lethal effects)	Range 0 to 2500 m (lethal effects)
Increased lethal effective range – fragmentation grenade (low-medium velocity)	Low	Range 0 to 800 m	Range 0 to 1000 m
Increased lethal effective range – Personal defence weapon (includes pistol)	Low	Range 0 to 150 m (lethal effects)	Range 0 to 150 m (lethal effects)
Increased non-lethal weapon effective range	Medium	Range 0 to 100 m (non-lethal incapacitation)	Range 0 to 500 m (non-lethal incapacitation)
Increased incapacitation - unprotected targets	High	+25% in incapacitation	+50% in incapacitation
Enhanced penetration against protected targets	Medium	3.5 mm thick steel plate at 800 m Ceramic (NIJ3) plate at 800 m	3.5 mm thick steel plate at 1000 m Ceramic (NIJ3) plate at 1000 m
Increased behind barrier effectiveness (kinetic)	High	Effective behind automotive front wind screen	Effective behind automotive front wind screen
Increased behind barrier effectiveness (airbursting, fragmenting)	High	Effective when target is behind wall (mud brick – 30 cm)	Effective when target is inside a building (through door/window, behind a corner)
More accurate (guided) ammo	Low	40 mm	12.7 mm
Increased lethal radius	Medium	80% probability of incapacitation within 8m radius while minimizing danger beyond lethal radius	95% probability of incapacitation within 8 m radius while minimizing danger beyond lethal radius
Improved lethal and non-lethal effects	High	Better understanding of the physiological and psychological effects of lethal and non-lethal ammunition, electro-shock devices, etc.	Optimized non-lethal effects
Reduce environmental impact (footprint) and lifecycle cost (range cleaning)	High	Reduced impact, negligible cost increase	Fully green and cost-neutral

Challenges	Priority	Requirements	
		2015–2020 (Horizon 2)	2020–2025 (Horizon 3)
Improved training ammunition – same ballistic profile over short ranges (frangible)	Medium	+50% reduction in danger zone	+75% reduction in danger zone
IR and low temperature tracers	Low	100°C	20°C
Breaching capability (e.g. door, wall)	Low	Better understand the requirements	Identify/develop solutions
Programmable ammunition (i.e. airburst, tunable)	High	Acquire knowledge on programmable ammunition (study)	Identify/develop solutions
Guided ammunition	Medium	Acquire knowledge on guided ammunition (study)	Identify/develop solutions
Suicide micro-UAVs (expendable UAVs with 40 mm war heads)	Medium	Acquire knowledge on efficacy of semi-autonomous/autonomous miniature killer drones	Identify/develop solutions

Table D-2: Enabling/Emerging Technologies

Technology	TRL (1–9)	Year for TRL 7	Strength (S)/Weakness (W)	Critical Barriers/Gaps	TSC Recommended Action
Case-telescoped ammo	7	2010	S: Reduced weight and volume W: Robustness	• Co-development of M249-like for ammunition testing • Significant work is already being done in the US (SIPES)	Leverage
Caseless ammo	4	2013	S: Reduced weight and volume W: Cook-off, system conversion/ replacement cost	• Robustness of chamber sealing mechanism and ammunition • Significant work is already being done in the US (SIPES and Small Arms SOR Development Program)	Leverage
Novel propellants Green, low temperature coefficient, coextruded	5	2014	S: Elimination of toxic ingredients, higher muzzle velocity, less sensitive W: Cost	• Manufacturing process investment cost • Technology is under development	Monitor
Novel explosives, insensitive high explosives, green enhanced blast 3 types: melt pour, cast-cure, pressed thermo baric	7	2010	S: Less sensitive to unplanned stimuli, elimination of toxic ingredients W: Cost of ingredients, more difficult to initiate in smaller size	• Cost of application on thermo barics • Cost of large scale manufacturing of cast cure process • Technology already used in other systems • RIGHTRAC studies on green HE	Monitor/leverage
Micro-electromechanical systems (MEMS) for guided kinetic rounds	2	2038	S: Improved accuracy W: Cost	• Extreme firing environment (heat, acceleration, pressure) • Applied to guided ammo	Monitor

Technology	TRL (1–9)	Year for TRL 7	Strength (S)/Weakness (W)	Critical Barriers/Gaps	TSC Recommended Action
Case materials Lightweight plastic case (LSAT, PCP, BML/BEL)	5–7	2011	S: Reduced weight W: Reduced strength, potential extraction difficulties, increased cost	• Robustness in field use • Different versions of the technology exist in industry (SIPES and Small Arms SOR Development Program)	Leverage
Case materials Lightweight stainless steel program	7	2010	S: Reduced ammo weight W: Thermal management in the weapon	• 7.62 mm round is significantly more advanced than 5.56 mm round • Technology is being advanced by industry (Small Arms SOR Development Program)	Leverage
Case materials Lightweight aluminum case programs	5	2012	S: Reduced weight W: Strength during extraction, combustion of case	• Overcoming case combustion and extraction problems under all conditions • Least likely technology to succeed	Monitor
Igniters electronics	3–7	2015	S: Supports assisted target engagement capability, reduced mechanical weapon components W: Need energy source	• Potential EMC vulnerability resulting in unwanted initiation • EMP vulnerability resulting in total system failure • Determine the optimal technological solution • Significant work must be performed which is not being done elsewhere in the world (Small Arms SOR Development Program)	Invest
Intermediate rifle round (e.g. 6.5 mm Grendel and 6.8 mm Remington bullet programs)	7	2010	S: Reduction in ammo types at the section level, improved effect at close-in and far ranges W: Non-standard calibre	• Development of caseless/ case-telescoped versions • Commercially available rounds already exist (Small Arms SOR Development Program)	Leverage
Glowing tracer	4	2015	S: Prevent fire in the field, many possibilities for IR colour palette W: Limited shelf life to be determined, tracer visibility during day light questionable	• Will flash generated by propellant be sufficient to ignite the glowing tracer? Cost, manufacturing process • Will it be robust enough to sustain military environment?	Monitor
Frangible round	8–9	2012	S: Small safety template, no ricochet, used only for training because of treaties war law, legal issue. Suitable for training and possibly domestic operations W: Not penetrative enough	• Cost, manufacturing process • Different concepts already exist in different calibers • Could be adapted for specific requirements	Leverage

WEAPONS EFFECTS (LETHAL AND NON-LETHAL)

Technology	TRL (1–9)	Year for TRL 7	Strength (S)/Weakness (W)	Critical Barriers/Gaps	TSC Recommended Action
Short range training	7–9	2012	S: Reduce SDZ, less damaging to infrastructure, reduce life cycle cost W: Usually unit price is higher	• Cost, manufacturing process • Different concepts already exist in different calibers • Could be adapted for specific requirements	Leverage
Extended range ammunition (design, speed, etc.)	7–9	2011	S: Same projectile weight but longer range W: Terminal effects to be assessed	• Barrel wear, chamber pressure, barrel length • Low priority requirement	Monitor
Blind to barrier piercing rounds (material/bullet design)	7–9	2010	S: increased lethality in QCB scenarios W: Non-standard rounds	• Unclear, as the performance of existing rounds has not been established • Rounds exist, but their performance is not known (Small Arms SOR Development Program)	Assess
Improved door breaching munitions (improved shotgun shell, blast overpressure grenade)	9 (shotgun) 5 (grenade)	2010 2015	S: Efficient W: Cost	• Shotgun shell exists for this application • Development work is necessary for grenade • Not in service yet • Requirements/gaps to be validated	Monitor/assess
Air bursting fragmenting rounds of various calibers (20, 25, 40 mm) Programmable ammunition	6–9	2011	S: Increase in lethality against targets in defilade, smaller calibre (20 and 25 mm) provide longer range and improved precision W: Smaller calibre provides lower lethal radius requiring improved precision	• Range estimation technology • Rounds exist but their capability is presently unknown (Small Arms SOR Development Program)	Assess
Suicide micro UAVs (Lethal miniature aerial munitions system)	7	2015	S: Recon micro UAVs with sensors and can be converted to munitions, disposable W: UAV performance in urban canyons and in winds, operator workload	• US Program investing in command controlled drones acting as "smart" 40 mm munitions	Monitor

Table D-3: Proposed R&D Focus Areas

R&D Focus Areas	Scope/Description (Needs and Opportunities)	Priority Order (1, 2, 3)
Cased ammunition	System optimization • Overall system optimization (includes calibre, bullet nature, pressure profile, etc.) same as for weapon Ammunition optimization • Use novel explosives and propellants technology developed in large calibers to small calibers such as green and less sensitive explosives and propellants • Evaluate potential of increasing muzzle velocity using low temperature coefficient and coextruded propellant Experimental characterization of CF and MOTS rounds • Develop an understanding of external ballistic behaviour of kinetic rounds and its effect on terminal behaviour • Develop and validate a methodology for the experimental validation of the terminal ballistic performance of kinetic rounds • Experimentally characterize the terminal ballistic behaviour of CF (5.56, 7.62, .338 and .50) and COTS (M855A1, Mk 318, 6.5, 6.8) kinetic rounds Ammunition design parameters • Quantify the importance and effect of different design parameters on the terminal performance of small arms ammunition through theoretical/numerical analysis (bullet shape, materials, calibre, operating pressure, etc.) • Experimentally validate ratings with new ammunition designs Lightweight non-telescoped cased ammunition • Experimentally validate 5.56 stainless steel cartridge case Improved ammunitions (lethal) • Improved behind barriers and armour effect (glass, doorways, body armour) • Environmentally friendly (green) Sound suppressor compatible ammunition • Development of ammunition/propellant compatible with the sound suppressor for automatic weapons	1
Case-telescoped ammunition	Polymer cased non-telescoped ammunition • Use of experiments and modeling to develop a thorough understanding of the technology and issues related to polymer cased non-telescoped ammunition • Evaluate suitability for CF operational use and determine where it fits in the continuum of lightweight ammunition offerings Electronically initiated ammunition • Examination of existing electronically initiated systems and testing them for potential issues or problems and to determine their vulnerabilities. • Evaluation of new formulations and ignition systems to solve these issues	1
Caseless ammunition	Caseless and polymer cased telescoped ammunition Use of experiments and modeling to develop a thorough understanding of the technology and its issues related to caseless (CL) and polymer cased telescoped (CT) ammunition Bring caseless and polymer cased telescoped ammunition to a higher level of technological maturity. Novel calibers (i.e. 6.5 /6.8 mm) in CL and CT • High temperature ignition propellants • Varying primer ignition systems • Laser, bridge-wire, semi-conductor	2

R&D Focus Areas	Scope/Description (Needs and Opportunities)	Priority Order (1, 2, 3)
Improved understanding of incapacitation effects	Vulnerability/lethality modeling of lethal rounds • Modeling of current CF bullets such as 5.56, 7.62 mm, 0.338 and 50 calibre, shotguns and high/low velocity grenade launchers (40 mm or others) • Modeling of other bullet options (M855A1, MK318, 6.5 mm, 6.8 mm, etc.) • Predict vulnerability in the context of direct fire (bullets) or indirect fire (grenades, shotgun), accounting for both P[kill|hit] and dispersion (P[hit] or variations of point of explosion for grenades). Consider effects vs. different barriers. • Modeling of different targets including personnel in different postures and in different situations such as open field, entrenched, foxholes, partially masked by street corner or low wall, inside buildings, etc., and different levels of protected (unprotected – different body physiologies, and protected) • Assessment of fusing for air-burst lethality (complete range dispersions) Penetrating trauma model of lethal rounds • Implementation of the detailed 3-D Zygote Human Model for representation of various tissue types, locations, and geometry. Procure a realistic representation of the virtual man for accurate threat-human interaction. • Definition and modeling of internal representation of the human structures and tissue types, including body orientation relative to the threat • Experimental characterization of ballistic impact with different tissues for different projectiles. Determination of depths of penetration measurements, permanent and temporary cavitations measurement, trajectory offset and the effect of tissue combinations or discontinuities, including the use of PPE. • Development of a database of threat interactions with different tissues, with or without barriers • Determination of threat-human interaction methods and development of algorithms, including the establishment of penetration models • Definition of assessment metrics for the impact analysis to be used to predict the physiological and operational consequences of threat interaction with the human body, based on several injury ranking systems and taking into account additional damage models such as the communication systems (e.g. nerves, spinal cord), mechanical systems (e.g. bones, joints, muscles) and circulatory system. Physiological effects to consider include single vs. combined injuries, threat to life, and quality of life (with military medical input). Finite-Element Based Wound Ballistics • Increase knowledge through a literature review on Human FE model (University of Waterloo) which could focus on material properties in order to build a Ls-Dyna or CTH FEM, including material properties at static and high strain rate and the constitutive law for some specific part of human body. • Building of human FEM of various lethal and non-lethal projectiles using Ls-Dyna or CTH hydrocodes • Investigation and prediction of the biomechanical response of an actual torso to blunt ballistic impacts • Parametric study on the effect of velocity and projectile characteristics (material and geometry) V/L model development • Development of new models of bullet penetration and wound tracks in the human body • Development of more realistic models for PPE, leveraging the FE model development task and the VMAN task to implement intermediate level wound models into SLAMS (e.g. wound tract)	1
Programmable bursting ammunition	Airburst round (fragmenting) • Development of a Canadian expertise in this domain • Determination of optimal calibre or calibre mix for enhanced accuracy • Experimental and numerical characterization of lethality	2

R&D Focus Areas	Scope/Description (Needs and Opportunities)	Priority Order (1, 2, 3)
Non-lethal technologies	Improved ammunitions (non-lethal) • Extended range electro-shock 20-100 m (tazer, shotgun) • Tuneable ammunition Non-lethal technologies • Investigate effectiveness and injury potential on non-lethal weapon technologies – Electromagnetic: electric currents (CED), lasers, RF, HPW, etc. – Chemical: calmatives, malodorants, anti-traction, etc. – Acoustic – Mechanical and kinetic: entanglement, blunt impact devices, etc. • Determine suite of technologies to be used to improve effectiveness and meet requirements (determine target intentions, deny access, disable target) Managed lethality • Develop concepts of effectors that can be tuned to incapacitate or disrupt the target (either material or personnel) lethally or non-lethally. The goal is to employ the managed lethality system to determine target intentions, deny access, disable or destroy target. • Can be a suite of technologies or one technology tuned up and down	3

Annex E: Theme 7: Weapon-Mounted Situational Awareness and Targeting Suite

Annex E includes the following tables:

- Table E-1: Challenges/Requirements
- Table E-2: Enabling/Emerging Technologies
- Table E-3: Proposed R&D Focus Areas

Table E-1: Challenges/Requirements

Challenges	Priority	Requirements	
		2015-2020 (Horizon 2)	2020-2025 (Horizon 3)
Increased accuracy of engaged target from close to far seamlessly	High	Semi-automatic transition from close to far target engagements	Fully automatic transition from close to far target engagements
Assisted target engagement – the capability where the weapon system decides the optimum time to fire, where the soldier has already pulled the trigger	High	Integrated with existing EO sensors	Integrated with fully fused EO sensors
Reduced weight and bulk of WM-SATS	High	-25% weight	- 50% weight
Integrated system with soldier systems	High	Linked to soldier system/accessories	Seamlessly linked to soldier system
Retain zero	High	Retain zero	Retain zero
Automatic zero	Medium	Automatic zero for all accessories	Automatic zero for all accessories
Weapon collimation	Medium	Manual indication	Fully automatic collimation (automatic compensation)
Ballistic computation	High	Limited to sniper system	Fully integrated with the WM-SATS

Challenges	Priority	Requirements	
		2015-2020 (Horizon 2)	2020-2025 (Horizon 3)
Target sharing capability (hand-off)	High	Seamless target hand-off for non-line of sight engagements (automated)	Seamless target hand-off for non line of sight engagements (automated and integrated)
Improved EO target detection sensors (same performance in poor light conditions as in day light)	High	Up to 800 m identification Up to 1600 m recognition (X2 weapon range) Up to 2400 m detection (x3) (day and night)	Up to 1000 m identification Up to 2000 m recognition Up to 3000 m detection (day and night)
Day-night sensor transition	High	Clip on sights (IWNS-T)	Integrated day/night fused sights
Alternate, target detection sensors (i.e. acoustic and flash, IFF)	High	Improve acoustic, flash, and IFF detection	Fully integrated EO/acoustic/flash/IFF suite on weapon platform
Improved recognition and accuracy against difficult targets (partially exposed, in defilade and/or fleeting) while under operational stress and in non-optimal firing positions (i.e. standing)	High	Same accuracy as for normal target	Semi-autonomous target detection, identification and engagement capability Through sight IFF
Programmable ammunition (see Ammunition Theme)	High	FCS and fusing system to permit area, impact and delayed effects +100% improved accuracy against targets in open (15 m x 2.5 m)	Target hand-off for non line of sight engagements 200% improved accuracy against targets behind walls, in trench (7.5 m x 1.25 m), windows, etc.
Target localization (range, azimuth, and elevation)	High	N/A	Fully integrated in soldier systems suite
Environmental monitoring (temperature, wind, barometric pressure)	Medium	N/A	Contiguous (non-discrete) shooter to target monitoring
Weapon orientation	High	N/A	Fully integrated in soldier systems suite

Table E-2: Enabling/Emerging Technologies

Technology	TRL (1–9)	Year for TRL 7	Strength (S)/ Weakness (W)	Critical Barriers/Gaps	TSC Recommended Action
17 micron pitch VOx sensors (microbolometer)	8	2006	S: Resolution W: Cost, availability	• ITARS barriers in USA • ULIS (Sofradir) in Europe and SCD in Israel produces 1024 x 768 XGA format 17 micron pitch detector • Improved detection performance	Invest
12 micron pitch a-SiGe sensors	3		S: Resolution W: Cost	• Ability to incorporate Ge into Si • Improved detection performance	Monitor

Technology	TRL (1–9)	Year for TRL 7	Strength (S)/ Weakness (W)	Critical Barriers/Gaps	TSC Recommended Action
25 micron pitch sensors (LWIR, SWIR, etc.)	8–9	2006	S: Good sensitivity for day-night use W: Cost, power, size, resolution	• ITARS barriers in USA (e.g. InGaAs based SWIR) • Sofradir and Xenics in Europe have MCT and InGaAs based SWIR 20-30 micron pitch, but cooling requirement more demanding in MCT based SWIR (power consumption), and SWIR general performance in term of noise level is inferior to US SWIR • Raptor Photonics of Northern Ireland InGaAs based SWIR 30 micron pitch camera. Performance is inferior to US SWIR • No issues for LWIR as products from Europe are as good • Operational advantage in SWIR	Invest
New detector materials – e.g. SiGe, doped Si	5		S: Low cost alternatives to visible and NIR W: Size	• Manufacturability • Lower costs	Monitor
SWIR	9	2006	S: Non-detectability W: Resolution, cost	• ITARS barriers in USA • ULIS (Sofradir) and Xenics in Europe • Operational advantage	Invest
Micropore MCP	4–5	2015	S: High resolution W: Cost, robustness	• All optical coupling inside the I2 tube, and need high res 12M pixel camera, high res micro display to truly benefit the enhanced Gen III performance • Improved detection performance	Monitor
Multi-band sensors	5	2015	S: Used in the day, night and through fog and haze W: Cost, bulk	• E.g. CMOS imager (Tri-wave: visible, SWIR and LWIR) • Cooling may be the issue • Seamless transition from day to night	Monitor
High density displays – SXGA micro display	9	2006	S: Used in HMD and weapon sight W: Power	• eMagin SXGA 1280x1024 colour 30-85 fps • 2K by 2K in 2012 (TRL 6-7)	Monitor

Technology	TRL (1–9)	Year for TRL 7	Strength (S)/ Weakness (W)	Critical Barriers/Gaps	TSC Recommended Action
Miniaturized sensors	5–9	2006	S: Size and weight makes them potentially integratable on weapon platform W: Accumulative power consumption of all sensors	• Precision of some mini-sensors, especially for weapon platform (e.g. 0.1 deg resolution in accelerometer is not acceptable) • Operational advantage	Monitor
Miniature laser range finder system (Insight AN/PSQ-23 STORM)	9	2006	S: Small weight and form factor W: Range	• Mini laser range finder (LRF) with integrated multifunction lasers and a digital magnetic compass (DMC). LRF and DMC may be used in combination to obtain accurate positional information for targeting purposes • Operational advantage	Invest
Brashear XM104 (for XM 25)	9	2010	S: Highly accurate sight/FCS for airbursting rounds W: Cost	• NA (system is fielded) • Performance limitations of the technology are not known (Small Arms SOR Development Program)	Assess
Dual range optic sight (Specter DR)	9	2011	S: Combine both CQB and long range engagements capability W: Day sight only	• Operational advantage	Monitor
Automatic target detection / recognition / identification	4	2015	S: Significantly improves soldiers situational awareness, minimizes cognitive load and false alarms	• Image processing speed • Sensor and display resolution • Technology is not being developed elsewhere (Small Arms SOR Development Program)	Invest
Assisted target engagement	2	2015	S: Turns every soldier into a sharp shooter W: Potential cost	• Processing speed of image and decision criteria • Image resolution • Low cost solutions • Electronic ignition systems • Soldier perception of weapon not firing when triggered pulled • Technology is not being developed elsewhere (Small arms SOR development program)	Invest

Technology	TRL (1–9)	Year for TRL 7	Strength (S)/ Weakness (W)	Critical Barriers/Gaps	TSC Recommended Action
Ballistic calculation	4	2013	S: Component technology for assisted target engagement	• Implementation in small arms size volume and mass envelope • Technology is ITAR controlled and we need our own modifiable version with specifically Canadian specified capabilities (Small Arms SOR Development Program)	Invest
Rapid target acquisition sight which presents a virtual target on an transparent HMD	4	2012	S: Optimized situational awareness when engaging targets W: Potential for cognitive overload depending on implementation	• Requires optronics sights and integration with night vision capability • Technology is ITAR controlled and we need timely Canadian access (Small Arms SOR Development Program)	Invest
Visible/LWIR/SWIR/ II sensor	5–9	2020	S: All sensors cover the full spectrum W: Each single sensor is not sufficient	• Resolution, power, cost, size • ITAR limit for good quality sensors • Operational advantage	Monitor/invest
IFF active system - Laser+RF/RF and Laser/RF cooperative combat ID IFF	7–8	1996 (NATO trials)	S: High accuracy (95–100%) W: Cannot ID combatants from neutral	• Other active cooperative CID: infantry markers and beacons (TRL 9) • Operational advantage	Monitor
IFF passive system – non cooperative combat ID IFF - miniUAVs	9	2006	S: Low cost and compact W: Range and cost for long range system	• MiniUAVs such as Dragon Eye and Raven operated by Marine Corps • Operational advantage	Monitor
Acoustic sensor	2–7	2010	S: Additional input for localizing enemy W: Weight and bulk and integration on weapon	• Development of advanced, small and lightweight sensors, data processing algorithms • Integration into WM-SATS • Commercial systems exist (Small Arms SOR Development Program)	Assess
Flash sensor	4	2020	S: Availability of sensors to detect flash W: Need for arrays to localize, processing and power	• Sniper detection system using light as a cue	Invest

Table E-3: Proposed R&D Focus Areas

R&D Focus Areas	Scope/Description (Needs and Opportunities)	Priority Order (1, 2, 3)
Requirements definition	WM-SATS requirements and development • Development of a thorough understanding of the benefit that a WM-SATS could bring in terms of overall mission effectiveness as well as probability of hit for small arms under various operating scenarios • Development of a ballistic engine capable of providing correction for a wide range of parameters in real-time Grenade launcher WM-SATS performance requirements and developments • Evaluation of the performance of current state-of-the-art grenade launcher WM-SATS for in-service rounds in order to better understand how they can improve the accuracy and precision of this weapon system and to get a better understanding of the limitation of such system • Improvement of the performance of existing 40 mm grenade launcher WM-SATS • Evaluation of the performance potential of WM-SATS for various air-bursting grenade technologies and calibers in order to rate performance and determine optimal mixes for different operational scenarios	1
Human system integration	Quantifying the effect of the human on accuracy • Increase understanding and knowledge of the factors affecting shooting performance from a rifleman's perspective • Quantitatively determine the sources of operator error and using scientific evaluation methods • Develop error budgets for static and dynamic (shooting on the move) rifleman performance for target at various ranges • Assessment of future technologies for training approach Testing/shooting platform for increased shooting accuracy and accuracy in range • High speed tracking system to determine contribution of poor aiming techniques to shooter performance • Sensored weapons and targets to quantify error budget for poor range Optimizing sighting systems for the human • Investigate design requirements and novel design concepts for digital sight design and functionality, the type and means of displaying information in the sight, the performance implications and characteristics of an off-set sight design, the use of sight imagery off the weapon to enhance target engagement and shooter survivability, and the functionality and design of a WM-SATS Head-mounted displays and digital sight technologies • Increase knowledge of human-machine-interface in weapon sights and HMDs for effective target engagement in small arms. These include the requirements of sight displays and associated HMDs (both occluded and see-through), exit pupil and eye relief of the sight, information display on sights and HMDs, types (dot, lines, or something new, or currently used C7 reticule, etc.) and presentation (lumination, colour) of reticules, and various shooting positions via HMD targeting. Optical parameter requirements of target acquisition in small arm operations • Increase knowledge of required optical and related parameters (spatial resolution, contrast, magnification, frame rate, etc.) of a resolved target in an image by optical or optronic sights for effective target engagement using small arms, including fragmenting rounds • Evaluate two novel concepts (foveal sight and dynamic frame rate-resolution switching) to determine potential optimization on targeting capability	1

R&D Focus Areas	Scope/Description (Needs and Opportunities)	Priority Order (1, 2, 3)
BMS integration	Local battle management system for small arms • Target information sharing system. Develop a local battle management system for small arms to provide the dismounted soldier in complex environments or during fast paced operations with a means to share among its section, tactical data such as aiming direction, target designation, target hand-off and imagery from its weapon sight • Weapon Orientation Sensor. Increase understanding of the factors that affect long term attitude and bearing measurements in a small arms operational environment as a risk reduction task, including the evaluation of strengths and weaknesses of attitude and heading (bearing) reference systems in their various configurations and the data fusion filtering algorithms • Assess potential new concepts from the perspective of constraints imposed by weight, configuration, and dynamic motion range • The following technologies are important: visible/LWIR/SWIR/II sensor, IFF sensor, acoustic sensor, and flash sensors Power and data enabled rail • Embedded sensors • Connectivity to soldier system - wireless/cable? Integration of auxiliaries (laser, flash light, LRF, etc.) • Reduce weight • Reduce bulk	2
Assisted engagement and decision support	Hostile intent sensors/automated decision support • Evaluate the state of the art of rifle mountable hostile intent sensors • Pursue research to advance areas of weakness Evaluation of the potential of automatic target cueing and assisted target engagement (ATC/ATE) • Evaluate the relative levels of shooting accuracy and engagement time of soldiers with the use of an optical scope, optronic scope, and optronic scope with automatic target cueing and assisted target engagement • Determine potential advantages of automatic target cueing and assisted target engagement functions during target detection and engagement • Develop the ATC/ATE	2
Sensors (please see Technical Domain 8 - Sensing for a thorough description)	Emerging EO technologies for small arms • Increase knowledge of potential advantages of emerging EO technologies such as SWIR and image fusion over that of image intensifiers (I2) associated to small arms SWIR sensors (see Sensors) • Reduce pixel pitch and increase resolution • Reduce power consumption • Low cost optics Acoustic and flash sensors • Evaluate the state of the art of rifle mountable acoustic and flash sensors from the perspective of angular accuracy, signal processing, size and weight and power requirements • Pursue research to advance areas of weakness IFF Sensors • Evaluate the state of the art of rifle mountable IFF sensors • Pursue research to advance areas of weakness	2

Chapter 7: Command, Control, Communications, Computer and Intelligence (C4I)

7.1 Introduction

The Soldier System Technology Roadmap (SSTRM) Command, Control, Communications, Computer and Intelligence (C4I) technical domain encompasses a number of enabling elements that directly relate to the NATO soldier systems capability of C4I. These enabling elements permit the combat soldier to efficiently execute the commander's intent and enhance interoperability. They also optimize the integration of people, processes and technologies for the sharing of information, decision-making and coordinated action. The C4I enabling capabilities cover everything from military strategy and policy to information management, information assurance, system architecture; technology and security—all of which rely on a seamlessly integrated and network-enabled backbone. In aligning with the CF C4I Surveillance and Reconnaissance (C4ISR) Capability Development Plan (CDP), the strategic focus of the C4I technical domain is therefore "to enable the collective exploitation of information at all levels of command while simultaneously supporting centralized command, decentralised execution and planning of operations."[35]

As with the other SSTRM technical domains, C4I does not reside as a stand-alone capability, but must integrate with sensors, weapon systems, personal protective equipment and logistics, and must also be able to operate within adaptive dispersed operations across multiple domains. For the purposes of this chapter, however, only the C4I technical domain will be discussed.

Within the C4I technical workshop, a number of themes were explored and now reduced to four:

- Theme 8: Command and Control
- Theme 9: Communications
- Theme 10: Computer
- Theme 11: Intelligence

Although the following four themes are treated individually, it is recognised that C4I is an integrated concept, and a holistic approach to integrated capability development is required. Surveillance, Reconnaissance and Target Acquisition are also interdependent elements with Intelligence Surveillance, Target Acquisition and Reconnaissance (ISTAR), however, are addressed in the Sensing technical domain (Chapter 8). Target Acquisition is discussed in the Weapons Effects technical domain (Chapter 6) of this Capstone Report and Action Plan. These topics will therefore not be covered within this chapter.

In support of this discussion of the C4I technical domain, a number of strategic guidance documents[36] should also be referenced. At the Canadian Forces and Army level, the C4ISR strategy is still evolving and should be monitored.

35 Department of National Defence, Chief of Force Development. *C4ISR Capability Development Plan* (2009).

36 Chief of Force Development. C4ISR CDP (31 August 2009); Chief of Force Development. IC2 Capability Strategy (23 July 2008); Chief of Force Development. C4ISR Capability Development Strategy (14 July 2009).

7.2 Technical Domain Deficiencies

A total of 26 general deficiencies were identified in the C4I technical domain. The rank of these deficiencies varied from high to low (see Annex A to Chapter 7). Twenty-two high-priority deficiencies were identified and associated to one or more of the four themes. Four high-priority deficiencies were found to be common to all C4I themes:

- **Common to all C4I Themes**
  – Excessive size, weight, volume and power demand
  – Inadequate consideration of human factors
  – Scalable security
  – Limited affordability
- **Command and Control**
  – Doctrine
  – Mission phase
  – Human dimension
  – Navigation
  – Interoperability
  – Information and Knowledge Management
- **Communications**
  – Mission phase
  – Integrated communications
  – Interoperability
  – Human-machine interface
  – Power/data connectors/connections
  – Connectivity
  – Voice/data management
- **Computer**
  – Interoperability
  – Human-machine interface
  – Power/data connectors/connections
  – Connectivity
  – Computing hardware
  – Computing software
- **Intelligence**
  – Human dimension
  – Situational awareness
  – Information assurance

The results of the SSTRM workshop and subsequent subject matter expert review suggest that there are many capability deficiencies within C4I. Deficiencies common to all four themes were identified (e.g., size, weight, volume and power demand, human factors, security and affordability), however, as the C4I technical domain encompasses many diverse elements within the various themes, several unique but interdependent deficiencies were also identified. As well, although the focus of the SSTRM is on the dismounted soldier, for C4I in particular, many attributes were driven by aspects such as policy, standards and the implementation of infrastructure. The deficiency Table in Annex A, therefore, includes an array of topics, from military strategy and policy (doctrine, training) to technology and system architecture (hardware, software, network technology, connectivity), to information management (information fusion, data mining), information assurance and security.

7.3 C4I Vision 2025

In order to more efficiently execute the commander's intent within the future security environment in a Joint, Interagency, Multinational and Public (JIMP) setting, the vision of the C4I technical domain in 2025 is **to enable a combat soldier to obtain an accurate, relevant and timely understanding. This understanding must be applied to the area of interest based on the common operating picture through a fully integrated information and system-based capability. All elements of this technical domain will respect constraints such as security, weight, volume, power and cognitive load. To ensure continued relevance, this system will be scalable and evolutionary.**

7.4 Overall System Goals (2015–2020, 2020–2025)

In order to achieve the technical domain vision, near-term and far-term goals have been identified. While the near-term (2015–2020) goals can be categorised as incremental improvements on existing systems, the far-term (2020–2025) goals are characterized, in many cases, as revolutionary.

The goal for the 2015–2020 timeframe is that the network–enabled soldier will permit commanders to have improved command and control (planning, decision making, briefing, training and execution) over their area of interest. This seamless network will allow the soldier and the commander to have improved communications, decision-making aids, navigation and human-machine interface capabilities, thereby reducing cognitive burden and ensuring a better situational awareness for the soldier.

The goal for the 2020–2025 timeframe is that the autonomous and continuously networked enabled soldier will permit commanders to have optimized command and control across the spectrum of operations over their area of interest. This optimization shall result in improved capability to train, collect, process, disseminate and exploit timely and accurate information and intelligence. This seamless, self-forming and self-healing ad-hoc network will allow each soldier to maintain a Common Operating Picture (COP) and access C4I assets regardless of environment through a multi-tier and opportunistic (i.e. any waveform, any channel, any medium available) communications platform. An increase in situational awareness through flexible, high-bandwidth communications, constantly available navigation in combination with autonomous information management, naturalized human interfacing, sensor integration, and adaptive artificial intelligence, will permit an increase in operational tempo—faster time to initiate, act, react and deploy. The overall system goals include the following:

Table 7-1: Overall System Goals

2015–2020 (Incremental improvement)	2020–2025 (Revolutionary change/improvement)
Information Exchange Mechanism to optimize the use of the communications channel/bandwidth/ throughput and vagaries of radio communications (e.g. loss and recovery of network)	Seamless information assurance solution throughout all system-based data at rest and in-transit, with potential for tailoring to required levels of mission-role modifiable security
Increased computing power provided to individual soldiers (within the energy budget)	Unconstrained communication in signal degraded/denied environments
Improved integrated Information and Knowledge Management	Multiband conveyance (line-of-sight (LOS) /beyond-line-of-sight (BLoS)
Improved data collection, fusion, filtering and access to information/ intelligence through vertical tiers of command	Autonomous data collection, fusion, and processing of information/ intelligence and unconstrained access across horizontal and vertical tiers of command
75% available position determination system, regardless of terrain, with an accuracy in the order of the metre and Global Positioning System (GPS)-independent	100% available position determination system with an accuracy in the order of the centimetre and GPS independent
Integrated communications (e.g. multiple-effects communication capability in a single device, multi-modal user interfacing)	Ubiquitous communication and computing adapted to available spectrum and bandwidth in all environments
Optimized human and systems integration	Unified commonality within the Canadian Dismounted Soldier System (DSS), Army and CF
Increased commonality between the Canadian DSS, Army and Canadian Joint Forces	Horizontal and vertical integration and universal interoperability (within the JIMP environment through common waveforms on Software-Defined Radio (SDR), cross-domain solutions and common data models and a common communication stack)
Increased interoperability within the JIMP environment	All within a fully integrated system (power, data, sensor and weapons) at less than current equipment size, weight and power (SWaP)

2015–2020 (Incremental improvement)	2020–2025 (Revolutionary change/improvement)
Increased security (computing, data, information and network)	Seamless dual-direction, enabled cross-domain bridging for voice and data across different security level networks
All within the constraints of reduced size, weight, volume and power (10 watts for soldier) and cost	Naturalized human-machine interface integrated to enable immediate reaction and feedback-based interaction with system and user

7.5 Technical Domain Specific Drivers

The SSTRM participants identified a number of drivers and constraints that will have a major impact on technology options. Several of the universal drivers detailed in Chapter 4 also apply to this technical domain. Drivers unique to this technical domain are listed below (see Annex B to Chapter 7 for a full description). These are categorised according to each of the four C4I themes as well as top-level constraints/parameters:

- **Top-Level constraint parameters**
  - Policy
  - Future Security Environment (FSE)
  - Concept of employment
  - Technology availability and resulting uncertainty
  - Size, Weight and Power (SWaP – include volume, encumbrance, bulk, etc.)
  - Cost
  - Security
  - Standards
  - Health and Safety
  - Human Systems and Integration (HSI)
  - Baseline Soldier System 2010
  - Intellectual property
- **Command and Control**
  - Control hierarchy
  - Tactics, Techniques, and Procedures (TTPs)/Concept of Operations (CONOPS)
- **Communications**
  - Spectrum availability (crowding of the radio spectrum)
  - Denied environment (jamming, urban canyon, etc.)
  - Commonality and interoperability
  - Cross-domain communication
  - Connectivity
- **Computer**
  - Intelligent agents in software technology
  - Commercial off-the-shelf (COTS) expectations
  - Embedded instrumentation
- **Intelligence**
  - Intelligence hierarchy

The four C4I technical domain themes will be summarised below and discussed in greater detail in Annexes C, D, E and F.

7.6 Theme 8: Command and Control

7.6.1 Scope

According to the Pigeau-McCann framework for command and control, command is defined as "the creative expression of human will necessary to accomplish the mission… (where) the degree of command capability embodied by a military person is a function of the person's competency, authority and responsibility."

Control is defined as "those structures and processes devised by command to enable it and to manage risk, (where) control's sole purpose is to support command by allowing it to take action in the operational context."

Furthermore, the concept of command and control (C2) is defined as "the establishment of common intent to achieve coordinated action." Without coordinated action, military power is compromised. Without common intent, coordinated action may never be achieved.[37]

7.6.2 Objective

The objective of this theme is to optimize C2 within all echelons of the Army Joint forces and coalition partners. "Optimization" is intended to include the successful achievement of inter-participant communication through voice (obligatory) and information exchange to support C2 activities within all operational mission environments and hierarchies. This will allow for the flow of timely and pertinent tactical information at the individual soldier, section, platoon and company level, and within the Army, CF and JIMP environment. The near-term objective is to achieve full interconnectivity between participants at the company level and below within the next three to five years. The far-term objective is to achieve full interconnectivity between all tiers of participants (including upper-tier C2 infrastructure systems) within the next five to ten years.

37 McCann, C., Pigeau, R., English, A. *Analyzing command challenges using the command and control framework: Pilot study results*. DRDC Toronto Technical Report 2003-034 (2003); Pigeau, R., McCann, C. "*Re-conceptualizing Command and Control,*" Canadian Military Journal. Pg. 53 – 64. (2002).

7.6.3 Challenges/Requirements

The SSTRM participants identified ten key performance parameters to be improved. The deficiencies were clustered around interoperability and compatibility, decision aids, network and training issues. A total of six high priorities were identified. For a full list of the critical challenges see Annex C to Chapter 7, which provides mid-term (2015–2020) and long-term (2020–2025) performance targets.

Key Mid-term Challenges and Requirements:

- Increased commonality within the context and constraints of the security policies.
- Provision of decision aids based on mix of manual and automatic sensor and data inputs.
- Increased on-soldier self-system, weapon, and environmental status monitoring (overlap with sensor section).
- Increased interoperability to fielded and support sensor network data (overlap with sensor section).
- Fully interoperable data interchange with all international partners.
- Unidirectional transfer, from the unclassified domain to a Secret classified domain of tactically relevant information that is considered sensitive but timely and pertinent to the conduct of operation to ensure mission success.
- Multiple data link options capability in soldier systems for militarised tactical line-of-sight options.
- Improved Information and Knowledge Management.

Key Long-term Challenges and Requirements:

- Optimized commonality (bi-directional flow of information between security domains with autonomous control handling) within the context and constraints of security policies.
- Automated recommended courses of action with select tasks autonomously performed.
- Availability of direct feeds (e.g., video) from all in-field organic sensor assets to as-required participants (overlap with Sensor technical domain—see Chapter 8).
- Fully interoperable voice and data interchange with all international partners.
- Bidirectional transfer, to and from the unclassified domain and classified Secret level domain of tactically relevant information that has been sanitized in such a way to exclude data that mark the information as Secret.
- Multiple data link options capability in soldier systems for communications using as needed military and commercial off-the-shelf line-of-sight, beyond-of-sight (LOS, BLOS), and mass-market or commercially available e.g. mobile phones, Wi-Fi, satellite.

7.6.4 Enabling and Emerging Technologies

The SSTRM workshop on C4I included a number of presentations identifying emerging technologies that could address deficiencies in the C2 theme. Attendees at the workshop also participated in a brainstorming breakaway session that identified other potential solutions and collaborative industry teams that could solve these problems. After the workshop, an analysis of gaps and proposed solutions was undertaken to identify other enabling or emerging technologies. These potential solutions are detailed in Annex C to Chapter 7.

The solutions to the identified gaps were evaluated by technology readiness level (TRL) to identify incremental improvements in the near term (TRL 7–9) and solutions available in the longer term (TRL 1–6).

Based on this review, emerging near-term solutions to gaps in the C2 theme were limited to training. Potential technologies that may provide near-term solutions to the performance gaps include:

- Gaming technology; and
- Training simulator

Several revolutionary technologies were identified that may resolve deficiencies in the current C2 climate. These enabling technologies revolved around human-machine interface, decision-making aids and interoperability. In addition, and as outlined in the 2009 C4ISR CDP,[38] effective interoperability requires "common security controls such as releasability caveats and security levels, (where) enablers of interoperability (include) common lexicons, common privacy rules, shared operating concepts, personnel exchanges, collective training and cross-education." A list of the revolutionary technologies identified is provided below:

- Embedded instrumentation to enable in-situ health monitoring of persons as well as equipment and device status through built-in-testing.
- Mixed-initiative interfaces that automatically adjust to the current C2 task by providing appropriate decision-support functionalities.
- Case-based reasoning that automatically provides identification of similar situations.
- Data-exchange standards to improve interoperability.

7.6.5 Proposed R&D Focus Areas

Based on an analysis of the SSTRM workshop results and subsequent subject matter expert reviews, three potential research and development focus areas were identified. These addressed the following:

- Human systems Integration
- Enhanced training through augmented reality
- Full or partial virtual reality training

A detailed list of R&D needs and opportunities is detailed in Annex C to Chapter 7.

38 Chief of Force Development. C4ISR CDP (31 August 2009); Chief of Force Development. IC2 Capability Strategy (23 July 2008); Chief of Force Development. C4ISR Capability Development Strategy (14 July 2009).

7.7 Theme 9: Communications

7.7.1 Scope

For the purposes of this discussion, communication is defined as follows:

Communication is a process whereby information is enclosed in a package and is channelled and imparted by a sender to a receiver via some medium. The receiver then decodes the message and gives the sender a feedback. All forms of communication require a sender, a message, and an intended recipient; however the receiver need not be present or aware of the sender's intent to communicate at the time of communication in order for the act of communication to occur. Communication requires that all parties have an area of communicative commonality. There are verbal means using language and there are nonverbal means, such as body language, sign language, paralanguage, haptic communication, chronemics, and eye contact, through media, i.e. pictures, graphics and sound, and writing.[39]

Communication is also one of two pervasive enabling technologies that support C2 and intelligence, surveillance and reconnaissance. The other technology is further discussed in Theme 10 of this chapter.

7.7.2 Objective

The objective of this theme is to provide a communications link for voice and data exchange that is:

- Low-cost
- Mission-scalable
- Securable with low detectability an interceptability (EMCON)
- Adaptive (to available frequency, bandwidth, waveform and environmental condition-dependent power)
- Seamless and intuitive.

The communications link should be always accessible between soldiers, between their devices and systems, and within the Army, coalition and JIMP environment.

The near-term objective is to achieve this capability with 50 percent less power consumption for the same capability, and the long-term objective is to reach the same capability with 90 percent less power consumption.

7.7.3 Related Challenges and Requirements

The SSTRM participants identified 15 key performance parameters to be improved in this theme. The deficiencies were clustered around data transmission and network technology, human and systems integration and interoperability issues. A total of 11 high priorities were identified. For a full list of the critical challenges, see Annex D to Chapter 7, which provides mid-term (2015–2020) and long-term (2020–2025) performance targets.

Key Mid-term Challenges and Requirements:

- A communication system fully mission-configurable, modular and integrated into the Soldier System for each individual soldier;
- Exploitation and usage of a an as large as possible radio-frequency spectrum at soldier's level in a soldier compatible SWaP (e.g. UWB with a 5 to 10 Gigahertz bandwidth);
- Software Defined Radio offering selectable suite of programmable waveforms to adapt to the complex terrain of operation;
- Multi-hop capability, robust, fault tolerant, self-forming, self-healing Mobile Ad hoc Network (MANET)) with 30 percent improvement in power consumption over present available technology— infrastructure independent;
- Capability to extend range up to at least 10km even on the move (terrain-dependent);
- Secure Public Key distribution and renewal to enable secure data communications;
- Accessibility to selective bandwidth to support high throughput data exchange when required;
- Common radio interface standard defined through an international effort and adopted by Canada (e.g. STANAG). This standard shall offer the capability to monitor and configure the radio from any computing device;
- Standardized information exchange mechanism and communication management with effective capability to provide Quality of Service (QoS), including taking charge of message priority, temporary loss of communication[40];
- Alternative modality user interfaces with configurable applications;
- Directed stereophony (2-D) for voice channel spatial separation of incoming communication.
- Recharge capability in tactical vehicle for in use Dismounted Soldier while mounted and on the move;
- Voice and Information Exchange for Dismounted soldier from and to tactical vehicle and select sensor assets;
- Mounted Voice and Information Exchange for Soldier System users with the Tactical Vehicle platform (e.g. intercoms, server access) with automatic radio cut-off while mounted;
- Global Navigation Satellite System (GNSS) hot-start navigation capability to dismounted soldier from the mounted vehicle (e.g. rebroadcasting signal).

Key Long-term Challenges and Requirements:

- A communication system with automatic mission-configuration based on mission order, modular and integrated into the Soldier System for each individual soldier, with a 50 percent improvement in power consumption on present technology offer;
- Integrated non line-of-sight (NLOS) communications in similar single-unified device with no volume (i.e. bulk) increase;
- Adaptive frequency and bandwidth sensing communications links for continuous high-throughput data exchange capability between individual users (active cognitive radio and network awareness of the Communication system to choose the best link available);
- Fully Implemented Information exchange and radio communication management with viable QoS for all interconnected voice and data services[41];

39 Wikipedia. "Communication" (Downloaded 30 November 2010 from http://en.wikipedia.org/wiki/Communication).

40 For a full description of the problem and a proposed solution please refer to : Land capability Group 1 - White Paper, NATO Information Exchange Mechanism for Dismounted Soldier Systems, JDSSIEM Joint Dismounted Soldier System Information Exchange Mechanism, Dr. Norbert Härle

41 For a full description of the problem and a proposed solution please refer to : Land capability Group 1 - White Paper, NATO Information Exchange Mechanism for Dismounted Soldier Systems, JDSSIEM Joint Dismounted Soldier System Information Exchange Mechanism, Dr. Norbert Härle

- Common radio interface standard (fully implemented standard in the DSS radio communication sub-system);
- Enhanced unified Radio Frequency (RF) and signal processing capabilities to continuously retain communication and navigation channel access;
- Automatic configuration of communications system based on user Identification (ID), connected interfaces, and mission role needs;
- Automatic adaptive ad hoc network capabilities for all equipment;
- Fully implemented Common Information Exchange Data Model between soldier systems, vehicles, sensors, repositories (e.g. "MAJIIC" CSD, ODB);
- Automatically assignable COI for section, platoon and company level communications with ability to monitor all COIs with collision protection/resolution of messages;
- Three-dimensional (3-D) spatial for voice channel spatial separation of incoming communication.

7.7.4 Enabling and Emerging Technologies

The SSTRM participants identified 24 enabling and emerging technologies that could address a number of specific deficiencies in the Communications theme. These potential solutions are detailed in Annex D to Chapter 7. The solutions to the identified gaps were evaluated by TRL to identify incremental improvements in the near term (TRL 7–9) and solutions available in the longer term (TRL 1–6).

Based on this review, a number of enabling and emerging near-term solutions to gaps in the Communications theme were identified. A number of the proposed technologies and processes identified in the workshop have already been evaluated by DND (e.g., communications network systems and technologies, software radio architecture, sound spatialisation). Potential technologies that may provide near-term solutions to the performance gaps include:

- software-defined radio that provides flexible waveform hosting for multiple site or situation-use with no modification to hardware;
- multi-band, ad hoc networking radio;
- magnetic wave communications;
- beam-forming adaptive array (switched or phased);
- multiple-Input and Multiple-Output (MIMO) antenna technology;
- network-monitoring dynamic priority-based allocation;
- airborne platform to extend range of communication;
- ear canal moulding/head scanning technologies;
- automatic speech recognition (directed speech and free speech, or natural language processing);
- speech synthesis; and
- design of environment adaptive Waveforms.

A large number of revolutionary technologies were identified that may resolve deficiencies in the Communications theme. The majority of these technologies revolve around waveform and frequency exploitation, optimal use of radio spectrum and data management, as well as intelligent radios (cognitive, adaptive and dynamic spectrum access). Potential far-term solutions to the performance gaps include:

- cognitive radio to help augment the throughput of the radio spectrum;
- adaptive radio with channel aggregation (Dynamic Spectrum Access (DSA));
- millimetric radio waveforms to expand the accessible spectrum at 10 GHz and above;
- adaptive RF filters to enable for true Software Design Radio (SDR) for spectrum adaptive communications systems;
- ultrasonic Personal Area Network (PAN) which could be detected in close proximity (≤100m);
- multiprotocol Label Switching (MPLS) applied to DSS Radio networks to manage network traffic and help improve efficiency;
- digital Video Broadcasting–Return Channel via Satellite with Very Small Aperture Terminal (DVB-RCS VSAT);
- spatialisation of sound (3-D audio); and
- security cross-domains solutions to facilitate cross-domain communication.

7.7.5 Proposed R&D Focus Areas

Based on an analysis of the SSTRM workshop results and subsequent subject matter expert reviews, nine potential R&D focus areas were identified:

- Cognitive mesh network radio;
- Power and data infrastructure (see Chapter 5);
- Adaptive spectrum analysis and detection capabilities;
- Security and reliability of Mobile Ad hoc Networks (MANETs);
- Wireless networking for biosensors;
- Biometrics;
- 3-D audio radio communication and audio restitution (e.g. alarm, cueing, speech-to-text);
- System management radio common interface;
- Voice data corpus for voice recognition systems.

A detailed list of R&D needs and opportunities is available in Annex D to Chapter 7.

7.8 Theme 10: Computer

7.8.1 Scope

This theme encompasses the physical and digital attributes and components of electronic systems (hardware, software, servers, connectors/connections and interfaces) to sense, process and respond to stimuli and commands, the implementation and distribution of those systems within the environment, related security aspects as well as the interaction and operation of those attributes and components by the human.

7.8.2 Objective

The objective of the Computer theme is to provide a powerful, mission-adaptive, intelligent, securable and ubiquitous computing capability to soldiers that will help maintain and improve their situational awareness while minimising system physiological and cognitive burden. The near-term objective (within three to five years) is to achieve this capability with 50 percent less power consumption for the same capability as current equipment. The long-term objective is to achieve this capability with 90 percent less power consumption within the next five to ten years.

7.8.3 Related Challenges and Requirements

The SSTRM participants identified 13 key performance parameters to be improved. The deficiencies were clustered around size, weight, power and human-machine interface issues. A total of eight high priorities were identified. For a full list of the critical challenges see Annex E to Chapter 7, which provides mid-term (2015–2020) and long-term (2020–2025) performance targets.

Key Mid-term Challenges and Requirements:

- 50 percent weight reduction;
- Distributed and modular design to reduce system bulk;
- Customisable multimodal user interface;
- Directed voice recognition;
- Gesture detection for computing input/output;
- Sound/tonal audio input and output;
- Scalable high-resolution display;
- 75 percent increased capability in processing vs. current capability at similar power impact.

Key Long-term Challenges and Requirements:

- 75 percent weight reduction;
- Conformal and flexible computing design to minimise bulk;
- Portable man-machine interface, which reduces cognitive load and is adaptable to mission-phase, intuitive and user-driven design;
- Free-speech recognition;
- Lips reading, eye movement detection as Human-Machine Interface;
- Speech synthesis;
- Scalable high-resolution see-through display;
- 150 percent capability increased in processing vs. current capability at similar power impact.

7.8.4 Enabling and Emerging Technologies

The SSTRM participants identified 16 enabling and emerging technologies that could address a number of specific deficiencies in the computing theme. These potential solutions are detailed in Annex E to Chapter 7. The solutions to the identified gaps were evaluated by TRL to identify incremental improvements in the near term (TRL 7–9) and solutions available in the longer term (TRL 1–6).

Based on this review, a number of enabling and emerging near-term solutions to gaps in the Computer theme were identified. Potential technologies that may provide near-term solutions to the performance gaps include:

- Service-Oriented Architecture (SOA);
- Low-power consumption electronics;
- Power consumption optimization and management;
- Cross-platform operating systems and programming languages;
- Open source software utilisation
- Wireless personal small network (e.g. Bluetooth, Zigbee, Z-wave, Ultra Wide Band (UWB)); and
- Smart Fabric (see Chapter 5 Theme 3 and Chapter 9 Theme 16).

Several revolutionary technologies were identified that may resolve deficiencies in the current computing climate. These emerging technologies were clustered around computing hardware, power and connections, and are listed below. One revolutionary technology that addressed the optimization of the man-machine interface was a brain computer interface.

- Brain-computer interface;
- Low-power algorithms and waveforms;
- Induction power and connections.

7.8.5 Proposed R&D Focus Areas

The SSTRM participants and the TSC identified two potential R&D focus areas:

- Flexible, customisable interfacing materials and approaches
- Advanced hybridized multimodal interface development and evaluation

A detailed list of R&D needs and opportunities is available in Annex E to Chapter 7.

7.9 Theme 11: Intelligence

7.9.1 Scope

Intelligence is the product resulting from the collection, processing, integration, analysis, evaluation and interpretation of available information provided in the context of a specific question or area of interest. Information and knowledge about an adversary obtained through observation, investigation, analysis or understanding is also included in this definition.

Situational Awareness (SA), (one of the sub-themes to this Intelligence theme), resides in the operator's cognitive or mental model of the state of his or her environment and facilitates decision-making. To achieve good SA, the information obtained must be accurate and thorough, timely, pertinent, relevant to the task at hand, and must be effectively applied. In the case of a group, the individual SA needs to overlap so that the group shared at least a common understanding of the situation. This is achievable only if information is fused, woven and well integrated in the CONOPs from the start. The other sub-themes to the Intelligence theme include Information Assurance (IA) and Scalable Security.

7.9.2 Objective

The objective of this theme is to improve the capabilities of the soldier in every aspect of the information management process, from access, collection and management to processing, integration, analysis, evaluation, dissemination, archiving and the secure protection of data and information.

A second objective of this theme is to increase the individual soldier's capacity to generate rapidly a more complete SA by providing the tools to help create the cognitive or mental framework necessary to understand and perceive a situation in an accurate, thorough, timely, pertinent manner while minimising psychological and cognitive burden. The soldier shall be able to achieve the following:

- Timely absolute geo-location and position determination of self
- Degree-of-accuracy conditional on mission role needs (position reporting, navigation, targeting and weapons operation over various periods of time)
- 100 percent availability regardless of environment or surroundings

All of these conditions, and shall supply soldiers with confidence in the information that they are sending and receiving.

7.9.3 Challenges and Requirements

The SSTRM participants identified 15 key performance parameters to be improved. The deficiencies were clustered around information management and exchange, SA and security. A total of nine high-priority intelligence deficiencies were identified. For a full list of the critical challenges see Annex F to Chapter 7.

Key Mid-term Challenges and Requirements:

- 5 Mb/s data exchange (within the 10 Watts power budget).
- Multimodal user-adaptive interfacing to improve cognitive absorption of information.
- Timely delivery of relevant information (maximum five-minute delay) with improved Information and Knowledge Management.
- Complete information with some access to background-related information through drill-down capabilities (limited access to full detail).
- Timely and accurate Common Operating Picture through continuous synchronization of information between all Army nodes.
- Validated information assurance (IA) approach to Blue Positional Awareness (PA) information exchange systems (information, processing, communications and C4I).
- GPS equivalent accuracy over 60 minutes (near-term goal 1 m within 1 second).
- Information guard (stand-alone) and security solution to bridge different security domains.
- Secure bridging function to allow one-way (unidirectional) exchange of information from unclassified realm to a Secret Level domain using proven Type 1 security devices for data in transit or at rest, with cryptographic materials following the US Federal Information Processing Standards Publications (FIPS PUBS) framework and if an overall system needs security functional and assurance requirements specified then the Common Criteria Evaluation and Validation Scheme should be the reference, accordance with the Treasury Board - Government Security Policy.

Key Long-term Challenges and Requirements:

- 100 Mb/s data exchange within the power budget and allowed frequency band.
- Autonomous decision aid and COA analysis applications to extend cognitive understanding and improve response of user to information.
- Timely delivery of relevant information (maximum 1-second delay).
- Information is complete and fully accessible when desired.
- Timely and accurate COP within the Canadian Joint Forces and JIMP environment.
- Active spoofing and intended error detection algorithms in Blue PA and IA data-exchange systems.
- GPS equivalent accuracy over 24 hours with long-term goal of 0.25 m within 1 second (enable altitude at position within 2 m (one building-floor separation).
- Autonomous securitization and information assurance.
- Bi-directional security bridge capability to enable mixed-tier secure data links to exchange select data without user involvement.

7.9.4 Enabling and Emerging Technologies

The SSTRM participants identified 123 enabling and emerging technologies that could address a number of deficiencies in the Intelligence theme. These potential solutions are detailed in Annex F to Chapter 7. The solutions to the identified gaps were evaluated by TRL to identify incremental improvements in the near term (TRL 7–9) and solutions available in the longer term (TRL 1–6).

Based on this review, a number of enabling and emerging near-term solutions to gaps in the Intelligence theme were identified. Potential technologies that may provide near-term solutions to the performance gaps include:

- Meta-data tagging standards with ability to subscribe to information and intelligence produced by other government departments (OGDs) and allies;
- Collaborative tools to enable rapid information acquisition;
- Online Analytical Processing (OLAP);
- Standardised iconography and symbology;
- Geographic information systems;
- 3-D visualisation software;
- Augmented reality;
- Inertial platform technologies, Inertial Measurement Units (IMU);
- Barometric altimeter;
- Global Navigation Satellite System (GNSS) e.g. Navstar GPS, Galileo, Glasnoss;
- Selective Availability Anti-Spoofing Module (SAASM);
- Optical light detection and ranging (LIDAR), radio and laser ranging;
- Astrometrics;
- Embedded firewalls;
- Data encryption and decryption;
- MCM encryption engine with turnstile computer data source (CDS);
- Context parser for structured data;
- Selective security approach; and
- Active (meaning simultaneous) multi-Biometric security (facial, speaker, scent, handwriting recognition, finger, palm print and eye scan).

Several revolutionary technologies were identified that may resolve deficiencies in the current intelligence climate. These emerging technologies were clustered around information access and management, and common operating picture. However, the greatest proportion of enabling and emerging technologies was clustered around navigation, positional location awareness and security—accounting for more than 85 percent the technologies identified in the current exercise. As there are over 100 navigation and location or positional awareness and security-related technologies, only the high-level categories are listed below.

7.9.5 Proposed R&D Focus Areas

Based on an analysis of the SSTRM workshop results and subsequent subject matter expert reviews, seven potential R&D focus areas were identified.

- Information collection, management, filtering and retrieval (drill-down and reach-back)
- NATO symbology an iconography – at dismounted infantry soldier level
- Affordable Cognitive Radio Securable with adaptive range, throughput and spectrum exploitation to support soldier's communications (voice and Information)
- Low-cost selectable-security encryption (e.g. protection of information with in the JIMP)
- Navigation aid (e.g. using dead reckoning processing techniques, radio ranging (see below) low cost inertial sensors to enable the navigation capability in complex environment and GNSS denied environment)
- Development of transparent radio ranging layering capability to support navigation and localization where relative positioning information (lower layer) is linked with one of more referenced positions (upper layer) used to anchor the lower layer
- Sensor integration/processing.

A detailed list of R&D needs and opportunities is available in Annex F to Chapter 7.

Annex A: C4I Deficiencies

Table A-1: C4I Deficiencies

<table>
<tr><th>Rank</th><th>Theme 8:
Command & Control</th><th>Theme 9:
Communications</th><th>Theme 10:
Computer</th><th>Theme 11:
Intelligence</th></tr>
<tr><td>High</td><td colspan="4">Scalable security
• Limited protection against cyber-attack
• Limited protection against electronic warfare
• Insufficient secure exchange of data with balance of security level vs. bandwidth vs. cost for mission role
• Insufficient authorization capabilities (limited access control /management)
• Insufficient cross domain access
• Insufficient encryption
• Differences in use-case policies impact types/levels of security impressed on various equipment or users
• Encryption not able to change type or level flexibly
• Poor detection management (visible / IR / I^2 / thermal / electronic wave / acoustic / seismic / radar, intrusion)
• Insufficient identification (biometric) capabilities
• High cost of implementation for all users</td></tr>
<tr><td>High</td><td colspan="4">Excessive size, weight, volume and power demand
• Increasing weight and power demands from growing capability additions
• Increasing size and volume in particular components depending on integration approaches
• Limits to physical carry capabilities due to human frame and load bearing system
• Limits to current state power technologies and viability of certain alternative approaches</td></tr>
<tr><td>High</td><td colspan="4">Inadequate consideration for human factors
• Lack of general human machine interface concepts
• Lack of soldier-specific environment considerations in application of HMI
• Dominant reliance of visual-based interfaces (when available) versus other implementations
• Poor Information and Knowledge Management</td></tr>
<tr><td>High</td><td colspan="4">Limited affordability
• Growing interest and need to outfit every soldier contrasts with cost of current systems
• Current state of specific technologies require further cost reduction for broad availability</td></tr>
</table>

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Rank	Theme 8: Command & Control	Theme 9: Communications	Theme 10: Computer	Theme 11: Intelligence
High	Scalable security • Limited protection against cyber-attack • Limited protection against electronic warfare • Insufficient secure exchange of data with balance of security level vs. bandwidth vs. cost for mission role • Insufficient authorization capabilities (limited access control /management) • Insufficient cross domain access • Insufficient encryption • Differences in use-case policies impact types/levels of security impressed on various equipment or users • Encryption not able to change type or level flexibly • Poor detection management (visible / IR / I^2 / thermal / electronic wave / acoustic / seismic / radar, intrusion) • Insufficient identification (biometric) capabilities • High cost of implementation for all users			
Medium	Lack of effective integration • Insufficient power integration • Inadequate data integration • Lack of power and data infrastructure standards • Limited integration with sensor systems, weapon systems, marine based assets, land based assets (i.e. vehicle), air based assets • Inadequate integration with space based assets • Lack of integration with legacy systems • Insufficient growth flexibility			
Low	Lack of standards • High variance in physical and signal/data/power interfaces utilised • Numerous proprietary approaches and resulting mix of standards • Uneven mix of commercial and military-based standardisation applied • Lack of unified soldier system-relevant standards in primary integration areas			
High	Doctrine • Ineffective utilisation of and access to the chain of command • Inefficient exploitation of organisational structures (i.e. small teams, swarming technology, unit/sub-unit structure, unit/sub-unit capabilities, geographically dispersed teams, doctrinal structures) • Deficiencies in the use of non-networked and enhanced soldier-optimized current TTPs • Deficiencies in the execution of Rules of Engagement	N/A	N/A	N/A

Rank	Theme 8: Command & Control	Theme 9: Communications	Theme 10: Computer	Theme 11: Intelligence
High	Mission phase • Deficient planning tools (briefing, individual planning, collaborative planning, collaborative mission rehearsal, geographic information, predictive energy requirements, system management) • Inadequate decision-making aids (decision support systems, context awareness) • Inefficient execution (report exchange, orders) • Inefficient adaptation of capability, function, and human machine interfacing based on changing mission role and phase needs • Limited use of user feedback • Limited use of task based adaptation • Limited use of time based / temporal adaptation of capability	Mission phase • Lack of environmentally adaptive tactical communica-tions (to change frequency / power as required by mission phase actions or changes in motion, location) • Lack of flexibly securable communications to enable secure transmissions when required • Limited solutions for adaptive reach back when desired per mission phase needs	N/A	N/A
Medium	Individual and group training • Poor distributed learning capabilities • Lack of simulator-based training • Lack of embedded training • Lack of ad-hoc just in time in field training • Lack of Institutionalized ability to deliver Land Forces (LF) C4ISR training	N/A	N/A	N/A

Rank	Theme 8: Command & Control	Theme 9: Communications	Theme 10: Computer	Theme 11: Intelligence
High	N/A	Integrated communications • Lack of multiple communication links in a single device • Limited growth and flexibility of capability • Insufficient network technologies (limited ability to link into network (COY and below), network awareness) • Insufficient waveform / modes • High cost of dual band, secure, and adaptive communication solutions • Lack of bi-directional cross domain data and voice exchange approaches • Mix of doctrine and security use issues regarding encryption / securitisation level of communications at various user tiers • Lack of cognitive radio	N/A	N/A
Medium	N/A	N/A	Computing integration • Lack of distributed computing capability on one system • Lack of distributed computing on the SCT scale (peer to peer, client server, 3-tier)	N/A
High	Human dimension • Poor cultural awareness • Limited access to stress and coping mechanisms • Limited ability for perception / cognition • Limited creativity and adaptability • Lack of trust and dependency in automation / technology • Ineffective status (comfort) feedback • Inefficient ability of addressing differences in diverse individual backgrounds	N/A	Human dimension • Lack of rapid cultural assimilation and environmental training methods • Lack of language translations for audio and visual input	N/A

Rank	Theme 8: Command & Control	Theme 9: Communications	Theme 10: Computer	Theme 11: Intelligence
High	Navigation • Inaccurate geo-location • Inaccurate orientation regardless of pose and location • Lack of 100% availability of location regardless of environments • Mix of commercial navigation approaches incurs risk for interference, jamming, loss of access in military environments • Lack of integrated navigation aiding from available communications	N/A	N/A	N/A
High	Interoperability • Lack of commonality within the LF and within Coalition (NATO) • Lack of interoperability in a joint, interagency, multinational and public (JIMP) context • Lack of interoperability with Air, Navy and SOF • Lack of interoperability between agencies (OGD, OGA and FGN) • Lack of interoperability with multinational forces when in a Coalition Operations • Lack of interoperability with NGO	Interoperability • Lack of standardisation (architecture, data, symbology, iconography, formats, interface, protocol) • Lack of upper, lower, and cross-tier communications voice and data exchange via common formats and waveforms • See Command & Control Theme	Interoperability • Lack of common platform, secured, vetted, and validated operating systems • Lack of cross-platform application and software operation	N/A
Medium	Group dynamics • Inefficient exploitation of Area of Responsibility • Inefficient exploitation of Area of Influence • Limited command climate (Unit) • Limited cohesion • Limited social Influence • Limited trust • Limited communication, Information and Knowledge Management • Limited exploitation of networked effects between unit participants	N/A	N/A	N/A

Rank	Theme 8: Command & Control	Theme 9: Communications	Theme 10: Computer	Theme 11: Intelligence
High	N/A	Human machine interface • Lack of multi-modal interfaces (effectively interface with all devices through different means and different senses (sight, hearing, touch, smell and taste.) • Limited display capabilities (limited visual display capability, limited auditory display technology / protection / enhancement, no audio spatialisation, limited tactile displays, no olfactory displays) • Over dependence on voice audio and visual displays (when available) • Poor management of cognitive overload • Lack of ubiquitous communications • Lack of context awareness (mission adaptive, posture adaptive, self-awareness, environment awareness) • Lack of user-tailorable or system-adaptive interfaces	N/A	N/A

Rank	Theme 8: Command & Control	Theme 9: Communications	Theme 10: Computer	Theme 11: Intelligence
Medium	N/A	Interference management • Insufficient electromagnetic compatibility amongst different components, systems • Insufficient protection against electromagnetic environmental effects • Insufficient protection against electromagnetic interference • Insufficient inter-environmental interference management • Insufficient intra-environmental interference management • Insufficient management of other modality interference • Lack of standards • Poor shielding • Poor filtering • Poor interference detection • Difficulty to address IM with several future technology approaches for interconnectivity • Differences in use case policies for wired and/or wireless interconnectivity approaches incurs mix of IM issues	N/A	N/A
Medium	N/A	Environmental shielding • Inadequate shielding in day / night operations • Limited shielding in all climactic condition • Insufficient ruggedization • Potential cost to enable throughout system	N/A	N/A

Rank	Theme 8: Command & Control	Theme 9: Communications	Theme 10: Computer	Theme 11: Intelligence
High	N/A	Power/data connectors/ connections • Lack of standards • Lack of common connectors / connections between different computer hardware / peripheral devices and other components, mix of modalities (wired, wireless / cable less, contact, non-contact) • Differences in use case policies for wired and/or wireless interconnectivity solutions • Inadequate protection against environmental factors • Dependency on certain load bearing equipment, chassis/ legacy equipment designs limits innovation in approaches	N/A	N/A
Medium	N/A	Integration within a different language/culture • Challenge communicating in a foreign language • Challenge operating within a different cultural environment • Poor speech intelligibility	N/A	Integration within a different language/ culture • Lack of rapid assimilation training capabilities • Mix of available power and data infrastructure support and interfacing hinders operations • Lack of rapid collection and translation of visual and audio intelligence inputs

Rank	Theme 8: Command & Control	Theme 9: Communications	Theme 10: Computer	Theme 11: Intelligence
High	N/A	Connectivity • Inefficient frequency allocation • Lack of bandwidth availability • Insufficient range (achieving beyond line of sight, inadequate range, power, environment) • Inadequate role based configuration • Inadequate redundant communication • Inadequate space-based communication • Poor legacy systems integration • Poor system management • Lack of standards • Mix of physical connections / pin-outs • Mix of data formats and protocols	N/A	N/A
High	N/A	Voice/data management • Insufficient throughput (ability to send and receive large quantity of voice, and data with limited power) • Poor information exchange mechanism required to manage TX-RX • Lack of unified approach to voice handling (digital IP) • Lack of cross domain capabilities to bridge voice and / or data across differing networks and /or security boundaries	N/A	N/A

Rank	Theme 8: Command & Control	Theme 9: Communications	Theme 10: Computer	Theme 11: Intelligence
High	N/A	N/A	Computing hardware • Lack of standards • Excessive power demand • Limited processing power • Limited computer memory • Limited ruggedized technologies • Limited growth flexibility • Lack of standard architecture / mix of alternative architectures and processors • Cost	N/A
High	N/A	N/A	Computing software • Lack of standards • Lack of cognitive computing • Lack of agent-based systems • Insufficient drill down and reach back capability • Poor usability of software • Poor reuse of software • Mix of operating systems and application/service languages • Lack of cross platform hostable solutions • Lack of standard architectures • Limitations involving open source vs. proprietary software • Lack of virtualization • Impacts to cost/time of development due to military requirements for vetting, test, validation, and security	N/A

<table>
<tr><th>Rank</th><th>Theme 8:
Command & Control</th><th>Theme 9:
Communications</th><th>Theme 10:
Computer</th><th>Theme 11:
Intelligence</th></tr>
<tr><td>High</td><td>N/A</td><td>N/A</td><td>N/A</td><td>Situational awareness
• Inadequate data collection capabilities
• Poor data management capabilities
• Insufficient integration of information
• Lack of effective means to access information (push, pull)
• Inadequate information (Limited common operating picture, Status, Time, Geo-location, Symbology, Iconography, Information exchange
• Insufficient analysis capabilities (Difficulty fusing, filtering, analysing, processing, mining, matching and disseminating intelligence in a timely manner, Timely processing and distribution, Automation)
• Inadequate extrapolation and prediction capabilities
• Mix of standards utilised for data formats, iconography/ symbology, reports, etc.
• Lack of all-tier connectability and information exchange
• Dependency on self-position reporting of friendly units
• Lack of enemy detection and reporting solutions</td></tr>
<tr><td>High</td><td>N/A</td><td>N/A</td><td>N/A</td><td>Information assurance
• Poor reliability of information
• Inadequate trust in information
• Inadequate tamper resistance
• Lack of standards across user groups and equipment
• Mix of use case and doctrinal guidelines for levels of assurance and applicability by user tier</td></tr>
</table>

Annex B: Drivers

Table B-1: C4I Drivers/Constraints

Drivers/Constraints	Implications
Top Level Drivers/Constraints	
Policy	Having the right Policies in place within DND, the CF and the Army will be beneficial to all and will foster greater cooperation and information exchange. Policy areas of relevant C4I impact include: security doctrine and levels of application, process and mandates related to selections of operating systems and application software development and test validation, and interoperable data format and network protocol connectivity standard selections (i.e. Standardisation and enforced compliance to C4I architecture with defined processes, and protocols according to the DNDAF).
Future security environment (FSE)	The FSE will demand more autonomy and decision capability at lower echelons than previously experienced. This in turn will require an increase in information access, exchange, process and management.
Concept of Employment	The growing impressed utility of enhancing soldier capabilities via select systems (position reporting and data/ communications exchange, etc.) will create new efficiencies and approaches to unifying soldier group operations and tasks, requiring revisions to TTPs and CONOPS that currently do not take these enhancement opportunities in account.
Technology availability and resulting uncertainty	The amount of technologies and the speed at which these appear and are replaced will increase exponentially as a function of time (i.e. Moore's Law). The commercial world is the leader in most areas and the Defence industry and the CF will need to learn how to best leverage these rapid advances in science, technology and society while addressing lower than commercial quantities in manufacturing and ruggedized for the military environment. Furthermore, the CF (the soldiers) will need to adapt to new and emerging societal schemes related to the insertion of technological breakthroughs, as well as the associated training to understand how to best exploit and to accommodate these technologies.
SWaP – V	The speed of advancement of technology and computing hardware (i.e. Moore's Law) will inherently lower the cost of technology and decrease the amount of power required by sensors and displays. Technology insertion should enable improved SWaP and mobility due to reduced system volume (especially outward volume).
Cost	Future systems must not be cost prohibitive not only at procurement time but throughout its life cycle. Furthermore, the institutionalizations of new capabilities always have a cost that should be taken into account early in the process of procurement. Examples include: software defined capabilities, wideband bandwidth, flexible tier-use based security, and militarised requirements in COMSEC, TRANSEC, etc.
Security	Greatly impact cost and to a lesser extent SWaP for communications and data systems depending on level of required security (classified versus not classified and as security increase cost goes up) Differing requirements in security between Soldiers, immediate Leadership and higher echelon tiers call for a more tailorable and customisable security, which will result in higher cost based solutions Difference between nation-state definitions or mandates for levels of security and information assurance require versatility in solutions and imply potential cost/SWAP impacts until the technologies required have attain maturity

Drivers/Constraints	Implications
Top Level Drivers/Constraints	
Standards	Connectors/connections compatibility, commonality reduces end costs
	Data oriented information exchange (system independence) increased interoperability while minimising development
	Common data model aids same
	Software standards aid vetting/validation commonality and assurance
	User interface standardisation may enable unified training and operation
	Data transfer protocol (e.g. codec, internet protocols) standardisation aids simplified integration and reduced development
	Information exchange mechanism agreements aids same
Safety	As most soldiers' communications are through radio networks, the HERO and especially HERP impact could become significant
	Batteries energy density is increasing and may present some hazards (e.g., vent and fume)
	As new power sources technologies are emerging like fuel cells, the fuel required may present hazards
HS&I	User acceptance (utility, usability) low, training time high without broader attention to systemic HS&I to all components, actions
	Multi-modal interface to effectively interface with all devices through different techniques and using different senses (sight, hearing, touch (including gesture), smell and taste, biofeedback (e.g., BCI))
	Need for increasing adaptation of "most beneficial" user interface approach based on mission role timing/context
Baseline2010	There will be a need to manage legacy equipment that may or may not have the required connectivity or capabilities to be easily integrated in the future
	The present operations may not offer the proper framework to establish the required CONOP for the future of DSS
	The integration of new C4I equipment on soldiers may impact recent Clothe the Soldier project delivered capabilities
	Conversely, existing carriage/load bearing equipment systems, connection systems, and clothing and pouching selections may set limits to overall solution
Intellectual property	Development of future C4I systems will require the proper management of IP rights
	More collaboration between players
	Lack of knowledge on who works on what technologies and areas
	Lack of knowledge on the patents affecting or covering the DSS technologies and solutions.
	Need to address differences in international criteria for development, licensing/use, and access of intellectual property

Drivers/Constraints	Implications
Command & Control Drivers/Constraints	
Control hierarchy	Legacy hierarchies for communication exchange and command becoming flattened and changed from broader use of per-soldier interconnectivity and situational awareness/reporting systems and require change
TTP / CONOPS	Legacy procedures and functional task assignments and methods do not yet reflect benefits gained in tempo and broader availability of personnel due to networked soldier system effects; often impacts testing of such systems as many are evaluated against "older"/current TTPs vs. true potential utility
Spectrum availability	May restrict frequency and bandwidth available for use in voice and data exchanges resulting in a less than optimum operational use of systems. Requirements for significantly more versatile systems to address the potential exploitation of the larger electromagnetic spectrum are impacted by policies and law nationally and internationally. In any case, these will incur cost and likely impact system SWaP. Different policies for security regarding data, device, operation, or boundaries of exchange will also incur cost and have an impact on system SWaP to enable tiered or customisable systems solutions. • Limited Frequency allocation • Limited radio spectrum (i.e. bandwidth) • Battle space spectrum is congested (more flexible, dynamic spectrum management needed) • Adequate confidence of spectrum availability • Impacts to system / radio design for flexible frequency selection solutions (if pursued)
Denied environment	Impacts to line of sight connectivity are significant with current/legacy frequency and power based communications due to broader influence of fighting environments (increased diversity in terrain, increased urban operation, etc.) Lack of cost effective non line-of-sight (NLOS) communication solutions (to broadly distribute vs. only commanders) exists to aid operation in denied environments Use of commercial GPS integrated with communications for position are highly susceptible to interference and denial in fighting environments and from unintentional and intentional jamming, eliminating effectiveness Use of commercial communications systems lack required security and often perform poorly in areas of interference common to military operations
Commonality and interoperability	Data model commonality and available and accurate data translators throughout the Army and the CF will enable the exchange of timely, pertinent information with the help of gateway or guard permitting cross-domain information exchange with little to no human intervention. Common data model used in international settings (JIMP concept) will foster interoperability through various radio communications network systems gateway and guard and will be especially useful in multinational (combined, coalition) operations. Ability to engage any user seamlessly into operations, regardless of language and system interface reduces training/operation time and increases utility of the system (common symbology, iconography) Equipment interoperability limited due to nation-state and individual developer mix of physical and data formats used in system components, reducing rapid joint integration Often independently-pursued communications programs and large investments by individual nation states create legacy systems impacting interoperability and integration requirements of future systems
Cross domain communication	Mix of security levels utilised in various user tier networks creates secure boundary crossing issues of data and voice not well addressed for cost or integration; dual-direction passing of same difficult due to most doctrine positions not allowing higher-to-lower tier flow down of data/voice Rigid national security posture which is even worse between coalition forces and different from case to case (e.g., ABCA, 4 eyes and 5 eyes impacts operational voice/data exchanges) Lack of cost effective solutions render dual radio utilisation and SWaP-C impacts to primarily commanders, use of operationally inefficient switching between voice radio systems, and limited to no data exchange opportunities

Drivers/Constraints	Implications
Command & Control Drivers/Constraints	
Connectivity	Use of existing civil infrastructure to augment the forces communication capability beneficial in availability but lacks necessary security and interoperability elements common to military tactical communications Networked Technologies • Enterprise networks and tactical networks fundamentally different due to underlying physics of mobile ad hoc networks (MANETs) versus physics of fibre bundle connectivity, complexity of implementation, and cost • Lack of unified network protocol adoption (IP, etc.) limits unified interoperability within various networks • Asynchronous and non-continual presence of most tactical communications challenges network-based connectivity approaches Application-to-application connectivity (users and applications synonymous in the sense that users interact with system via applications) • Applications exchange multimedia information over heterogeneous collection of networks • No prior knowledge of capacity of instantaneous network connectivity between instances of applications • Differences in application data exchange, language/service-based implementations (limiting cross platform hosting and use)
Computing Drivers/Constraints	
Intelligent software technology	Acceptation of virtualization at soldier level Self-healing (e.g., due to data corruption or memory leakage) Platform independence Proprietary vs. open source Mix of OS and languages utilised minimising cross platform utility Mix of security validation, development vetting and verification processes amongst providers Trend progressing from programs to applications and service-based architectures often ahead of legacy investments in military software Large investments in legacy software by most nation states impacts interoperability/hosting requirements for future systems
COTS expectations	Example: younger generation use intelligent phone and have expectations that Military systems should operate in a similar fashion; impacts exist regarding differences in COTS/commercial vs. military process and security / validation needs in development, testing, vetting, distribution, and access to developed software
Embedded instrumentation	This opens up the possibility to having embedded Built in Test System (BITS) in more per component and per-system implementations Help in capturing usage information as to provide focus information to avoid information overload (Infobesity) and for post and real time diagnostics to improve logistics support and reduce downtime Will help to a certain extent to have a system that would be aware of the context in which it operates, first step in raising the level of "intelligence" in the system
Intelligence Drivers/Constraints	
Intelligence hierarchy	Information management (e.g., decomposition for declassification) Information Integration (e.g., accessibility) Prioritization Separation of collection, analysis, and use tiers and hierarchies and limited connectivity between networks and individual participants impacts timely dissemination and application of relevant intelligence

Annex C: Theme 8: Command and Control

Annex C includes the following tables:

- Table C-1: Challenges/Requirements
- Table C-2: Enabling/Emerging Technologies
- Table C-3: Proposed R&D Focus Areas

Table C-1: Challenges/Requirements

Challenges	Priority	Requirements	
		2015–2020 (Horizon 2)	2020–2025 (Horizon 3)
Integration with the CF Command and Control system	High	Increased commonality within the context and constraints of the security policies. The minimum acceptable would be from a security point of view the equivalent of a data-diode between different security domains to provide access control of data to differing security tiers in one direction.	Optimized commonality within the context and constraints of the security policies. The minimum would be the bi-directional flow of information between security domains with autonomous control handling (no user actions required).
System configurability based on role	Medium	Fully configurable system true configuration set-up and menus	Automatically and fully configurable system based on identity and role
Scenario and mission rehearsal capability within the section and platoon	Medium	Partial in-field mission rehearsal capability (infrastructure independent but compatible with WES) and deployable simulation capabilities	Fully capable in-field mission rehearsal (embedded in the system, virtual and augmented reality) and integrated simulation capabilities
Built-in operator and system training capability	Medium	90% of in-field training, system operation fully embedded	100% ability for in-field training activities
Decision aids for mission success	High	Provision of decision aids based on mix of manual and automatic sensor/data inputs	Automated recommended courses of action with select tasks autonomously performed (taking into consideration all aspects of mission and human states).
Accessibility to sensors by dismounted soldiers (sensors and effectors integration – target handoff)	High	Increased on-soldier self, system, weapon, and environmental status monitoring Increased interoperability to fielded and support sensor network data Please see the Sensing Technical Domain for details Access to and exploitation of sensors will impact the throughput of the DSS communication networks In the case of the Target handoff, this should be fully achieved by 2020 for the organic effects applications (SCT & platoon)	In the case of the target handoff, this should be fully achieved by 2025 for the organic effects applications from COY and above. Availability of direct feeds (e.g., video) from all in field organic sensor assets to as-required participants
Multiple communication platforms on soldier to support communication with different partners (dependent on single communications link)	High	Put in place the required R&D efforts and operational requirements (OR) that would define this deficiency and proposed way-forward Enable multiple data link options capability in soldier systems for militarised tactical line of sight options	Enable multiple data link options capability in soldier systems for militarised LOS and NLOS and COTS/commercial communications options This may not be achievable in this timeframe but as the miniaturisation of communications systems continued we may have the capability to add communication links in the future.

Challenges	Priority	Requirements	
		2015–2020 (Horizon 2)	2020–2025 (Horizon 3)
Interoperability in the JIMP construct (consistent approach required)	High	Fully interoperable data interchange with allinternational partners via translation interfacing Put in place the necessary framework to have interoperability within the context of the security policies with Allies (NATO) Taking only a subset of available information aimed at immediate tactical and coordination information at Section level	Fully interoperable voice and data interchange with all international partners Augment the quantity and quality of information to enhance interoperability within the context of the security policies
Backward compatibility (legacy systems)	Medium	Enable/maintain select legacy system interoperability as defined case by case through cost benefit analysis	Transition of hardware / software to open systems architecture to create forward-based adaptable architectures and systems
Data exchange between different security domains and organisations	High	Type 1 to type 3 security cross-domain (data diode). N.B.: There is indication that this line item would be fulfilled by approved technology before 2020 Selectable encryption approaches programmable to systems without replacement	Bi-directional type 1 to type 3 security cross-domain Fully programmable information assurance implementations using indigenous security algorithms from users

Table C-2: Enabling/Emerging Technologies

Technology	TRL (1–9)	Year for TRL 7	Strength (S)/Weakness (W)	Critical Barriers/Gaps	TSC Recommended Action
Embedded instrumentation	4	2020	S: Can enable in-situ health monitoring of equipment, devices, etc. through Built-in-Test, can provide information gathering of system's operation to further optimize the system and below W: Size and cost of electronics	• Cost	Monitor (Rationale: need to improve information integration and management at the soldier's level)
Mission Phase					
Coalition battle management language (C-BML)			S: Unambiguous language used to provide for situational awareness and a shared, common operational picture between C2 forces and equipment conducting military operations W: Software modifications, interfacing of legacy equipment to accommodate requires cost/time		

Technology	TRL (1–9)	Year for TRL 7	Strength (S)/Weakness (W)	Critical Barriers/Gaps	TSC Recommended Action
Mixed initiative interfaces	4–5	2015	S: User interface automatically adjusts to the current C2 task to be done by providing appropriate decision support functionalities W: Complexity in selecting correct modalities and representations to user, issues with customisation and differences in per-user interaction	• Context awareness at system level (application) • High degree of software integration required • Need multi-modal HMI to enable this	(Rationale. Leverage the R&D effort done in lab and companies need to invest into this kind of software and integration)
Case based reasoning	4–5	2015	S: Automatic identification of similar situations W: Complexity in adapting scope and context of current situation, access and use of relevant information, and tailoring TTP/CONOPS for adaptive situations		
Training					
Gaming technology	9	2025	S: Progressive use of artificial intelligence algorithms useful for decision aid work; advanced work in graphics and multi-participant communication useful for future simulation and training W: Lack serious consideration by establishment in Canada		Leverage (Rationale: With millions of user the gaming industry has developed novel interface an way of presenting information
Add-ons to existing service games e.g. VBS2	6	2025	S: (none identified) W: Misunderstanding of the capability offered by this kind of environment.	• Have gaming industry develop and adopt the equivalent of HLA in simulation	Monitor
Training simulator	9		S: DRDC-T asset W: Most current implementations are infrastructure dependent, need to advance capabilities to be infrastructure independent		
Interoperability					
Data exchange standards - JC3IEDM - ADatP-3 (NATO standard, text-based) - USMTF (US and allied nations, text-based) - VMF (Binary) - Link-16 (Binary)	6–9 depen-ding on product type	Now to 2015	S: Existing software based approaches exist to enable cross format/data type translation and interoperability W: Many approaches still too manual, little automatic detection and adaptation	• Cross platform hosting of software • Memory • Cost of approaches and to enhance for automatic adaption	Invest (Rationale: Key enabler to future state of widely interoperable data exchange systems)

Table C-3: Proposed R&D Focus Areas

R&D Focus Areas	Scope/Description (Needs and Opportunities)	Priority Order (1, 2, 3)
Human systems integration (HSI)	Contribution to the development of policy and doctrine for concept development, definition, and acquisition of systems. Please refer to the HSI Technical Domain for more details	1
Augmented reality (AR) training	Need to develop the navigation capability aided and unaided that would provide the localization or position resolution needed to render AR feasible Need to develop the proper human system interface and representation of augmented reality versus normal reality	3
Virtual reality training (full or partial immersion)	Develop a working system to train user on the system, and extend this toward group cooperation in training (game like)	2

Annex D: Theme 9: Communications

Annex D includes the following tables:

- Table D-1: Challenges/Requirements
- Table D-2: Enabling/Emerging Technologies
- Table D-3: Proposed R&D Focus Areas

Table D-1: Challenges/Requirements

Challenges	Priority	Requirements	
		2015–2020 (Horizon 2)	2020–2025 (Horizon 3)
System configurability based on role	High	Fully configurable system for individual and mission role specific capability needs	Automatically and fully configurable system for individual and mission role specific capability needs
System management (radio common interface)	High	Have radio manufacturer deliver a common radio interface standard, so user can then connect to the radio to configure the system and thereafter monitor its state	Have manufacturers implement the common interface standard
Reduced system size	High	Single communications device per soldier Increased integration of communication systems 100% mission-configurable and modular	Integrated NLOS communications in similar single unified device with no volume increase
Efficient and optimized flow of data / information	High	Standardisation of the information exchange mechanism Enable simultaneous transmission / reception of voice and data. Also allow for chat and messaging functions as well as file transfer capabilities and varied traffic	Full implementation of the information exchange mechanism that will optimize the throughput, and synchronization of COP while autonomously accommodating for per-tier security boundaries and adaptively accommodating for fluctuating bandwidth availability

Challenges	Priority	Requirements	
		2015–2020 (Horizon 2)	2020–2025 (Horizon 3)
High throughput for rich services	High	Enable selective bandwidth access and availability to support high throughput data exchange as required between individual users	Enable adaptive frequency and bandwidth sensing communications links (including use of signals of opportunity) to enable continuous high throughput data exchange capability between individual users
Quality of service	High	Enable viable QoS accounting for mix of legacy and new development systems for key / critical data	Enable viable QoS for all interconnected voice and data services
Enhanced network	High	Establishing a robust, fault tolerant, self-forming / healing / relaying mesh network (PAN to MANET) with 30% improvement in power consumption compared to legacy performance. Infrastructure independent	Enable signal of opportunity adaptive communications data links to extend available connectivity for individual user voice and data 50% improvement in power consumption compared to prior era performance
Exploitation of the radio-frequency spectrum	High	Exploitation and usage of the entire spectrum	Exploitation and usage of the entire spectrum
Adaptable waveform	High	Enable communications data links with selectable or programmable waveform	Enable communications data links with automatically adaptable waveform
Reduced multiple frequency antennas	Medium	Minimise antenna quantity through integration of select antennas	Enable unified compact and potentially flexible antenna element for all signal access and interchange needs
Ability to move in, out, through networks seamlessly	High	Establish ad hoc network capabilities that accommodate for asynchronous nature of legacy equipment	Establish automatic adaptive ad hoc network capabilities for all equipment
Operation in denied / degraded signal environment	High	Utilise militarised navigation and communication systems	Enable enhanced unified RF and signal processing capabilities to continuously retain communication & navigation channel access
Security			
Dismounted section, platoon and company level voice and data communities of interest (COIs)	High	Enable selectable COIs for section, platoon, and company level communications Enable ability to monitor 1 COI (objective 2) Enable sufficient (16 SEC minimum plus 1 COY) COIs to be accessible by individual communications system Utilise multi-hop capability in communication system to enable range extension to 10 km terrain dependent	Enable automatically assignable COIs for section, platoon, and company level communications; enable ability to monitor all COIs with collision protection/resolution of messages Enable scalable (up to 32) COIs to be automatically detected and monitored by individual communications system. Enable range extension to 10km terrain independent
Key management systems	High	Secure data communications between mobile devices (use cryptographic keys) Secure key distribution and renewal to enable secure data communications	Lightweight system to reduce overhead Distributed system suitable for distributed networks such as MANETs Hierarchical key management to utilise the hierarchical nature of military organisations
Biometrics	High	Provide identity information for access control and CF intelligence agency Using biometric data collected on the battlefield to identify terrorist suspects	Lightweight system to reduce power consumption Ruggedized system for harsh environment Ease of use and provide non-disruptive re-authentication

Challenges	Priority	Requirements	
		2015–2020 (Horizon 2)	2020–2025 (Horizon 3)
Miscellaneous			
3-D audio restitution	High	Do the R&D industrial effort to put in place, first a standard way of implementing 3-D, second implementation	Ensure that all radios and headset procured for DSS have this capability
Improved infection / comfort-related to C4I equipment (health & safety) (see Human Systems Integration Technical Domain)	Medium	Refer to H&SI section Explore material replacement and alternative modality interfacing	Enable alternative placement and human-integration approaches to minimise contact-based infection opportunity
Optimized UI configurability / usability	High	Enable alternative modality interfaces and implement configurable application	Enable automatic configuration of communications system based on user ID, connected interfaces, and mission role needs
Interoperability with vehicles, sensor platforms and JIMP partners	High	Enable dismounted soldier power recharge from mounted vehicle Enable dismounted data exchange to/from mounted vehicle and select sensor partners Enable GNSS hot start navigation to dismount from mounted vehicle Enable communications interchange between dismount and mounted platforms (intercoms)	Enable data-format adaptive exchange capability between soldier system and select sensor / vehicle / C4I data links

Table D-2: Enabling and Emerging Technologies

Technology	TRL (1–9)	Year for TRL 7	Strength (S)/Weakness (W)	Critical Barriers/Gaps	TSC Recommended Action
Radio The Radio section contains technologies related to wireless TX/RX (the general term "cognitive radio" denotes a radio that modify its transmission (TX) and reception (RX) parameters in order to communicate as efficiently as possible while maximizing the available radio spectrum. The ultimate cognitive radio will be software defined as to change the waveform when needed, it would be Ultra Wide Band to be able to use as much of the radio spectrum as possible. It would avoid collision with other radio signals through sophisticate spectrum sensing. It would be adaptive to the change in the medium, the air, and adapt the best waveform to the situation, exploit multi-path, aggregated multiple channel. Furthermore, it would use Mobile Ad Hoc Network (MANET) techniques to be able to work at high throughput without infrastructure and provide a transparent transition from wired to wireless network. And it would use the appropriate intelligent antenna technique to help the TX/RX. Furthermore it would have a context aware network capability in order to optimize the TX of information and help in providing better security. (see H&SI Technical Domain)					
Cognitive radio	5	2025	S: Will help augment the throughput of radio network by adapting access and frequency detection W: Costly and complex	• The technologies are mostly there on an individual basis. What is needed is a proper architecture and investment	Invest (Rationale: The optimal use of the radio spectrum is a required state if one wants to move growing information available. Some techniques have been demonstrated in real environment)

Technology	TRL (1–9)	Year for TRL 7	Strength (S)/Weakness (W)	Critical Barriers/Gaps	TSC Recommended Action
Adaptive radio with channel aggregation (dynamic spectrum access (DSA))	5	2025	S: (none identified) W: (none identified)		
Software defined radio (SDR)	7	Now	S: Provides flexible waveform hosting/multiple site or situation use with no hardware modification W: Expensive cost, integration effort needed to enable low cost to reduce SWaP	• Software defined radios are available on the market (MOTS) but they still don't have the capability to store multiple waveforms and have the agility to switch between waveform as the communication channel state dictates	Invest (Rationale: Benefits long term flexible use of communications system, must balance against ultimate short term costs however)
Millimetric radio waveforms	4	2020	S: Potential non-typical spectrum communications, useful in spread spectrum wide bandwidth (video) operations and other (imagery) applications W: Power hungry	• Exploit the 10 GHZ and above	Monitor (Rationale: Potential for spectrum-challenged future needs)
Adaptive RF filters	6	2015	S: Would enable same hardware use for various frequency uses W: Complexity, cost, power	• Complexity of sensor/materials, cost/SWAP of approaches	Monitor/Invest (Rationale: Enabler for true SDR/ spectrum adaptive communications system visions)
Multi-band, ad-hoc networking radio	8	2020	S: Could become readily available in MOTS, it is an evolution not a revolution W: Power hungry	• These radios need to become less power hungry • Work has to be done to provide these radios with aggressive power management and use very efficient electronic	Invest (Rationale: Trying to reduce power consumption of these radios should be a priority as they are readily available but represent 50% of the DSS power consumption)
Magnetic wave communications	6–9	Now (commercial equipment for limited power exchange, some communications exchange)	S: Could be used in denied environment like caves, near-field communications positive for contactless interfacing W: Low throughput, limited use	• Variations in approaches create difference in operational separation distances, power possible • Data rate improvement difficult with this modality of use	Monitor/invest (Rationale: Remains one of the few non-contact interface approaches for both data and power (optic for data, challenging for power))

Technology	TRL (1–9)	Year for TRL 7	Strength (S)/Weakness (W)	Critical Barriers/Gaps	TSC Recommended Action
Intelligent Antenna These new technologies (below) are making an entry in the DSS realm through COTS equipment. They offer a gain improvement and a reduction of the SNR.					
Beam forming adaptive array	9	Now	S: Exploit the multipath channel, to: mitigate fading, increase spectral efficiency, counter interference / jamming	• Need to be adapted on DSS radios	Invest (Rationale: This offers a rapid radio SNR gain)
Multiple-input and multiple- output (MIMO)	TBD	TBD	TBD	TBD	TBD
Beam forming switched beam	TBD	TBD	TBD	TBD	TBD
Close Proximity Communication This section regroups technologies that are useful on short distance and can be used in a Personal Area Network (PAN).					
Ultrasonic personal area network (PAN)	5	2015	S: New channels of communication W: Could be detected in close proximity (100 m), throughput will be low	• Emissions • Range • Power requirements	Monitor (Rationale: One viable PAN approach)
Information Exchange Techniques and technologies that will improve the transfer of information across a radio network.					
Mobile ad-hoc networks (MANETs)	5	2025	S: System of autonomous stations W: Security issues	• Security • Scalability • Policy	Invest (Rationale: Military network centric warfare (NCW) systems are highly networked & require using MANETs for successful end to end mission execution)
Multiprotocol label switching (MPLS) applied to DSS radio networks	6	2025	S: Offer way to manage network traffic and help improve efficiency W: Add to the size of information to be exchanged	• Need to be implemented in radio network • But study first if feasible and useful	Invest (Rationale: Need to characterized if there are marked advantages in implementing this protocol on radio network)
Biometric	7	2012	S: Direct user binding and ease of use W: Privacy issues	• Ruggedized biometric devices	Transition (Rationale: Enabler for identity management, physical and logical access control)

Technology	TRL (1–9)	Year for TRL 7	Strength (S)/Weakness (W)	Critical Barriers/Gaps	TSC Recommended Action
Range Extension and Information Wide Distribution					
Digital video broadcasting – return channel via satellite very small aperture terminal (DVB-RCS VSAT)	6	2020	S: Adapting existing technology to be used by DSS to be able to bridge the NLOS communication S: Already tested by NATO to support dissemination of imagery and ISR in NATO MAJIIC	• SWaP • Cost • Security level.	Leverage (Rationale: As the cross-domain security solution will mature this will be a way to gain rapid access at much needed intelligence)
Airborne platform	7	2015	S: Offer an easy way to extend range without loading the soldier W: May become target of their own	• Tactical micro UAVs • Improved MANET solutions matched to SWRs	Monitor (Rationale: Use airborne repeater to extend range and served as a relay)
Human Machine Interface					
Bone conduction audio display	9	Now	S: Avoids ear blockage, infection issues, can receive input W: Very susceptible to external noise, difficult to use covertly (whispers)	• Ergonomics • User acceptance	Monitor/leverage (Rationale: Potential future utility in embedded forms)
Ear canal moulding / head scanning technologies	9	Now	S: Custom fitted audio performs better with improved safety W: Time, high expense to identically fit vs. use variants of types	• The technology exist (ref: Sonomax) but need to be adapted to in-ear display	Leverage (Rationale: In-ear audio trend increasing for blast protection and ambient sound retention)
Spatialisation of sound (3-D audio)	5	2020	S: Help the soldier in lowering his fatigue, and lower the needed attention to separate the voice and alarm in the headphone, head related transfer function exists and can be implemented (as been done in airlines W: Cost, may need to alter the radio circuitry at the audio out stage W: may need to add meta data to voice data transmitted to be able to manipulate it	• Codec • This could be the single most important effort in the HMI and it would really have a good impact	Leverage / invest (Rationale: Common in the airline industry. Adapt technology from aviation world)

Technology	TRL (1–9)	Year for TRL 7	Strength (S)/Weakness (W)	Critical Barriers/Gaps	TSC Recommended Action
Language / Culture					
Speaker recognition	4	2025	S: Can be use a biometric to be authenticated on a computer; good for hands/eyes free IF W: Require processing, therefore power, if badly implemented users will reject it, covert issues	• Speaker • Data corpus acquired or created • Processing effort to achieve quickly and with near exact success	Leverage/invest (Rationale: One of the more positive / natural eyes/hands free input/ output but requires accuracy to work)
Automatic speech recognition (directed speech)	8	2015	S: Simple to implement and really robust W: If badly implemented users will reject it	• Dismounted soldier voice data corpus to optimize engine	Leverage/invest (Rationale: Reduced command speech aids accuracy significantly)
Automatic speech recognition (free speech or natural language processing)	8	2020	S: Can improve human machine interaction and permit the users to fill in complex report W: If badly implemented users will reject it	• Dismounted soldier voice data corpus to optimize engine	Monitor (Rationale: Difficult to achieve accuracy; look to capture audio file attachments in near future for reporting)
Speech synthesis	8	2015	S: Better to produce alarm, good natural IF W: if badly implemented users will reject it, aural only	• Recognition through noise of battle • Language translation • Syntax correctness • Cognition	Leverage/invest (Rationale: Good enhancement to simpler audio cueing if utilised for high information content updates)
Interoperability					
Waveforms	7	2020	S: Would permit to have the best throughput and the best range any time W: Complexity the radio system, no radio in sight that would permit the on the fly change of its waveforms	• No easily available waveforms exist (should be a standard possibly NATO) • Need different ones for different environments • One of the basis of cognitive wireless mesh network	Invest (Rationale: Need to have different waveforms to adapt the TX/RX to the soldier's environment and be able to manage the information avalanches that are coming)
Security cross-domain system	6	2020–25	S: Offer the capability to have security cross-domains communication W: May add another box on the soldier if not brought into a well though architecture, takes power	• CF security posture waiting for NSA approval • Technology is available but need to be CSE approved	Monitor/invest (Rationale: This technology would offer a nice way forward to link from top to bottom the CF especially in this case the DSS to the LCSS.)

Table D-3: Proposed R&D Focus Areas

R&D Focus Areas	Scope/Description (Needs and Opportunities)	Priority Order (1, 2, 3)
Cognitive mesh network radio	Define and conceive a radio that would bring at soldier's level at an affordable cost and SWaP all the advantages of cognitive radio with the added bonus of being able to create a mobile ad hoc network	1
Power and data infrastructure	All ready noted and taken care in the Power/Energy Technical Domain	1
Adaptive spectrum analysis and detection capabilities	Develop low cost, highly integrated being low processing dependent radio component that would sense the radio spectrum and the quality of the medium opening the door to adaptive radio that would exploit more fully the available radio spectrum (frequency, bandwidth) and possibly waveforms. This is a key component of cognitive radio technology.	3
Security and reliability of mobile ad hoc networks (MANETs)	To provide secure and timely information exchange in a dynamically-reconfigurable mobile networks in accordance with both coalition and national security policies	TBD
Wireless networking for biosensor	Recent advances in novel biological sensing materials, low-power wireless communications and high-performance microprocessors have stimulated great interest in the development of wireless biosensor networks (WBNs). Several vital body parameters can be monitored by WBNs. There are many military and civilian applications of WBNs such as authentication in secure information communications, healthcare and telemedicine.	TBD
Biometrics	Automatic recognition of a person based on distinctive physiological (fingerprint, iris, face) and behavioural (voice signature, gait) characteristics	TBD
3-D audio radio communication and audio restitution (alarm, cueing, speech to text, etc.)	Using different technology like HTRF the sound is placed in the three dimensional space around the head of the soldier to enable a discrimination of the different sources of sound (e.g., the voice coming from your commander appear to be emerging from above you head). While your team voice comes from the front and alarm on the right and cueing would move according to your head position and orientation.	1
System management radio common interface	This is to have a standard way to communicate with the radio internal to do setting up and interrogate the radio on is status and the link's status	2
Voice data corpus	Acquired or create a dismounted soldier voice data corpus representative of the Canadian Army gender mix and covering realistic noise environment (ambient sound) to be able optimize the speech recognition engine	3

Annex E: Theme 10: Computer

Annex E includes the following tables:

- Table E-1: Challenges/Requirements
- Table E-2: Enabling/Emerging Technologies
- Table E-3: Proposed R&D Focus Areas

Table E-1: Challenges/Requirements

Challenges	Priority	Requirements	
		2015–2020 (Horizon 2)	2020–2025 (Horizon 3)
100% mission-configurable and modular	Medium	Utilise modular, replaceable components	Enable fully configurable reprogrammable system elements
Reduced weight	High	50% less than present systems	75% less than present systems
Reduced bulk	High	Utilise distributed and federated designs to distribute volume	Utilise conformal and potentially flexible constructs to reduce volume

Challenges	Priority	Requirements	
		2015–2020 (Horizon 2)	2020–2025 (Horizon 3)
Optimized operational efficiency of man-machine interface (input/output) to maximize usability	High	Utilise multimodal interfacing tailorable to the user preferences	• Reduced cognitive load • Adapted for mobile user • Adapted for mission phase • Easily trainable, intuitive operational interface • User driven design
Address Technical and Use (ergonomics, HF) Challenges for the Following:			
Voice (speech synthesis, automatic speech recognition)	High	Utilise directed voice recognition	Enable free speech recognition
Visual input and output	High	Enable gesture detection	Enable lips reading, eye movement
Audio input and output	High	Sound, tonal	Speech synthesis
Haptic (tactile) input and output (sensitive surface, vibrators etc.)	Medium	Feedback (alerting/cueing)	Information display
Brain computer interface (BCI)	Medium	The BCI must have been demonstrated in relevant environment	The BCI must be integrated to the future head borne system
Improved infection / comfort-related to C4I equipment (health & safety) (see HSI Technical Domain)	Medium	Refer to H&SI Technical Domain Explore material replacement and alternative modality interfacing	Enable alternative placement and human-integration approaches to minimise contact-based infection opportunity
Improved ruggedization – overcoming operational wear/tear	Medium	Enable relevant standards to all elements of soldier system equipment	Enable stretch metric standards to environmental and exposure requirements for all soldier system equipment
Provide scalable high fidelity visualisation capability in a small form factor "device" of any modality	High	Enable increased resolution viewing of selectable display element	Enable see-through increased resolution viewing of selectable display element if on eye
Provide enough processing power to meet the processing requirements stated in all the themes	High	Enable 75% capability in processing vs. current capability at similar power impact	Enable 150% capability in processing vs. current capability at similar power impact

Table E-2: Enabling/Emerging Technologies

Technology	TRL (1–9)	Year for TRL 7	Strength (S)/Weakness (W)	Critical Barriers/Gaps	TSC Recommended Action
Brain computer interface	5	2015	S: Available for gaming, need training and CPU cycle W: (none identified)	• Level of error	Invest
Hardware					
RFID TAC	TBD		S: Technology keeps devices silent and sleepy till selective activation performed W: (none identified)		

Technology	TRL (1–9)	Year for TRL 7	Strength (S)/Weakness (W)	Critical Barriers/Gaps	TSC Recommended Action
Low power processors	9	2015	S: (none identified) W: (none identified)		
Low power algorithms	5	2020	S: (none identified) W: (none identified)		
Low power, low energy waveforms	6	2025	Develop high efficiency MANET waveform not based on beaconing		
Power optimization • DSP • FPGA • GPP	7	2025	S: (none identified) W: (none identified)		
Communications electronics			S: Adaptive communications, reduce power to necessary level based on SNR W: (none identified)		
Micro-projection system	5	2020	S: (none identified) W: (none identified)		
Computer vision	5	2025	S: (none identified) W: (none identified)		
Software					
Cross platform operating systems and languages	7–9	2010	S: Java-and related open platform language based applications can be hosted on multiple platforms, have single support point W: Limited availability in this form, need for securitisation and military test/ validation/ vetting	• Large legacy software investments worldwide not formulated in this manner • Cost/time for validation and development	Invest (Rationale: Trend forward for more supportable software elements)
Open source software utilisation	7	2010–2012	S: Low cost OS access, some cross platform host ability, leverage wide support base W: Limited securitization or validation for military operations	• Non-military development process	Invest (Rationale: Best long term support OS strategy)
Service-oriented architecture (SOA) UML, SysML	7–9	2012	S: Aids rapid feature development in existing platforms while minimising cost/time of same, symbolic method to map complex system design elements that translates to actionable code and diagramming W: Complex to initiate, cost, requires linkages to other systems for full benefit, requires adapted framework software approach not present in many systems	• Legacy software systems lacking support frameworks • Conversion costs/time to enable SOA ability functions vs. standalone programs • Other barriers: standardisation, adoption, learning curve, cost, expertise	Monitor/Invest (Rationale: Trend forward for software architectures)

Technology	TRL (1–9)	Year for TRL 7	Strength (S)/Weakness (W)	Critical Barriers/Gaps	TSC Recommended Action
Extensible Mark-up Language (XML) and other standards • Cap • Capan • GeoRSS • Oasis • Mas • C#	TBD				
Power / Data Connectors / Connections					
Wireless small network • Bluetooth • Zigbee • Z-wave • UWB	9		S: Low cost commercially available and easy to implement W: Non-secure network and easy to jam		
Induction	5	2025	S: (none identified) W: Low efficiency	• Improve efficiency • Detectability • Radiation	Invest (Rationale: Need to invest to make the technology more efficient - in the order of 90%)
Smart fabric: • Flat Cabling • Metal Rubber • Electro -textiles	7	2015	S: Capability exists in various forms today (see PPE Technical Domain)	•Shielding solutions and impedance adaptation	

Table E-3: Proposed R&D Focus Areas

R&D Focus Areas	Scope/Description (Needs and Opportunities)	Priority Order (1, 2, 3)
Flexible customisable interfacing materials and approaches	Advance select interface technologies using RF, magnetic induction, optic, and other means to eliminate cabling between soldier-worn devices and between soldier-mounted platforms (i.e. advance select "second skin"/sew able or integrated material approaches to enable data/power connectivity between devices on/within a tactical vest)	2
Advanced hybridized multimodal interface development and evaluation	Advance and identify most beneficial combinations of multimodal interface elements for soldier mission role relevant actions and needs	1

Annex F: Theme 11: Intelligence

Annex F includes the following tables:

- Table F-1: Challenges/Requirements
- Table F-2: Enabling/Emerging Technologies
- Table F-3: Proposed R&D Focus Areas

Table F-1: Challenges/Requirements

Challenges	Priority	Requirements	
		2015–2020 (Horizon 2)	2020–2025 (Horizon 3)
Exchange large volumes of information	High	5 Mb/s data exchange within the 10 Watts power budget	100 Mb/s within the power budget and allowed frequency band
Avoidance of information overload	High	Enable multimodal user adaptive interfacing to improve cognitive absorption of information	Enable autonomous decision aid and course of action (COA) analysis applications to extend cognitive understanding and improve response of user to information
Timely information	High	Relevant information is delivered in a timely manner with at most 5 minute delay	Relevant information is delivered in a timely manner with at most 1 sec delay
Thorough information	High	Information is complete with some access to background related information through drill-down capabilities. Access to full detail is limited	Information is complete and fully accessible when desired
Pertinent information	Medium	Pertinent information may cover less than required but need to be pushed to the dismounted soldier	All pertinent information is accessible by the dismounted soldier – significantly improved Information and Knowledge Management
Timely and accurate common operating picture	High	Information is maintained relevant by continuous synchronization of information between all nodes within the Canadian Land Forces	COP within the Canadian Joint Forces, and JIMP environment is achieved. Relevant (surrounding information) is accessible, and information not related directly to the battlefield but relevant to the operation (i.e. cultural information) is accessible
Task force wide high confidence Blue PA	High	Provide validated information assurance (IA) approach to Blue PA data exchange systems (data, processing, communications, C4I)	Enable active spoofing and intended error detection algorithms in Blue PA IA data exchange systems
Support situation analysis	Medium		
Accurate navigation / location awareness in 3 axis positioning regardless of signal environment	High	Retention of GPS equivalent accuracy over 60 minutes. Near term goal is 1 m within 1 sec.	Retention of GPS equivalent accuracy over 24 hrs. Long term goal is 0.25 m within 1 sec. Enable altitude at position within 2 m (1 building floor separation)
System security			
(protect against cyber-attack, unauthorised access)	High	Provide an information guard (stand-alone) and a security solution to bridge different security domains	2015 – 2020 requirement integrated into the communications equipment and perform autonomous securitization and information assurance
Signature management	Medium	Provide control of RF emissions from soldier-worn devices and systems such that signature detection is denied at a radius of 1m from user	Provide control of RF and other emissions from soldier-worn devices and systems such that signature detection is denied

Challenges	Priority	Requirements	
		2015–2020 (Horizon 2)	2020–2025 (Horizon 3)
Scale able security of data when in transit or when at rest	High	Provide security bridge function to allow one way exchange of select data; Enable selectable security hardware/software to provide FIPS to Type 1/US security of data at rest or in transit	Provide bi-directional security bridge capability to enable mixed tier secure data links to exchange select data without user involvement
Standards / agreed guidelines for information assurance and security	Medium	Define relevant standards for information acquisition, storage, use, and dissemination for soldier environment and equipment	Implement relevant standards as defined previously
Accreditation	Medium	Define required accreditation of methods, systems, and processes related to soldier information access	Implement said methods

Table F-2: Enabling/Emerging Technologies

Technology	TRL (1-9)	Year for TRL 7	Strength (S)/Weakness (W)	Critical Barriers/Gaps	TSC Recommended Action
Information					
Information and Knowledge Management	6	2015	S: (none identified) W:Large memory and fast CPU	• Proper on the fly classification	Leverage
Decision aids	5	2020	S: Can reduce time to understand and analyze information in order to act appropriately; eases cognitive workflow W: Limited by data base of events and learning algorithms, communications access	• Algorithm development and creation of a data corpus	Invest (Rationale: Key enabler for enhancing cognition and reducing r/t OODA loop actions)
VIRT (valued information at the right time)	6		S: Smart push information exchange mechanisms - publish and subscribe using notification W: (none identified)		
Meta data tagging standards	7	2015	S: Ability to subscribe to info/intel produced by OGDs and Allies and engage using chat or other means W: Standardization required, software implementation in most systems not enabled	• Format acceptance • Software implementation and validation	Invest (Rationale: Conversion aids interoperability of software)
Cross-boundary (domain) guards	4-6	2015 (diodes)	S: Ability to subscribe to info/intel produced by OGDs and Allies and engage using chat or other means, ability to connect to upper tier C2 and exchange data significantly needed W: Security doctrine restricts exchanges in direction and flow if levels are different	• Doctrine • National policy issues • Native state IA and cryptographic preferences • Accessibility and interconnection between soldiers, leaders, and C2 infrastructure	Invest (Rationale: Key need to resolving and enabling true cross networked force and exploiting most benefits of same)
Coalition battle management language (C-BML)	3		S: Digitized representation of tasks and orders to support exchange between soldiers and soldiers and C2 systems and soldiers and robots W: (none identified)		

Technology	TRL (1-9)	Year for TRL 7	Strength (S)/Weakness (W)	Critical Barriers/Gaps	TSC Recommended Action
Electronic biometric transmission specification (EBTS)			S: (none identified) W: (none identified)		
Computer algorithms to process information			S: (none identified) W: (none identified)		
Session description protocol (SDP)			S: Format for describing streaming media initialization parameters W: (none identified)		
Collaborative tools • Wikis • Blogs (weblogs) • Social networking • Chat applications e.g., teleconference facilities • Desktop office suites (including simultaneous editing tools) • Online collaboration environments • Networked simulators and trainers • Interaction of avatars in simulation environments • Web publishing and web based content management systems that allow for rapid global dissemination of information products and real time development and tracking of issues	9	2020	S: Includes broad perspective inputs, can enable rapid information acquisition W: Lack of structured vetting, relies on the willingness of the participants to provide more information and content as well as validation, issues of quality due to unlikely use/posting of proprietary information exist	• Adoption by establishment	Invest (Rationale: Sharing of information)
OLAP	9		S: Define meta data for heavy information sources and publish meta data on the net instead of raw data W: (none identified)		
Algorithm fractal pattern mapping identification application awareness			S: (none identified) W: (none identified)		

Technology	TRL (1-9)	Year for TRL 7	Strength (S)/Weakness (W)	Critical Barriers/Gaps	TSC Recommended Action
Common Operating Picture					
Standard iconography and symbology	9	2010	S: Aids common understanding of interoperable systems and participants, reduces training needs and confusion W: Differing policies, approaches, and capabilities to modify or enable exist between nation states	• Nation-state policies, software investment for adaptation • Formalized standardization	Invest (Rationale: Key to truly interoperable systems use)
Geographic information systems	9	2010	S: Vetted "engines" exist to manipulate geographic information system data for mapping, SA W: Cost, memory, proprietary nature of many or vetting/ validation of independent versions	• Software standards utilized • Licensing and/or vetting of engines • Format translation methods and standards • Cost/memory/processing impact for use	Leverage (Rationale: Core enabler to most SA systems needs)
3D visualization software		2010			
Common symbology	5	2015	S: (none identified) W: Need to be put into a standard (APP6 /MIL-STD 2525)	• Study completion and acceptance NATO wide	Invest
Geographical approximation algorithms			S: (none identified) W: Algorithm needed to automatically determine center of mass of an organization based on locations of elements		
Navigation / Location Awareness					
Extensible Mark-up Language (XML) and situation awareness and mapping standards • Cap • Capan • GeoRSS • Oasis • Mas	6	2011	S: (none identified) W: (none identified)		
Inertial Sensor Technologies • Gyroscopes • Accelerometers • Inertial azimuth	9	Now	S: Maintain attitude, can estimate difference in position/ range/ attitude/ velocity W: Relative only, drift over time, cost/ SWAP impractical for individual use	• Sensor drift with time • Cost / weight of stabilized sensors	Invest (Rationale: Progress positive but additional development required to meet promise of low cost/lightweight/high accuracy devices)

Technology	TRL (1-9)	Year for TRL 7	Strength (S)/Weakness (W)	Critical Barriers/Gaps	TSC Recommended Action
Velocity and Distance Travelled Sensors					
Speed sensors					
Pedometers					
Doppler velocity sensor					
Zero velocity update					
Visual odometry					
Orientation (Heading) Sensors					
Magnetic compass					
Digital magnetic compass (DMC)					
Magnetometers					
Gyrocompass					
Inertial measurement units (IMU) (i.e., dead reckoning system, MEMS inertial sensors, etc.)	7	now	S: Inexpensive INS near equivalent sensing aid W: Poor performance over time, higher errors than INS	• Sensor stability and construction • Selection of sensors • Algorithms of use	Leverage/invest (Rationale: Can utilize in tactical time scenarios now; push for integration with GPS/GNSS/SV navigation as first step towards 100% availability solutions)
Altitude / Depth Sensors					
Barometric altimeter	7-9	2010	S: Inexpensive method of assessing non-GPS based altitude W: Pressure modality susceptible to error & environmental changes, accuracy limited	• MEMS capability • Power consumption of advanced approaches and size	Leverage/invest (Rationale: Beneficial sensor to augment terrain database relationships in SA)
Radar Altimeter					
Water Depth					
Time of Arrival / Time Difference of Arrival (Range)					
Satellite: global positioning system / GNSS	1-9 (some GNSS in work)	2010	S: Worldwide signal in space access to precise time and absolute positioning, additional augmentation and separate services exist or in work, combination of GNSS enables higher availability and accuracy W: Need for line of sight to sky or other augmentation, susceptibility to RF interference	• Investment (other GNSS services) • Interference from other RF sources • LOS to sky operation • Militarized secure operation and interference resistance costs	Leverage / Invest (Rationale: Key enabler for position reporting / SA)
Satellite: New military GPS M-Code	5-6	2012 (full capability 2018)	S: Better accuracy, security, authenticity, anti-jam, allows satellite "flex power" and "spot beam", spectrally separate from civil C/A signals, 8 M-Code satellites in orbit now, initial capability in 2012, full capability in 2018 W: (none identified)		

Technology	TRL (1-9)	Year for TRL 7	Strength (S)/Weakness (W)	Critical Barriers/Gaps	TSC Recommended Action
SAASM	9	2007	S: Approved access module for PPS GPS in compact form W: Cost, size, power	• Technology investment • Government control/ influence of design	Leverage (Rationale: Aids existing COTS GPS susceptibility issues)
GPS augmentations					
LORAN-C					
eLoran					
Distance measuring equipment (DME)					
Ultra wideband					
Angle (Bearing Determination)					
VHF omni directional radio-range (VOR) system					
TACAN					
Ranging					
Optical mono/ SLAM ranging	6	2015	S: Inexpensive method of deriving ranges using single/dual camera systems as navigation aid and for mapping W: Dependent on other navigation solution/orientation sensors, limited modality to visual environment (smoke/ dark/fog)	• Processing, software, and integration of typical sensor system into inexpensive viable package • Addressing error sources (body pose, etc.)	Monitor/invest (Rationale: Work in progress from vehicular solutions during mid 2000's now becoming feasible to apply to dismounted system aids)
Ultrasonic ranging	5	2020	S: Potential independent ranging aid developed at low cost, usable for indoor scenarios and for mapping W: Range limited, susceptible to multipath issues	• Signature masking • Multipath/processing of signals • Maturity of approach	Monitor (Rationale: Growing alternative aid)
Optical LIDAR ranging	7	2015	S: Mature and becoming more compactly integrated ranging/ mapping/object detection aid especially for mounted solutions, precise W: Can be range limited, size/weight/ power to operate in dismounted form/costs	• Integration/SWAP-C for dismounted operation/ aiding • Processing to utilize data for navigation and/or mapping	Leverage (Rationale: Good progression from mature existing technology to navigation/mapping aid)
Radar	4	2025	S: Usable navigation and mapping and object detection aid, used in field sensor systems and larger platform sensors W: SWAP-C and integration for dismounted use, power management regarding potential body-worn capability for safety	• Integration/SWAP-C/power management and frequency of use vs. capability vs. safety issues • Processing to utilize data	Monitor (Rationale: Open area for exploration/ leveraging in mounted/ dismounted navigation /mapping/object detection space)

Technology	TRL (1-9)	Year for TRL 7	Strength (S)/Weakness (W)	Critical Barriers/Gaps	TSC Recommended Action
Radio ranging	7	2015	S: Capable-now navigation aid via various methods of estimating range between communications broadcasts W: Multipath, processing challenges for use, impacts of frequency and coding/ ranging choices applied, lack of capability in legacy radios	• Utilization of widely applicable coding/ranging waveform/ method for legacy and "new" communications/ data links • Processing, signal complexity and error mitigation	Leverage/invest (Rationale: Good signal of opportunity addition to needed/dependent data link/ communications systems relevant to C4I systems
Laser rangers	7-9	2015 (compact / low cost)	S: Most viable current method for long distance range estimation of targets of interest, can be fairly compact W: Cost, power consumption, current state size and technology, visibility/ detectability	• Laser technology, other supporting technology that may replace lasers insufficient at ranges, technology investment in more compact/ low power form	Invest (Rationale: Key enabler to "ever soldier a forward observer" scenario)
Signals of Opportunity					
Signals of opportunity detection and automation of use	4	2025	S: Enables true use of available spectrum, increases range, availability of required data links W: Maturity, processing, integration low, complex/cost/power	• Complexity/integration of techniques and hardware/ software • Cost/SWAP • Processing impacts for relevant frequency/power evaluation and adaptation	Monitor (Rationale: Challenging but valuable long term goal)
Radio / TV broadcast signals					
Mobile telephone positioning					
Radio-ranging / cooperative localization					
Radio signal triangulation					
Feature recognition triangulation: ultra-wide band					
Feature recognition triangulation: architectural representation					
Database Matching					
Map matching					
Image matching					
Laser imaging					
Terrain referenced navigation					
Celestial navigation					
Gravimetry					

Technology	TRL (1-9)	Year for TRL 7	Strength (S)/Weakness (W)	Critical Barriers/Gaps	TSC Recommended Action
Bio-Inspired Navigation					
Light polarization					
Landmark					
Magnetic					
Echo					
Olfactory					
Multi-Sensor Integration					
Kalman filter integration					
Loosely coupled					
Tightly coupled					
Deeply integrated / ultra-tightly coupled					
Novel integration techniques					
MMAE - multi-model adaptive estimation					
Sigma-point (Unscented) Kalman filter					
Particle Filters					
Miscellaneous					
Gravitometrics	3	2025+	S: Unique approach to locate via use of individualized gravity vector mapping around world W: Lack of resolute models and suitable sensors, cost/SWAP-C	• Lack of suitably resolute gravity models and dismount-relevant sensors	Monitor (Rationale: Long shot technology)
Astrometrics	7	2025+	S: Capable-now approach using star matching to extrapolate terrestrial locations, accuracy good W: Cost/SWAP, precision for broader dismount/mounted operations not there, environmentally dependent (see sky/ conditions, etc.)	• Environmental dependencies to overcome, SWAP-C • Processing issues for use as navigation aid	Monitor (Rationale: Interesting to look for inexpensive camera-based approaches here to enable initial aids via this technique)
Augmented reality	7	2015	S: (none identified) W: Greatly influenced by positional error	• Navigation accuracy	Invest

Technology	TRL (1-9)	Year for TRL 7	Strength (S)/Weakness (W)	Critical Barriers/Gaps	TSC Recommended Action
Security					
Embedded firewalls		2010			
Intelligent defensive measures					
Intelligent monitoring: intrusion detection system					
Intelligent monitoring: misuse detection					
Data encryption / decryption		2010			
Public key infrastructure					
Encryption algorithm					
JANUS MCM by Rockwell Collins with turnstile CDS	8-9	2010	S: Develop IA encrypted key management policy for S to TUI, vice versa use MILS crypto solution within system with crypto bypass for management of black data passed on may then be formatted for desired interoperability W: Size, cost, power	• Continued technology integration investment	Invest (Rationale: Key enabler for cross domain solution based network access in force)
Context parser for structured data	6-9				
Data packet keyword parser for digitized VOX and Free text	5-6				
Security guard	5	2012	S: (none identified) W: Power consumption	• Low power • Cost • Acceptance	Monitor (Rationale: In advanced prototype state; starting inspection and acceptance (NSA))

Technology	TRL (1-9)	Year for TRL 7	Strength (S)/Weakness (W)	Critical Barriers/Gaps	TSC Recommended Action
Selective security approach (hardware/ software)	7	Now (not at needed costs/ SWAP)	S: Scale able encryption enables multi-tier data exchange W: Cost/SWAP, different policies in levels of security/IA	• Integration of software / hardware in low cost form • Certification process for type of securitization (vary by nation-state)	Invest (Rationale: Key to providing protected C4I data exchange)
Handheld interagency identity detection equipment (HIIDE)			S: Iris, fingerprints, face picture W: (none identified)		
Individual combatant identification (iCID)					
Authorization					
RF tag					
Intelligent dog tag					
Smart card					
Input code					
Facial recognition		2010			
Speaker recognition		2010			
Finger/palmp		2010			
Eye scan		2010			
Scent recognition		2010			
DNA recognition		2025			
ECG Recognition					
EEG recognition					
Handwriting recognition		2010			
Behavioural traits					
Detection					
Emission controls: peak limiting					
Emission controls: adaptive power designs					
Emission controls: burst technology					
Emission controls: frequency hopping					
Emission controls: spread spectrum					

Technology	TRL (1-9)	Year for TRL 7	Strength (S)/Weakness (W)	Critical Barriers/Gaps	TSC Recommended Action
Emission controls: ultra-wide band					
Emission controls: sub-banding					
Magneto – inductive technology					
RF power management & brainstorming technique					
Electromagnetic noise cancellation waveform					
Seismic avatar					
Acoustic avatar					
EM avatar					

Table F-3: Proposed R&D Focus Areas

R&D Focus Areas	Scope/Description (Needs and Opportunities)	Priority Order (1, 2, 3)
Information collection, management, filtering, retrieval	Information is collected in a data cloud via an agent gateway from multiple interfaces. The information can be accessed / pulled from this information cloud through filters, areas of interest using this search engine and output is provided based on relevance (refer to DKKN).	1
NATO symbology – dismounted infantry soldier	Standardisation of symbology throughout all systems and users	1
Securable range/bandwidth relevant data/voice communications	Individual/section/platoon level communications suitable to provide C4I data exchange bridge	1
Low cost selectable-security encryption	Inexpensive (relative to use with individual soldier system) selectable encryption (commercial/ FIPS/Type 1 US) device/approach for data at rest and in transit use	2
Navigation aiding	Invest in select augmentation and aids to enable vision of 100% available, mission-relevant accurate position/navigation sources at the individual level	2
Sensor integration/processing	Invest in identified algorithmic development to enable scaled-down sensor aid approaches/ techniques to be suitable for dismounted processing systems	3
Radio ranging layering	Expand ability to use different ranging or position locator technologies in a layer of capability and accuracy to be able to support and enhance the GNSS ability. These location informations would be used to locate with more accuracy and improved precision. These information would be exchange over the radio links utilised in C4I.	3

Chapter 8: Sensing

8.1 Introduction

This technical domain combines a number of topics related to sensor systems and directly relates to the NATO soldier systems capabilities of C4I and indirectly to the other four technical domains. For the purpose of this report, a sensor system is composed of an operator/user, sensors, sensor carrier, data communication system and a computer system. Passive sensors simply measure and report on, via their response signals, whatever they detect in their local environment. Active sensors, on the other hand, typically stimulate the environment by generating and emitting known signals, which propagate out to the objects or targets of interest, interact with them, and reflect or scatter energy back to the sensor, which then responds as in the passive mode.

Sensing-dependent tasks and missions include: situational awareness, Identification Friend or Foe (IFF), surveillance, threat detection, identification and localization, weapons targeting, tracking, cross-cueing and logistics and maintenance.

Non-exhaustive, sensor-dependent tasks and missions include: Health Intervention and Monitoring System, Intelligence, Surveillance, Target Acquisition and Reconnaissance (ISTAR), Battlefield Combat Identification (BCID a.k.a. IFF), Threat Detection Recognition, Identification, Localization (DRIL), weapons targeting, threat and target tracking, logistics and maintenance. All of these, and others, benefit the user by enhancing the input of knowledge, which is the integral part of the situational awareness (SA) generation process.

This technical domain has been divided into four broad themes:

- Theme 12: Personal Sensing (Body-Worn)
- Theme 13: Weapons-Mounted Sensing
- Theme 14: Crew-Served and Hand-Held Sensing
- Theme 15: Unattended Area Sensing

Please note that sensors related to the interface are not part of this scope and are covered under the C4I technical domain (see Chapter 7). The Sensing technical domain is depicted in Figure 8-1. The sensing domain, as shown in Figure 8-1, is important as it is feeding the command function where decisions are made and leads to actions to take (e.g. exercise, fire power (weapons effects)).

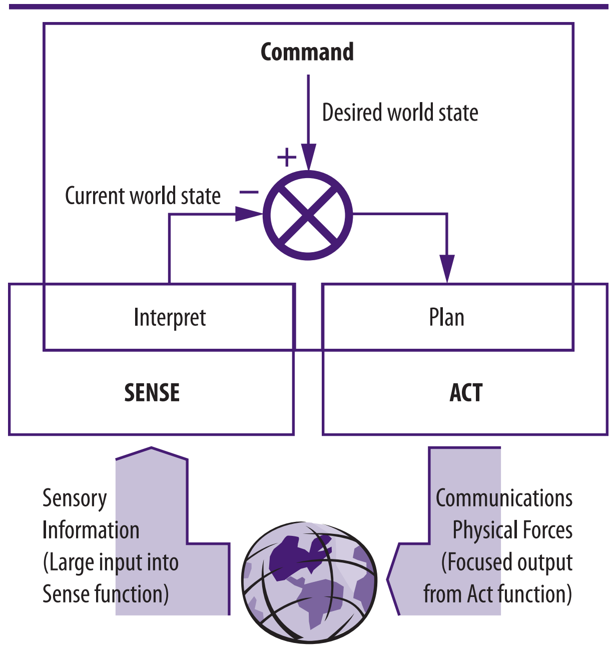

Figure 8-1: Depiction of the Sensing Technical Domain — The Relationships among the Command, Sense, and Act Domains

8.2 Technical Domain Deficiencies

A total of 45 general deficiencies were identified in the Sensing technical domain. The deficiency priorities are detailed in Table A-1 of Annex A to Chapter 8. Ten deficiencies were identified as being high priority:

1. Size, weight and bulk
2. Integration of multiple sensors
3. Integration with operator and soldier system
4. Excessive power demands
5. Operator workload
6. Resolution—detecting and identifying enemy targets
7. Lack of multispectral sensors
8. Sensors do not match capabilities of weapon systems
9. Lack of round-the-wall capability; lack of over-the-wall capability; and lack of through-the-wall capability
10. Poor performance in dynamic environments

The deficiencies were clustered around weight and bulk, human factors, systems integration, detector and mobile platform performance.

8.3 Sensing Vision 2025

The SSTRM vision of the Sensing technical domain in 2025 is of a **system that significantly improves individual, group and area sensing through a shared, intelligent and autonomous network to allow timely and efficient detection, recognition, identification and localization of objects of interest under all environmental conditions, in the whole spectrum of operations. This fusion of all the integrated sensing capability will bring the necessary information to generate the required awareness that enable effective command, control and force protection while minimizing physiological and cognitive burden.**

8.4 Overall System Goals (2015–2020, 2020–2025)

In order to achieve the technical domain vision, near-term and far-term goals have been identified. While the near-term (2015–2020) goals can be categorized as incremental improvements on existing systems, the far-term (2020–2025) goals are characterized as revolutionary. The goal for the 2015–2020 timeframe is to enhance a lightweight system that reduces the burden of the sensor system, improves sensor performance, reduces operator workload and is better integrated. The goal for the 2020–2025 timeframe is an adaptive, intelligent integrated sensor system that provides "plug and play" sensing capabilities with improved resolution, 360-degree extended coverage, a robust sensing network and a system that requires minimal operator workload. The overall system goals include the following:

Table 8-1: Overall Sensing Technical Domain Goals

2015–2020 (Incremental Improvement)	2020–2025 (Revolutionary Change/Improvement)
Incremental weight and bulk reduction	Revolutionary weight and bulk reduction
Improved resolution/performance (detection and identification) • Multi-spectral • Line-of-sight • Beyond line of sight (around and over the wall) • Dynamic environments	Revolutionary improved resolution • Match weapons systems • Beyond line of sight (extended ranges and through the wall) • Remote stand-off detection
Modular and mission configurable	Adaptive sensor systems
Optimized integration of personal, weapons, groups and area sensing capability	Highly integrated systems for personal, weapons, group and area sensing
Sensing networked infrastructure with capacity to share pertinent information	Fully autonomous, collaborative networked sensing systems Collaborative sharing of information
Integrated correlated information from the personal, weapons, group and area sensing and non-organic reconnaissance platforms to enable an enhance situational awareness as to allow more effective and timely decision making	Automated information fusion and correlation supporting augmented reality.
Reduced operator workload • Better Positional awareness: self and friendly forces; • Navigation; • Semi-autonomous payload vehicles; • Battlefield Combat Identification (BCID); • Improved interfaces.	Reduced operator workload • Improved Positional awareness: friendly and enemy; • Autonomous payload systems; • Automatic target detection, tracking and identification; • 360-degree coverage; • Efficient BCID.

8.5 Technical Domain Specific Drivers

Sixteen technology drivers unique to this technical domain were identified. Ten of the drivers were common across the SSTRM technical domains. Detailed below are the remaining four unique technical drivers in this technical domain. The drivers/ constraints included the following (see Table B-1 of Annex B to Chapter 8 for a full description):

- Continuous force transformation
- Adaptable mission solutions
- Integrating mounted and dismounted operations
- Robustness

The four Sensing technical domain themes will be summarized below and discussed in greater detail in Annexes C, D, E and F.

8.6 Theme 12: Personal Sensing (Body-Worn)

8.6.1 Scope

The Personal Sensing theme includes the sensors worn (i.e. wearable and ready-to-wear) by the operator that are used to monitor the health status of the operator, to support local his or her situational awareness and to monitor the local environment. The personal sensing from a system view includes the sensors, the user interface (control and displays), a central control unit (CCU) and information exchange network. Personal sensing also includes a Health Intervention and Monitoring System (HIMS), BCID and individual identification (through biometrics). This theme does not include hand-held (carried) (e.g., binoculars), and weapon sensors.

8.6.2 Objective

The objective of this theme is to develop a low profile, wearable and integrated sensor system for the soldier and the section that will increase the individual and shared situational awareness while minimizing system physiological and cognitive burden. The personal sensing system shall be integrated into the soldier system, providing context knowledge to the wearer and the user's leader.

8.6.3 Related Challenges and Requirements

Twenty-five key performance parameters to be improved were identified. The challenges were clustered around the following groupings: health monitoring, situational awareness, integration and weight reduction. For a full list of the critical challenges, see Table C-1 of Annex C to Chapter 8, which provides mid-term (2015–2020) and long-term (2020–2025) performance targets.

Key Mid-term Challenges and Requirements:

- Weight reduction
- Improved integration
- Remote health monitoring
- Positional awareness (vs. Location knowledge)
- BCID
- Improved personal vision
- Improved threat detection and identification

Key Long-term Challenges and Requirements:

- 25 percent weight reduction with added capabilities
- Full integration
- Remote health intervention
- Integrated multi-threat threat detection and identification
- Intelligent information exchange

8.6.4 Enabling and Emerging Technologies

Twenty-four emerging technologies that could address a number of specific deficiencies in the Personal Sensing theme were identified. These potential solutions are detailed in Table C-2 of Annex C to Chapter 8.

Based on this review, emerging near-term solutions to gaps in the Personal Sensing theme were extensive. Potential technologies that may provide near-term solutions to the capability gaps include:

- Biosensors or vital signs sensing;
- Miniature environmental sensors;
- Position sensors (Global Navigation Satellite System (e.g. GPS) and inertial sensors);
- IFF systems;
- Advanced vision devices (e.g., fused Night Vision Goggles (DB-NVGs); and
- Higher resolution detectors.

A number of revolutionary technologies were identified that may resolve deficiencies in the Personal Sensing theme. The majority of these technologies revolve around the processes and applications of nanotechnology. Potential far-solutions to the performance gaps include:

- Carbon-based nano-materials, e.g., particles and carbon nano-tubes for improved strength, electrical energy storage, insulation, semiconducting and conducting properties.
- Nano-sensors
- Processing on Focal Plane Array (FPA) Read-Out ICs (ROICs)

8.6.5 Proposed R&D Focus Areas

Thirty-six proposed R&D focus areas were identified. They can address generic sensor deficiencies (e.g., resolution) and integration as well as miniaturization. There are clustered around the following areas:

- Multi-spectral sensors
- Fusion
- Integration
- Miniaturization

A detailed list of R&D development needs and opportunities is available in Table C-3 of Annex C to Chapter 8.

8.7 Theme 13: Weapons-Mounted Sensing

8.7.1 Scope

The Weapons-Mounted Sensing theme includes the electro-mechanical sensors used to both accurately detect and identify enemy targets at maximum ranges. These sensors are subsequently used for accurate engagement purposes. The weapons sensing system includes sensors to accurately detect targets, determine ranges and to provide data to ballistic solutions, logistics, etc. The sensing system includes data and power links to weapon sights, fire control systems integrating it to the other part of the soldier system. This theme is closely related to the Weapons Effects technical domain (see Chapter 6: Theme 7— Weapon-Mounted Situational Awareness and Targeting Suite (WM-SATS)).

8.7.2 Objective

The objective of this theme is to improve operational effectiveness and efficiency by enabling the Canadian soldier to accurately engage point and area targets using a common fire control system. The fire control system shall be a weapon-independent device and capable of providing ballistic solutions for all section and platoon lethal and non-lethal weapon systems. The fire control system shall provide am accuracy better than one (1) Minute of Angle (MOA) (0.3 mil) for rifle ammunition at ranges less than 600 metres. The system shall include the following:

- Fire control system shall integrate miniature laser range finders, GNSS, heading/azimuth/bearing, inclination, fused sensors, 3-D accelerometers, etc. in a compact lightweight form factor.
- Enhanced sensors will allow effective target engagements at all ranges and in all lighting conditions.
- Fire control system, through the sensor system, shall significantly improve operator accuracy against moving targets and partially exposed targets.
- Weapon sensor system shall be integrated with the digital soldier system, allowing the engagement and hand-off of non-line-of-sight targets and improved through-sight SA.
- Sensing and fire control system will permit semi-autonomous target detection, identification and engagement of targets even in defilade.

8.7.3 Related Challenges and Requirements

Thirteen key performance parameters to be improved were identified. These deficiencies were clustered around five broad deficiency groupings: operator workload, improved target detection and identification, integration, situational awareness and weight reduction. For a full list of the critical challenges, see Table D-1 of Annex D to Chapter 8.

Key Mid-term Challenges and Requirements:

- Weight reduction of at least 25 percent
- Improved target detection performance
- Sensors fusion
- Integration with soldier system
- Sensors to quantify user error

Key Long-term Challenges and Requirements:

- Weight reduction (increased protection efficiency by 50 percent)
- Integrated day and night sights (Dual Band Weapon sights)
- Integration with soldier system
- Through-sight Identification Friend or Foe (IFF)
- Actuators to compensate for sensors quantified user errors (e.g. Automated FCS)

8.7.4 Enabling and Emerging Technologies

Six emerging technologies that could address a number of specific deficiencies in the Weapon Sensing theme were identified. These potential solutions are detailed in Table D-2 of Annex D to Chapter 8.

Based on this review, a number of emerging near-term solutions to gaps in the Weapons Sensing theme were identified. Potential technologies that may provide near-term solutions to the performance gaps include:

- 17 micron pitch Long Wave InfraRed (LWIR) Focal Plane Arrays (FPAs);
- 17 micron pitch Short Wave InfraRed (SWIR) FPAs;
- clip-on thermal and image-intensified (I2) sensors;
- light-weight laser range finders;
- lead-angle shooting system;
- shot counters;
- optically and digitally fused sensors; and
- centralized power.

A number of revolutionary technologies were identified that may resolve deficiencies in the Weapons-Mounted Sensing technical domain. The majority of these technologies revolve around the miniaturization and applications of nanotechnology. Potential far-term solutions to the performance gaps include:

- on-sensor machine vision processing that permits semi-autonomous and autonomous BCID, target detection, identification and tracking;
- dual-imaging detector on a single silicon chip (vertically stacked detectors);
- micropore, micro-channel plates (MCPs), for enhanced I2 sensor resolution;
- full integration with soldier system GPS, IMU, digital nonmagnetic compass, and inclinometer
- secure, wireless data transfer; and
- built-in training and operator feedback.

8.7.5 Proposed R&D Focus Areas

Seven potential R&D focus areas were identified. There are clustered around the following areas:

- Novel laser remote sensing
- Long-range laser radar systems
- Computational imaging
- Novel miniature radar concepts
- Miniature low-power sensors and networks

A detailed list of R&D development needs and opportunities is available in Table D-3 of Annex D to Chapter 8.

8.8 Theme 14: Crew-Served and Hand-Held Sensing

8.8.1 Scope

The Crew-Served and Hand-Held (CS&HH) Sensing theme includes sensor systems operated or carried by more than one soldier. The CS&HH sensing system is composed of electro-mechanical sensors used to detect, classify, and identify enemy targets at line-of-sight. CS&HH-served sensors provide inputs into weapon fire control systems and crew-served weapon sights. CS&HH sensors also extend the soldier's and section's knowledge of the battlefield past their own individual sensors and weapon sights (e.g., surveillance systems, thermal binoculars, hand-held imager, tripod-mounted sensors, etc.) by up to one to two kilometres. The CS&HH sensing system also includes see-through-wall sensing.

8.8.2 Objective

The objective of this theme is to develop portable and integrated sensor systems for the soldier and section that will increase target detection and group-served weapon engagement performance. Group-served sensors will seamlessly provide data and information for future weapon fire control systems, will also include hand-held and tripod-mounted surveillance devices used for target detection, target localization, target designation, target hand-off, etc. as well as medium machine guns, automatic grenade launchers, anti-armour missile systems and rockets, and mortar systems.

8.8.3 Related Challenges and Requirements

Twelve key performance parameters to be improved were identified. The deficiencies were clustered around five broad deficiency groupings: operator workload, improved target detection and identification, integration, situational awareness and weight reduction. For a full list of the critical challenges, see Table E-1 of Annex E to Chapter 8.

Key Mid-term Challenges and Requirements:

- Weight and bulk reduction (-25 percent)
- Improved target detection performance (+ 25 percent)
- Improved target identification performance (+100 percent)
- Sensor fusion
- Integration with soldier system
- Enhanced through-wall sensing (50 percent improvement in performance)

Key Long-term Challenges and Requirements:

- Weight and bulk reduction (-50 percent)
- Improved target detection performance (+50 percent)
- Improved target identification performance (+200 percent)
- Sensor fusion
- Integration with soldier system
- Enhanced through-wall sensing (100 percent improvement in performance)

8.8.4 Enabling and Emerging Technologies

Fourteen emerging technologies that could address a number of specific deficiencies in the CS&HH Sensing theme were identified. These potential solutions are detailed in Table E-2 of Annex E to Chapter 8.

Based on this review, a number of emerging near-term solutions to gaps in the CS&HH Sensing theme were identified. Potential technologies that may provide near-term solutions to the performance gaps include:

- Handheld thermal imagers;
- Light-weight extended range thermal sights;
- Light-weight laser range finders;
- Digital fire-control units (integrated laser range finder, cant-angle sensors, ballistic calculator, etc.); and
- Optically and digitally processed fused sensors.

A number of revolutionary technologies were identified that may resolve deficiencies in the CS&HH Sensing technical domain. The majority of these technologies revolve around the miniaturization and applications of nanotechnology. Potential far-term solutions to the performance gaps include:

- Light Detection and Ranging (LIDAR) based weapon sensors;
- Higher-resolution crew-served weapon sensors;
- SWIR sights and illuminators;
- Fused sensors; and
- High-resolution displays.

8.8.5 Proposed R&D Focus Areas

Fifteen potential R&D focus areas were identified and are clustered around the following areas:

- Through-the-wall remote sensing
- Miniature LIDAR systems
- Advanced displays (e.g. rollable or foldable displays)

A detailed list of R&D development needs and opportunities is available in Table E-3 of Annex E to Chapter 8.

8.9 Theme 15: Unattended Area Sensing

8.9.1 Scope

The Unattended Area Sensing theme includes electro-mechanical sensors used to remotely detect, classify and identify enemy targets at line-of-sight and beyond line-of-sight ranges. The area sensing system includes sensors, delivery platforms, data and communication links, and central or distributed information processing units or stations. Although a significant number of Unattended Aerial Vehicles (UAVs), Unattended Ground Vehicles (UGVs) and Unattended Ground Sensors—Static (UGS-S) are available today. Their weight and size make them impractical at the level of the dismounted soldier or section. These systems are typically operated by dedicated ISTAR assets.

For the purposes of this discussion, SSTRM unattended area sensing systems include:

- **Micro and Mini UAVs**—Micro UAVs weigh less than 0.5 kilograms and are less than 15 centimetres in length in any dimension. Micro UAVs operate at low altitudes. Mini UAVs typically weigh between 0.5 and 18 kilograms and can operate at altitudes of up to 6000 metres. For the purposes of the SSTRM, only the smaller and lighter Mini UAVs are included in this discussion (see Figure 8-2).

Figure 8-2: Maverick Mini-UAV (in service with CF)

- **Mini UGVs**—Most UGVs available today are large robots under human control used predominantly for improvised explosive device (IED) operations. For the purposes of the SSTRM only very small, lightweight UGVs are included in this discussion.
- **Mote-based UGS-S, based on the Smartdust concept**—Motes are miniature, low-power, wireless-based Unattended Ground Sensors (UGS) systems.
- **UGS—Portable (UGS-P)**—For the purposes of the SSTRM, these systems include hand-thrown robots and camera systems.

The unattended area sensing system includes sensors, delivery platforms, data and communication links, and central or distributed controlling information-processing units or stations. The unattended area sensing system shall include passive and active sensors in the following modalities: electromagnetic, radar, passive radio frequency, electro-optics, LIDAR, acoustic, seismic, vibration, chemical and biological.

Organic (part of higher units) unattended area sensing systems include ground-based, fixed and mobile, airborne and water-based platforms. These systems are designed to monitor larger areas of interest with network sensors to increase SA beyond the local vicinity and into regions Beyond Line-of-Sight (BLoS).

8.9.2 Objective

The objective of this theme is to provide an autonomous, integrated and networked BLoS sensing capability that can enable intelligent data capture, collation, processing, and information dissemination for SA and force protection. Elements of this objective include:

- Detection of targets via multiple sensors;
- Utilizing stationary, semi-autonomous and autonomous platforms;
- Classification of targets;
- Recording of targets;
- Tracking of objects of interest;
- Data transmission;
- Collation and correlation of data;
- Production of required information;
- Effective presentation of information; and
- Timely transmission of information.

8.9.3 Related Challenges and Requirements

Twenty-eight key performance parameters to be improved were identified. The deficiencies were clustered around five broad deficiency groupings: improved target detection, classification and identification, improved platform performance (sensor resolution and platform/sensor range) (Unattended X Vehicle (UXV), UGS), weight and size reduction, reduced operator workload and integration with soldier systems. For a full list of the critical challenges see Table F-1 of Annex F to Chapter 8.

Key Mid-term Challenges and Requirements:

- Increased area of interest, mission duration
- Increased sensor resolution, reduction in false alarm rates (False positives and False negatives)
- Increased platform endurance and ruggedness
- Increased platform mobility and manoeuvrability
- Weight and size reduction for portability
- Improved control interfaces

Key Long-term Challenges and Requirements:

- Increased area of interest, mission duration
- Enhanced multi-spectral sensor resolution, elimination of false alarms
- Significantly increased platform mobility, endurance and ruggedness
- Autonomous platforms, minimal operator workload
- Adaptive, collaborative platforms
- Seamless integration with soldier system

8.9.4 Enabling and Emerging Technologies

Twenty-one emerging technologies that could address a number of specific deficiencies in the Unattended Area Sensing theme were identified. These potential solutions are detailed in Table F-2 of Annex F to Chapter 8.

Based on this review, a number of emerging near-term solutions to gaps in the Unattended Area Sensing theme were identified. Potential technologies that may provide near-term solutions to the performance gaps include:

- autopilots for mini/micro UAVs;
- improved propulsion units for UXVs;
- improved UXV materials (strength); and
- miniature GPS and position sensors.

A number of revolutionary technologies were identified that may resolve deficiencies in the Unattended Area Sensing theme. The majority of these technologies revolve around the miniaturization and applications of nanotechnology. Potential far-term solutions to the performance gaps include:

- advanced image processing;
- improved sensor resolution; and
- improved vetronics and avionics.

8.9.5 Proposed R&D Focus Areas

Five potential R&D focus areas were identified and are clustered around the following areas:

- Micro/nano UAVs
- Portable UGVs
- Autonomous UXV navigation
- Multifunction and multispectral Sensors and Multi-threat (e.g. CBRN)
- Improved operator-machine interfaces

A detailed list of R&D development needs and opportunities is available in Table F-3 of Annex F to Chapter 8.

Annex A: Sensing Deficiencies

Table A-1: Sensing Deficiencies

Rank (High/ Medium/ Low)	Theme 12: Personal Sensing (Body-Worn)	Theme 13: Weapons-Mounted Sensing	Theme 14: Crew-Served and Hand-Held Sensing Sensing (platoon, section, reconnaissance platform)	Theme 15: Unattended Area Sensing (off-board - remote sensing)
	e.g., Health sensors, NBC detectors, NVG	e.g., Sights, ammo counter	e.g., Hand held imagers, tripod mounted system	e.g., UXVs, UGS', hand thrown sensors, projectile sensors, through the wall sensors
High	Size, weight, bulk			
High	Integration of multiple sensors			
High	Integration with soldier systems			
High	Excessive power demands			
High	Operator workload			
High	Deficiencies in resolution – no capability	Resolution – detecting enemy targets		
High	Lack of detection Integration of observation devices and weapon sighting devices (needs to be less boxes, unobtrusive)		Accurate Target Location Determination and Handover	
High	Poor knowledge of position (own and others) poor knowledge of situation	Poor knowledge of situation		
Medium	Poor monitoring capabilities	N/A	N/A	N/A
Medium	Lack of effective operator interface	N/A	N/A	N/A

Rank (High/ Medium/ Low)	Theme 12: Personal Sensing (Body-Worn)	Theme 13: Weapons-Mounted Sensing	Theme 14: Crew-Served and Hand-Held Sensing Sensing (platoon, section, reconnaissance platform)	Theme 15: Unattended Area Sensing (off-board - remote sensing)
Low	Definitive/critical care: Monitors give measure of late indicators, little trend analysis, & no decision support	N/A	N/A	N/A
Medium	Lack of digital video interface	N/A	N/A	N/A
Low	Casualty/health status: Few monitor capabilities & no remote capability	N/A	N/A	N/A
Low	Provide snap-shot of the user state of mind (stress, nervousness, confusion, etc.)	N/A	N/A	N/A
Medium/Low	Computer context awareness, day vs. night, environmental conditions (outside temperature, humidity level, etc.), stress condition of user, etc.	N/A	N/A	N/A
High	N/A	Resolution – IFF		
Medium	N/A	Poor operator interface -tunnel vision		N/A
High	N/A	Lack of integrated solutions to provide DRIL at line-of-sight small arms range		Lack of integrated solutions to provide DRIL
High		Lack of adjustable field of view/magnification (1x and parallax free to >7x stabilized)		
High	N/A	Insufficient range, mismatch between weapon and sensors		
High	N/A	Beyond line of sight detection capabilities at the section/soldier level (lack of around the-wall capability, lack of over-the-wall capability, lack of through-the-wall with capability)		
High		Poor performance in dynamic lighting environments (halo, blooming – saturation)		
High	N/A	Performance in dynamic environments (thermal cross-over, camouflaged)		
High	N/A	Lack of automatic target detection and automatic target recognition (ATD/ATR)	Lack of ATD/ATR	
High	N/A	Poor integration - balance and stability (ergonomics) with personal weapons	N/A	N/A
Medium	N/A	Active but also totally passive if required	N/A	N/A
High	N/A	DRIL using full electromagnetic spectrum	N/A	N/A

Rank (High/ Medium/ Low)	Theme 12: Personal Sensing (Body-Worn)	Theme 13: Weapons-Mounted Sensing	Theme 14: Crew-Served and Hand-Held Sensing Sensing (platoon, section, reconnaissance platform)	Theme 15: Unattended Area Sensing (off-board - remote sensing)
High	N/A	Lack of multispectral sight (fused sights or modular): • Optical • Near Infrared • Thermal short-wave (SWIR) • Thermal mid-IR • Thermal far-IR (LWIR) • Others (acoustic, laser, LIDAR, radar, etc.)	N/A	N/A
Low	N/A	N/A	Lack of automated scanning of crowds for suspicious behaviours (nervous people, discussions of red intent)	N/A
High	N/A	N/A	N/A	Lack of effective operator interface
Medium/High	N/A	N/A	N/A	Remote/stand-off IED detection at the section/ soldier level
Medium	N/A	N/A	N/A	UAV deficiencies in: (SWaP) endurance sensors (resolution, wavelength) GCS interface robustness data links (range, noise rejection)
Low/Medium	N/A	N/A	N/A	Deficiencies in remote CBRN/ sniper detection capabilities at the section/soldier level.
High	N/A	N/A	N/A	No UAV over watch capability at the section level
Low	N/A	N/A	N/A	No UGS capability at the section level

Annex B: Drivers

Table B-1: Sensing Drivers/Constraints

Drivers/Constraints	Implications
Adaptable mission solutions	Situational awareness, threat detection, target tracking Full Mil ruggedized technology Configurable for a changing mission profile Open architecture adapts to the current need COTS - The "Practical to Tactical" conundrum
Integrating mounted & dismounted operations	Real-time information relevant to tactical situation Dismount with seamless inter-connectivity Common picture between mounted and dismounted domains
Reduced size, weight and power (SWaP)	Lower cost/lower power sensors and displays AA battery operability (most common/available) Smaller pixel pitch cooled and uncooled sensors to reduce system size Technology insertion should enable SWaP
The overcrowded EM spectrum	More efficient use of allotted bands to penetrate materials and low/poor visibility environments Dual or multi-band convergence
Force protection - better sensors improve survivability and safety	Need for longer detection/recognition ranges to react/counter-react Higher resolution for group and driver vision enhancers, thereby increasing vigilance and reducing fatigue Reduce/eliminate signature (passive vs. active) Reduce/eliminate "blooming" effect (street lights/headlights/flares)
Conduct of convoy, convoy escort and mounted patrol operations, the need to reduce exposure times and opportunities for enemy attack:	Increased convoy speed More open formations Aerial over-watch Mix of terrain (open, closed, urban, rural)
Force protection - obstacle avoidance and detection IED detection capabilities proven in combat	Improved IED detection and recognition range Improved resolution Group and soldier mounted devices
State of technology	Need higher resolution/resolving sensors in smaller, lighter and less bulky packages. LWIR, SWIR, NVD systems
Power (portable energy, temperature, weight)	Future power sources must have greater power density and be more energy efficient
Robustness	Future systems must be robust to withstand operational handling
Cost	Future systems must not be cost prohibitive
Access to US technology	ITARS restriction may limit the use of US research, technology, etc. for Canadian projects
IP rights	Development of future systems will require the proper management of IP rights
R&D capability in Canada (barrier)	Canada has limited R&D capabilities in this area
Continuous force transformation	

Annex C: Theme 12: Personal Sensing (Body-Worn)

Annex C includes the following tables:

- Table C-1: Challenges/Requirements
- Table C-2: Enabling and Emerging Technologies
- Table C-3: Proposed R&D Focus Areas

Table C-1: Challenges/Requirements

Challenges	Priority	Requirements	
		2015–2020 (Horizon 2)	2020–2025 (Horizon 3)
Health (physical and psychological) monitoring	Medium	Remote health monitoring	Remote health intervention
Enhanced basic environmental knowledge (temperature, pressure, elevation)	Low	Capture local temperature, pressure, elevation, etc.	Capture local temperature, pressure, elevation, etc.
Passive acoustic target (small arms) detection	Medium	Detection (2km) Direction (1 mil) ATD/ATR	Detection (2km) Direction (1 mil) Target localization
Augmented hearing for target detection	Low	30dB amplification of sounds	Automatic noise signature detection, recognition and soldier cueing (machine hearing)
Identification of friendly forces on the battlefield (BCID)	High	Implement STANAG 2129	Embedded in clothing system (see Survivability, sustainability, mobility)
Positive identification of a threat prior to engagement	High	Blue positional awareness	Blue positional awareness
Augmented vision (for: personal mobility, target detection/recognition)	High	Augmented, all weather, 24h	Multi-spectral 360 degree vision ATD/ATR
Multi-modal attention cueing (e.g., visual, tactile, auditory) (applicable to all themes)	Low	360 degree 2-D	360 degree 3-D
Target detection (e.g. NVG)	High	See Weapon Effects Technical Domain	See Weapon Effects Technical Domain
Target recognition (e.g. NVG)	Low (assumes Detection has happened)	See Weapon Effects Technical Domain	See Weapon Effects Technical Domain
Target identification	Medium (assumes Detection has happened)	See Weapon Effects Technical Domain	See Weapon Effects Technical Domain

Challenges	Priority	Requirements	
		2015–2020 (Horizon 2)	2020–2025 (Horizon 3)
Enhanced chemical, biological, radiological, nuclear, explosive (CBRNE) detection	Low	Portable, section level	Integrated multi-threat detection Individual level
Directed energy detection (e.g. laser, radar, Electromagnetic pulse (EMP))	Low	Integrated at individual system level for detection and training	Embedded in clothing
Own localization	High	See C4I Technical Domain	See C4I Technical Domain
Navigation	High	See C4I Technical Domain	See C4I Technical Domain
Active camouflage (see Personal Protective Equipment)	Low	Passive	Active
Operator interface (context)	High	See C4I Technical Domain	See C4I Technical Domain
Reduced sensing system weight	High	Weight neutral with added capability	-25% weight with added capability
Sensors integration (see Human and Systems Integration)	High	Modular	Integrated Optoelectronics - optical, electro-optic and electronic components together in monolithic semiconductor form
Integrated with personal area network (see Human and Systems Integration)	High	Linked at soldier level	Linked to higher level network
Information exchange to soldier system	High	Intelligent information exchange mechanism	Intelligent information exchange mechanism
Personal area network (PAN)	High	See C4I Technical Domain	See C4I Technical Domain
Data processing (including fusion)	Medium		On-device processing

Table C-2: Enabling and Emerging Technologies

Technology	TRL (1–9)	Year for TRL 7	Strength (S)/Weakness (W)	Critical Barriers/Gaps	TSC Recommended Action
Physiological Monitoring					
Body area network sensors • BP • ECG • Etc.	9		S: (none identified) W: Interoperability, complexity, invasion of privacy, sensor validation, data consistency, interference, cost	Miniaturize sensors	Monitor
Biosensors • Thermistor (ACR system) • ECG (e.g. Medtronics-Reveal) • Sp02 (e.g. CardioMEMS)	9		S: Size W: Power requirements, bulk, need		Monitor

Technology	TRL (1–9)	Year for TRL 7	Strength (S)/Weakness (W)	Critical Barriers/Gaps	TSC Recommended Action
Miniature environmental sensors • Temperature • Pressure • Etc.	7–9		S: SWaP W: Cost		Leverage
Actigraph Monitor	9		S: Provides physical activity measurements such as activity counts and vector magnitude, energy expenditure, steps taken, activity intensity levels, MET's		Monitor
Polar heart rate monitor	9				Monitor
Hearing					
Augmented hearing	9		S: (non identified) W: Requires active system		Invest
Directional hearing (3-D hearing)	7		S: Improved directionality W: Head transfer functions, cost, power	Universal head transfer function	Monitor
Navigation/ Localization Sensing (See C4I Technical Domain) • Inertial positioning, GPS)	7–9		S: SWaP W: Resolution; poor resolution in GPS denied environments	GPS on a chip	Invest
Identification of Friends and Foes					
IFF - Passive systems • Near IR reflective flags & tape	9		S: Inexpensive W: Requires NVG/thermal systems		Leverage
IFF - Blue force tracking (GPS/IME)	7–9		S: Improves CID, improves engagement, improves SA performance W: If lag, then poorer performance, reliability	Functionality in ISSP	Invest
IFF - Active systems • Near-IR beacons • Coded IR laser systems + RF • MMW technology	9 5		S: Improves CID, improves engagement, improves SA performance W: Weight/cost/power, trust, reliability, covertness, false alarm rate		Invest

Technology	TRL (1–9)	Year for TRL 7	Strength (S)/Weakness (W)	Critical Barriers/Gaps	TSC Recommended Action
Night Vision Device Technologies					
- Night Vision Systems					
Fused monocular vision devices (I^2 and IR) for personal vision	8–9		S: fused visible, I2 SWIR and LWIR W: Cost, weight, power demands, mount	Access to high resolution sensors	Invest
Fused binocular NVDs (e.g., ATN FIITS14)	9		S: Less expensive fusion W: Weight/bulk, neural fusion	Lower resolution	Monitor
Wider FOV NVDs • WFOV PVS-14 • AN/PVS 25 • ANVG	9		S: Improved FOV with wider displays W: Reduced resolution, mount stability		Monitor
Panospheric imaging systems – for dismounted vision	3	2020	S: Increased SA W: Cost, resolution, SWaP		Monitor
- Imager/Detectors					
I^2 Tube (Gen 5) using micropore MCPs	4–5	2015	S: High resolution W: Cost, robustness	• All optical coupling inside the I2 tube, and need high res 12M pixel camera, high res micro display to truly benefit the enhanced Gen III performance • Improved detection performance	Monitor
Multi-band sensors	5	2015	S: Used in the day, night and through fog and haze W: Cost, bulk	• E.g. CMOS imager (Tri-Wave: visible, SWIR and LWIR) • Cooling may be the issue • Seamless transition from day to night	Monitor
Higher resolution non image intensified night – digital sensors • ICCD • EBAPS • EMCCD • EBCMOS • CCD/CMOS Hybrid • Colour CMOS • ICMOS • LLTV	7	2015–2020	S: Allows digital fusion, improved SWaP W: Resolution, band coverage		Monitor

Technology	TRL (1–9)	Year for TRL 7	Strength (S)/Weakness (W)	Critical Barriers/Gaps	TSC Recommended Action
25-micron pitch sensors (LWIR, SWIR, etc.)	8–9	2006	S: Good sensitivity for day-night use W: Cost, power, size, resolution	• ITARS barriers in USA (e.g. InGaAs based SWIR) • Sofradir and Xenics in Europe have MCT and InGaAs based SWIR 20-30 micron pitch, but cooling requirement more demanding in MCT based SWIR (power consumption), and SWIR general performance in term of noise level is inferior to US SWIR • Raptor Photonics of Northern Ireland InGaAs based SWIR 30 micron pitch camera. Performance is inferior to US SWIR • No issues for LWIR as products from Europe are as good. • Operational advantage in SWIR	Invest
17 micron pitch VOx sensors (microbolometer)	8	2006	S: Resolution W: Cost, availability	• ITARS barriers in USA • ULIS (Sofradir) in Europe and SCD in Israel produces 1024 x 768 XGA format 17 micron pitch detector • Improved detection performance	Invest
Innovative imager/ detector technology (e.g. carbon nano-tube arrays)	3	2025	S: (none identified) W: (none identified)		Monitor
Third Generation FPAs – conduct image processing on the FPA Read Out ICs (ROIC) • On-chip hyperspectral functionality,	6	2020	S: Multiband MWIR/LWIR detection (CdZnTe and GaSi or Si), high resolution, reduced power, weight, size W: Size, cost, 20 micron pitch FPAs		Monitor
CBRNE Detectors					
Nanotechnology – chemical detectors • Nanomix • Applied Nanotech • Owlstone • Nanotech	6	2015	S: SWaP W: clothing network, threat level		Monitor

Table C-3: Proposed R&D Focus Areas

R&D Focus Areas	Scope/Description (Needs and Opportunities)	Priority Order (1,2,3)
Personal sensor networks	See C4I and Power/Energy Technical Domains Embedded sensor networks (See Operational Clothing Theme) Integrated position and navigation sensors (e.g. GPS and IMU)	3
Enhanced interfaces/ controls/ displays	See C4I Technical Domain for other interface elements Neural controls • Interpret brain signals • Improve brain interfaces (more precisely electro encephalogram) • Adaptable trainable interface • Train soldiers, while considering human factors of brain control	3 (Neural control)
Enhanced hearing	See C4I Technical Domain Directional hearing Improved HTF Active noise reduction	2
Enhanced vision (night and days)	Multi-spectral sensors fusion • Merging of information from many cameras • Colour night vision • Multi-band • Image processing & Algorithm • Fusion algorithms High resolution display and WFV Sensor integration • Fault tolerant architectures • Miniaturization (e.g., laser range finders, DM compass) – Submicron integrated circuit technologies • Power reduction Advanced sensors • Advanced FPAs • Variable frequency (smart) sensors • Higher resolution sensors • Wide band sensors (Visible/Near Infrared/SWIR (VNS) detectors) • New photonic materials extending E-O sensor performance • New photonic materials • Nanotechnology/nanosensors • Submicron integrated circuit technologies MEMS	1
Enhanced physiological monitoring	Health status sensors Hydration level, core temperature	3
Enhanced embedded threat detection sensing (e.g. CBRNE)	Chemical, biological, radiological, nuclear, and environmental sensors	3

Annex D: Theme 13: Weapons-Mounted Sensing

Annex D includes the following tables:

- Table D-1: Challenges/Requirements
- Table D-2: Enabling and Emerging Technologies
- Table D-3: Proposed R&D Focus Areas

Table D-1: Challenges/Requirements

Challenges	Priority	Requirements	
		2015–2020 (Horizon 2)	2020–2025 (Horizon 3)
Reduce operator workload	Medium	Shot counter Lead angle sensor	ATD/ATR
Operator limitations	Medium	Develop sensored weapons and targets to quantify error budget for poor range and lead estimation	Develop technologies to compensate for poor range and lead estimation
Reduce weight and bulk of sights and sensors	High	Lightweight laser range finders, inclinometers, GPS, INS, accelerometers, etc. -25%	Fielding of a rifle sight/sensor system that allows seamless transition from close to far target engagements -50%
Improved target detection sensors (same performance in poor light conditions as in day light) – smaller pitch LWIR/MWIR/SWIR sensors	High	1000m	2000m
Improved multi-spectral target detection sensors (same performance in poor light conditions as in day light)	High		Micro-pore MCPs Active thin films Miniature anodes
Integrated multi-spectral sensors	High		Dual-imaging detector on a single silicon chip Vertically stacked
Integrated with soldier systems	High	Link to soldier system	Seamless target hand-off for non line of sight engagements
Improved SA and IFF	High		Through sight IFF
Centralized power and data	Medium		
Ammunition counter	Low		Through sight

Table D-2: Enabling and Emerging Technologies

Technology	TRL (1–9)	Year for TRL 7	Strength (S)/Weakness (W)	Critical Barriers/Gaps	TSC Recommended Action
Threat detection					
Multi-spectral sights • I2 and LWIR • SWIR and LWIR • I2, SWIR and LWIR Optical and digital fusion	9		S: Resolution W: Bulk, cost, display resolution, sensibility (SWIR), access to technology		Invest
SWIR sensors	9	2015	S: Resolution, covert W: Cost, access, resolution	• Access	Invest
12/17 micron pitch sensors (LWIR, SWIR, etc.)	7–9	2020	S: Resolution W: Cost, availability	• Manufacturability • Access	Monitor
Directional Microphones (aided hearing)	7–9	2015	S: (none identified) W: Resolution, bulk and weight		Monitor
Weapon accessories					
Gyroscope-based non-magnetic GPS	7–9		S: Position locating in GPS denied environments W: Size, weight		Monitor
Micro laser range finders (mLRD) and designator • Small Tactical Optical Rifle Mounted (STORM) Micro-Laser Rangefinder (MLRF).	9		S: Mini laser range finder (weight and small size) W: Cost, access		Invest
Ammo counter	9			• Currently designed for barrel wear applications – not for operational application	Monitor

Table D-3: Proposed R&D Focus Areas

R&D Focus Areas	Scope/Description (Needs and Opportunities)	Priority Order (1, 2, 3)
Enhanced EO detectors (night and days)	Multi-spectral sensors fusion • Merging of information from many cameras • Colour night vision • Multi-band • Image processing & algorithm • Fusion algorithms High resolution display and WFV Sensor integration • Fault tolerant architectures • Miniaturization (e.g. laser range finders, DM compass) – Submicron integrated circuit technologies • Power reduction Advanced sensors • Advanced FPAs • Variable frequency (smart) sensors • Higher resolution sensors • Wide band sensors (Visible/Near Infrared/SWIR (VNS) detectors • New photonic materials extending E-O sensor performance • New photonic materials • Nanotechnology/Nanosensors – Submicron integrated circuit technologies MEMS	1
Novel non-EO target sensing	Laser radar, LADAR and LIDAR Sound Confirmation sensor	3
Efficient secured target identification (IFF)	See Sensing Theme 12: Personal Sensing (Body-Worn) See C4I Technical Domain See Power/Energy Theme 3: Power and Data Distribution	2
Weapon platform sensors	Temperature Ammunition counter Weapon movement (operator induced disturbances)	3
Improved weapon sensors integration	Miniature, low power sensors and networks Power rail See Power/Energy Theme 3: Power and Data Distribution Counter dazzling	1

Annex E: Theme 14: Crew-Served and Hand-Held Sensing

Annex E includes the following tables:

- Table E-1: Challenges/Requirements
- Table E-2: Enabling and Emerging Technologies
- Table E-3: Proposed R&D Focus Areas

Table E-1: Challenges/Requirements

Challenges	Priority	Requirements	
		2015–2020 (Horizon 2)	2020–2025 (Horizon 3)
Reduced weight	High	-25%	-50%
Reduced bulk	High	-25%	-50%
Improved target detection (electro-optical) (incl. IR, visual and ultra-violet spectrum)	High	25% increased performance (individual and collaborative)	
Multi-spectral target detection other than electro-optic (e.g. LIDAR, acoustic, flash)	Low	25% increased performance (individual and collaborative)	50% increased performance (individual and collaborative) ATD
Improved target recognition	Low	25% increased performance under operational stress	50% increased performance under operational stress ATR
Improved target identification	High	100% increased performance under operational stress	200% increased performance under operational stress ATI
Target tracking	Low	Track while scan	Track while scan
Enhanced through-wall sensing	High	+50%	+100%
Surveillance	Medium	Semi-automatic	Fully automatic
Sensors integration (incl. hardware and power)	High		
Integrated with soldier systems (data)	Medium		
System autonomy (power) (cross-domain)	Medium	24hrs (TBD) within weight budget and usage profile	72hrs (TBD) within weight budget and usage profile

Table E-2: Enabling and Emerging Technologies

Technology	TRL (1–9)	Year for TRL 7	Strength (S)/Weakness (W)	Critical Barriers/Gaps	TSC Recommended Action
Enhanced EO sensors	6–9		SEE WEAPON-MOUNTED SENSING THEME		Monitor
Multi-spectral target detection other than electro-optic (e.g. LIDAR, acoustic, flash)	6		SEE WEAPON-MOUNTED SENSING THEME		Invest

Technology	TRL (1–9)	Year for TRL 7	Strength (S)/Weakness (W)	Critical Barriers/Gaps	TSC Recommended Action
HH long range laser range finders: • LRM 2500CI • Vector 21B	9		S: Resolution, SwaP W: Not compatible with night operations		Leverage
Hand Held Thermal Imagers e.g.: • MRTB- Midrange Thermal Biocular, uncooled micro-bolometer • MTI- Mini Thermal Imager uncooled ubolometer	9		S: Short to medium wave infrared, cooled thermal imager, handheld, excellent detection ranges W: Challenges at identification		Leverage
Integrated fire control systems – e.g. ITL Optronics NVL-11, Vinhog IS2000, XM 25, DFCU	9		S: Automatic aim point, full ballistic solution; some have limited night capability W: Bulk, weight, integration	• Night scope • LRF • Fire control computer	Monitor
Through-wall sensing (X band)	7–9		S: Smaller form factors W: Resolution	Not used in arrays for higher resolution	Leverage

Table E-3: Proposed R&D Focused Areas

R&D Focus Areas	Scope/Description (Needs and Opportunities)	Priority Order (1,2,3)
Integration of other sensors with EO vision sensor (binoculars and group-served weapons sights)	Integrate other sensors to augment binoculars, vision devices – i.e. digital magnetic compass (DMC), laser range finder, inclinometer, etc. • Multi-spectral fusion (Fusion of LWIR, SWIR, etc.) • Novel laser sensing, laser radar, LADAR/LIDAR systems concepts	1
Enhanced optics and detectors	See – Weapons Sensing Theme Enhanced resolution of IR-type systems (lower pixel pitch sizes FPAs) Novel lightweight lens design (low F#) Micro-scanning Increased spectral band coverage Sensor to mimic eye performance and dynamic range and field of view Lens-less and computational imaging e.g., wave front coding	2
Enhanced behind wall sensing	Improve resolution of sensors Investigate performance of arrayed sensors to improve resolving power – e.g., CANTASS for urban ops	3
Small arms fire localization	Acoustic sensing — See the Personal Sensors Theme when the acoustic detectors are embedded in the body-worn sensing network. Acoustic sniper detection systems can also be crew-served. Flash sensing — See the Personal Sensors Theme when the flash detectors are embedded in the body-worn system. Flash sniper detection systems can also be crew-served.	3

Annex F: Theme 15: Unattended Area Sensing

Annex F includes the following tables:

- Table F-1: Challenges/Requirements
- Table F-2: Enabling and Emerging Technologies
- Table F-3: Proposed R&D Focus Areas

Table F-1: Challenges/Requirements

Challenges	Priority	Requirements	
		2015–2020 (Horizon 2)	2020–2025 (Horizon 3)
Reduced weight	High	Man portable system (sensor, platform, controller) < 2.5kg total	Man portable system (sensor, platform, controller) < 1 kg total
Reduced bulk	High	Micro sized systems 72 to 84 mm diameter x 1000 mm long tube form-factor for UAV 250 mm x 150 mm x 150 mm form-factor for UGV	Nano sized systems Controller functionality in soldier system computer
Area of interest surveillance coverage (static)	High	250 m radius 1 metre resolution	Up to 2 km radius Sub-metre resolution
Over-watch surveillance (on-the-move)	High	1 km in front, 150 m each side of centre line 1 metre resolution	3 km in front,300 m each side of centre line Sub-metre resolution
Detection	High	Reduce false alarm rate	Virtually eliminate false alarms
Recognition/classification t and activity)	High	General classification at specialized sensor nodes (air, ground water)	Precise classification at generic sensor nodes (Built-in computing on the sensor chip)
Identification	Medium	Improved capability	Aided recognition
Biometric capability	High	Improved capability	Identification using an on-board biometric data table of key personnel
Responsiveness	Medium	Reduced delay in correlated information transfer	Timely correlated information transfer
Identification of friendly forces on the battlefield (BCID)	Medium	Improved capability	Good capability, (note performances are sensor dependent)
Ground based static (UGS- S)	High	Sensing: multi-modality sensors package	Full-spectrum sensor package
	High	Endurance: operational life, EO/IR – 72 hrs Others – 90 days	EO/IR -7 days Others – 6 months
	Low	Deployment: capable of withstanding delivery via standard weapon systems	Self orienting devices after delivery
	High	Autonomy: Programmable sensors	Adaptive/collaborative sensors
Ground based mobile (UGV, for ground, underground and amphibious navigation) (Please note that armed UAVs are found in the Weapon Effects Technical Domain)	High	Sensing: mapping and localization, and obstacle avoidance Aided target detection	Autonomous mission oriented detection of objects of interest
	Medium	Deployment: single system single man portable	Multi-system single man portable
	High	Mobility: equivalent performance to current tracked and wheeled platforms	Highly mobile with human equivalent mobility
	High	Endurance: 1 day	1 week
	High	Autonomy: semi-autonomous	Fully autonomous/collaborative behaviour

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Challenges	Priority	Requirements	
		2015–2020 (Horizon 2)	2020–2025 (Horizon 3)
Airborne (with loitering capability and perching capability)	High	Sensing: mapping and localization, and obstacle avoidance Aided target detection	Autonomous mission oriented detection of objects of interest
	High	Mobility: Manoeuvrability around buildings and large structures	Extreme manoeuvrability in and among buildings and rooms
	High	Durability: Crash resistant	Unbreakable
		Deployment: single system single man portable and launchable	Multi-system single man portable and launchable
		Autonomy: semi-autonomous	Fully autonomous/collaborative behaviour including pursuit of objects of interest
		Endurance: 12 hour	3 days
Performance in adverse weather, lighting and environmental conditions	High	Good weather condition	24/7 in all conditions
Secure	Medium	Anti-tampering systems	Stealth mode to minimize activity
Mission tailorable	Medium	Swappable specialized sensors packages	Swappable generic sensor nodes
Fusion Level	Medium	At sensor level	At group level
Interoperable	Medium	Same sensor for multiple applications UXVs, UGS, Soldier sensors	Platforms share, collate, analyse data
Cost	Medium	Reusable	Consumable Massively deployable sensors (< 4100 ea)
Delivery reconnaissance platform Marsupial platform (a big platform contains smaller sensing platforms	Medium	Remotely operated	Goal-based operation
Navigation	High	Assisted navigation Obstacle avoidance	Goal-based autonomous navigation GPS denied environments
Repairable	Medium	2nd line component replacement	1st line (operator) repair
Minimum operator workload	High	Semi autonomous launch and recovery Autonomous mission execution	Autonomous launch, mission execution and recovery
Self locating	High	SEP 1 m (Open range)	SEP 0.1m in GPS denied environment
Easily deployed	Medium	-50% faster	-90% faster
Minimized signature • Noise • Electro-magnetic • Retro reflection for optic	High	Less than 30dB (TBC) Field tailorable camouflage move to solution	Undetectable SWIR based PIRs Adaptive camouflage move to solution
Secure	Medium	Anti-tampering	Defensive suite
Minimum of training	High	Minimal training	Intuitive operation
Power sources	High	Compatible/common	Energy harvesting/scavenging/scrounging
Interoperable	Medium	Stand alone	Seamless with soldier systems and C4ISR system

Table F-2: Enabling and Emerging Technologies

Technology	TRL (1–9)	Year for TRL 7	Strength (S)/Weakness (W)	Critical Barriers/Gaps	TSC Recommended Action
Advanced Micro UAV platforms — e.g., Aeryon Scout VTOL UAV CREX-B	9		S: Operator interface – semi-autonomous control via touch screen, switch out payload for NIR/LWIR cameras W: Operational duration (20 min), payload, bulk		Leverage
Advanced UAV autopilots • Kestrel • MicroPilot • Cloud Cap Piccolo • Paprazzi • UNAV 3500 • A3R YAPP • IATech	9		S: Small memory and processing resources required, reduced operator workload W: Stability in unstable wind conditions, weight/bulk, level of autonomy in some systems, rely on waypoints vs. area of interest, not cooperative, indoor guidance		Leverage
Sensing: advanced image processing	5	2015	S: Provides detection, classification, identification and mapping of objects in platform vicinity	High performance processing, advance in algorithmic and sensor modalities fusion	Leverage
Increased sensing devices performance	6	2015	S: Reduced power consumption and cost, miniaturisation	Mass manufacturing	Monitor
Autonomy: decisional process	5	2015	S: Mission planning is essential for timely employment of resources to meet demands. Currently executed offline	Algorithms that allow real-time planning with heuristic attributes	Invest
Autonomy: localization	4	2020	S: Self-localization in unmapped environments is essential for effective use of robots. Currently human must aid navigation	Resource efficient strategies and algorithms that fuse navigation sensor data to calculate vehicle states	Invest
Autonomy: network communications	4	2015	S: Wireless communication protocols are being developed by industry for point-to-point applications. New communications concepts are essential to enable multi-point data sharing	Algorithms that make more efficient use of available bandwidth and frequency spectrum	Invest
Autonomy: vehicle interaction	5	2015	S: Control strategies for collaborative behaviours are being developed and demonstrated in simulation and laboratory conditions	Fault tolerant cooperative control algorithms combined with artificial intelligence methods that can account for unexpected faults and conditions	Invest
Avionics/vetronics: control	6	2015	S: Algorithms to maintain platform stability based on inertial data well understood. Guaranteed stability in situations highly perturbed or non-equilibrium states requires improvement.	Control algorithm formulations that are based on non-linear dynamics and high fidelity 6DOF models	Leverage
Avionics/vetronics: autopilot	8	2015	S: Commercially produced hardware	Methods and designs that increase miniaturisation and processing capability	Leverage

Technology	TRL (1–9)	Year for TRL 7	Strength (S)/Weakness (W)	Critical Barriers/Gaps	TSC Recommended Action
Avionics/vetronics: state sensors	4	2020	S: Inertial and GPS-based position sensors are well developed. Navigation sensors for use in GPS-denied environments are lacking.	Miniaturized vision-based hardware and efficient image processing algorithms	Invest
Mobility: aerodynamics	8	2015	S: Physical principles for platforms based on steady aerodynamics well understood. Extracting aerodynamic efficiencies in unsteady flow not well understood.	Improvement of analysis and experimental methods to better understand implications of unsteady phenomenon	Leverage
Mobility: ground vehicle dynamics	5	2020	S: Physical principles involving wheeled or tracked locomotion for higher speed travel well understood. Few methods exist for traversing cluttered and irregular terrain.	Better kinematic analysis methods that compute platform stability, dynamics and link actuation and motion	Leverage
Prime mover: internal combustion	9		S: Commercially produced and provide high output with high efficiency	None	Monitor
Prime mover: electric	9		S: Commercially produced and provide high output with high efficiency	None	Monitor
Energy source: hydrocarbon	9		S: Commercially produced except polluting and limited	Alternative sources of hydrocarbons	Monitor
Energy source: fuel cell	4	2020	S: Offers increases in energy density. Depending on the concept, may result in increase in weight and volume.	Identification of chemical and separation systems that offer increases in conversion efficiency	Invest
Energy source: electrochemical	7	2015	S: Commercially produced. In some cases, formulations are unstable unless properly handled.	Chemical systems that offer greater energy densities and higher stability	Monitor
Actuator: electromechanical	9		S: Low cost, mass produced	None	Monitor
Actuator: solid state	4	2020	S: Offers lower parts count, smaller volume and lower weight actuators. Operating envelope currently limited either by frequency, displacement or force capability.	Identification of different material systems that increase transduction of electrical energy to mechanical energy	Leverage
Structures: composites	9		S: Offers lightweight, tailored strength and stiffness structures	Lower cost manufacturing methods	Monitor
Structures: multifunction	5	2020	S: Integration of sensing, actuation and power into structure offers weight and volume efficiencies	Multi-physics methods that permit multi-criteria trade-off studies	Leverage
Structures: shape changing	5	2020	S: Morphing aerodynamic surfaces offers improved flight performance. Currently lack of integration of actuators and structure leads to weight inefficiencies.	Better methods that enable integrated compliant mechanism and solid state actuator design	Leverage

Table F-3: Proposed R&D Focus Areas

R&D Focus Areas	Scope/Description (Needs and Opportunities)	Priority Order (1,2,3)
Micro/nano-UAVs	Collapsible structures (e.g. M72 tube-launch) Miniaturization (sensors, batteries, avionic, electronics) Power, fuel cells, energy harvesting (µSolar cell) cells (see Power/Energy Technical Domain) Agility in narrow urban structures Movement and navigation inside buildings Recognition and circumnavigation of obstacles Payload optimization Data link Ground control station Signature management (noise reduction; multispectral signature reduction) High performance propulsion system	2
Portable UGVs	Agility in narrow urban structures Stair climbing ability /mobility in non-urban terrain/ high inclination (UGV) Legged, hybrid mobility Movement and navigation inside buildings Recognition and circumnavigation of obstacles Payload optimization Data link Ground control station Signature management (noise reduction; multispectral signature reduction) High performance propulsion system	3
Autonomous Navigation	Positional Sensors • 3-axis accelerometers • 3-axis rate gyros • 3-axis magnetometers • GPS Navigation Sensors • scanning laser • cameras Navigation algorithms • SLAM – Simultaneous localization and mapping • optic flow algorithms • obstacle avoidance • Cooperative tactics (swarming) • Sensor data fusion • Path planning/trajectory generation	1 (enabler)
UGS	Orientation and positioning Sensor data fusion Miniaturization (sensors, batteries, avionic, electronics) Power, fuel, energy harvesting (µSolar cell) cells (see Power/Energy Technical Domain) Ad hoc networking	2

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R&D Focus Areas	Scope/Description (Needs and Opportunities)	Priority Order (1,2,3)
Sensors for UXV	Sensor types • Radar • LADAR • LIDAR • Range finder • CBRN • Audio • Meteorological (environmental) • EO/IR (visible, hyper spectral, active, passive) Sensor optimization • Low weight • Low power • Miniaturisation • Multi-function • Integration • High sensitivity/high resolution	1 (enabler)
Operator-machine interface	Input devices/data entry • Haptic • Touch screen • Joy stick • Switch Feedback devices • Audio • Heads-up display • Tablet/laptop • Terminal • Tactile Interface design • Immersive control environment • Intuitive operations Workload distribution	2

Chapter 9: Survivability/Sustainability/Mobility

9.1 Introduction

This technical domain combines a number of topics related to Soldier System survivability, sustainability and mobility, including personal protection. This technical domain is divided into two broad themes:

- Theme 16: Operational Clothing, Load Carriage and Mobility (including operational hand wear and footwear)
- Theme 17: Personal Protection which focuses on impact protection (collision/shock), ballistic or kinetic effects, Chemical, Biological, Radiological, Nuclear and Explosive (CBRNE) protection, that include, blast or thermobaric protection for the torso, head, lower body and extremities.

The Survivability, Sustainability and Mobility technical domain is depicted in Figure 9-1.

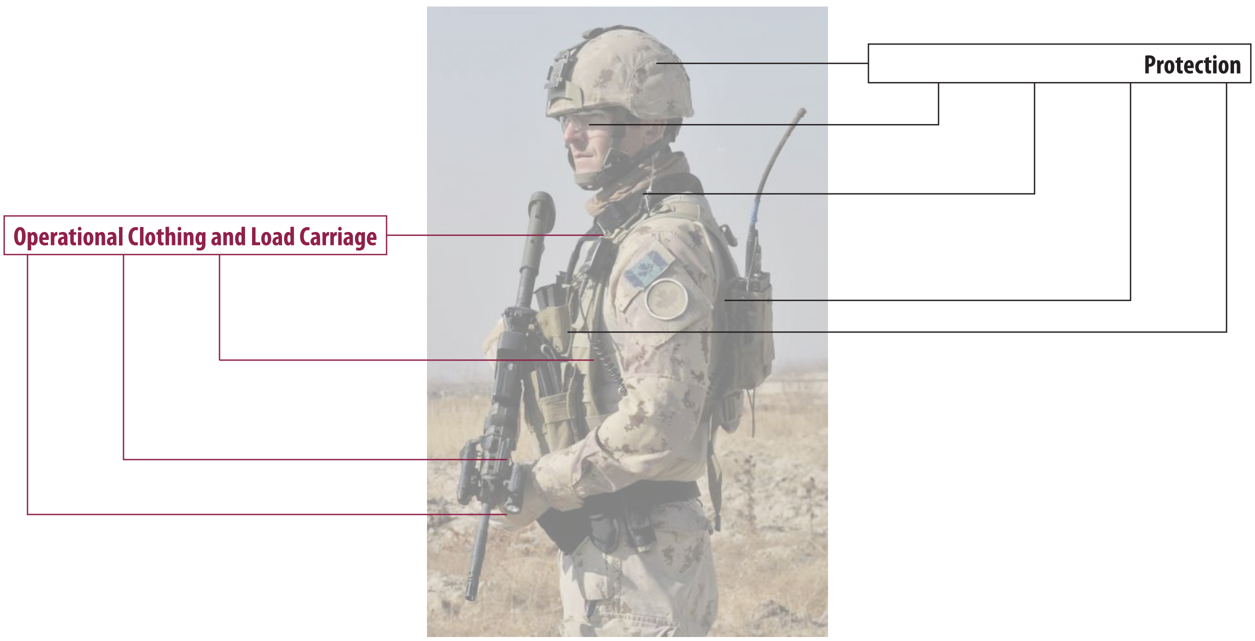

Figure 9-1: Depiction of Survivability, Sustainability and Mobility Equipment

Military activities and operations are intrinsically hazardous. Soldiers conducting full spectrum operations must assume calculated risks every day, based on the significance of the mission, the operational requirement and the opportunity offered to them. The survivability, mobility and sustainability functions preserve the combat power and potential projection of force by providing protection from known threats and hazards.

An assessment of the Future Security Environment suggests that future adversaries and the strategies, Techniques, Tactics and Procedures and technological capabilities they will employ against the Canadian dismounted soldier may be diverse and wide-ranging. Opposition to a mission can come from traditional and emerging threats, as well as from environmental and occupational hazards. Soldier survivability against the diverse threats and hazards encountered in their operating environment is a crucial aspect of full-spectrum dominance and mission success (see Figure 9-2).

Soldier survivability is also closely related to the Army of Tomorrow omni-dimensional shield functional concept (see Figure 9-2) that aims at providing force protection, survivability and freedom of action across the physical, human and informational planes for all hazards and threats and taking advantage of the various enablers.

The "survivability chain" is another supporting concept that covers all aspects of protecting personnel, installations, weapons and supplies (see Figure 9-3) and includes:

- the effective use of **concealment, deception and camouflage** (signature management);
- **mobility**—survivability is enhanced when soldiers can move or reposition themselves quickly and freely (avoid obstacles) when seeking cover or minimizing exposure when repositioning (i.e. speed is protection); and
- a well informed **situational awareness** (derived from the C4I and sensing functions)— provides critical information, including threats and hazard detection/assessment, combat identification (Blue Force Tracking), local population and installation location inside the soldier area of operations.

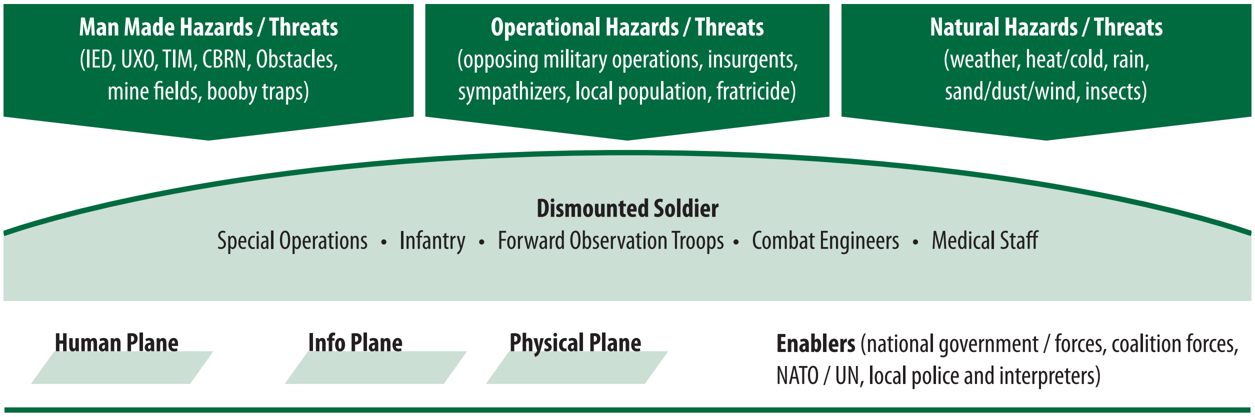

Figure 9-2: Spectrum of Hazards and Threats Facing Dismounted Soldiers

Operational clothing and personal protective equipment (PPE)—shields soldiers from natural and man-made threats, hazards and environments such as heat, cold, animals and insects or from CBRNE effects, impacts and noise. The "E" protection from CBRNE covers blast effect or thermobaric e.g. from Improvised Explosive Devices (IED), any threats resulting from direct and indirect fire such as fragmentation, ballistic or kinetic effects. This is accomplished by using soft and hard lightweight armour/barrier materials in systems designed to cover the most vulnerable body areas. These systems must not only defeat the primary effects from the threats but also negate or mitigate any secondary effects (e.g., behind-armour blunt trauma). Operational clothing is the critical foundation of the Soldier System as it is designed to protect the soldier from environmental threats and hazards associated with the theatre of operation that could potentially degrade readiness and endangered mission success. Every piece of equipment worn on the soldier must be designed to integrate seamlessly with Operational Clothing.

The Survivability Chain

Aim	Protective Measures
Don't be seen and detected	Signature Management
Don't be acquired	Countermeasures and Mobility
Don't be hit	Countermeasures and Mobility
Don't be penetrated	Body Armour
Don't be killed or injured	Behind armour body protection

Figure 9-3: Survivability Chain

9.2 Technical Domain Deficiencies

A total of 28 general deficiencies were identified in the Soldier System Survivability, Sustainability and Mobility technical domain. The deficiency priorities are detailed in Table A-1 of Annex A to Chapter 9. They were clustered around weight, material properties, protection, integration and comfort. They include both material performance properties and design processes (integration, compatibility, etc.) aspects.

Nine deficiencies were identified as being high priority and closely linked to one another (in alphabetical order), which can be gathered under five broad deficiency groupings: weight, material performance, protection, integration and compatibility, comfort and user acceptance:

1. Blast protection and effect mitigations
2. Comfort (physical and thermal)
3. Fire, flash and flame protection
4. Increased and improved ballistic coverage (head, neck, nape, groin, extremities)
5. Integration and equipment and clothing compatibility
6. Integrated aural protection
6. Melt/drip resistant clothing and equipment
7. Weight
8. Weight distribution

9.3 Survivability, Sustainability and Mobility Vision 2025

The SSTRM vision for this technical domain in 2025 is **a system that enhances significantly soldier survivability, mobility and sustainability, and increases operational effectiveness by providing a lightweight, highly comfortable, mission configurable, fully integrated and interoperable, multi- functional system for all environment and weather conditions.**

9.4 Overall System Goals (2015–2020, 2020–2025)

In order to achieve the technical domain vision, mid-term (2015–2020) and long-term (2020–2025) goals have been identified. These will require investment in R&D over the next 10–15 years. While the mid-term goals can be categorized as evolutionary or incremental improvements on existing systems, the long-term goals are characterized as revolutionary and will exploit novel emerging technologies. The goal for the 2015–2020 timeframe is a lightweight system that improves the balance between protection and performance, enhances functionality, comfort, personal protection, safety and mobility, and is better integrated. For 2020–2025, the goal is an adaptive, intelligent integrated system that offers "plug and play" capabilities and "self" functions (e.g., self-repair) providing substantial weight and bulk reduction. This will also allow the soldier to evade C4I detection through signature management, and fully exploit an optimized survivability chain with functions to avoid detection and identification, increase his or her manoeuvrability, and the capability to defeat attack and enable self-repair. The overall system goals are presented in table 9-1 below.

Table 9-1: Overall Survivability, Sustainability and Mobility Technical Domain Goals

2015–2020 (Incremental Improvement)	**2020–2025 (Revolutionary Change/Improvement)**
Incremental weight and bulk reduction (25-50 percent)	Substantial weight and bulk reduction (50-75 percent)
Mission configurable and modular	Fully configurable and modular
Optimized body coverage with flexibility, mobility (integrated joint and groin protection, integrated ocular and mandible protection) with better comfort and enhanced breathability	Uniform system with complete moisture management and recycling and self-repairing materials
Improved integration including: • Heat management (cooling and heating) (sealed system) • Electronics, flexible displays and input devices, C4I sensors and others • Power generation, distribution and storage (E-Textile) • Basic load carriage • Vital-sign monitoring and tracking and automated call-for-help	Fully integrated energy harvesting/storage/generation Integrated/ embedded (active/passive) wound management/healing with embedded C4I sensors
Personal Protection • Flame resistance • No melt/drip • Flash (ocular) • Heat/cold (integrated all-weather protection (e.g., Arctic) • Stab/needle/bite • Ballistic and blast • Anti-static/electric resistance • Antimicrobial • Blunt impact	Reactive personal protection (i.e. on-demand) Scalable and modular armour 360-degree whole-body protection CBRNE, self-decontaminating protection (head and body) Directed energy protection (sonic, micro-wave, laser)
Adaptive and reactive signature management, including multi-spectral protection (predator concept)	Smart adaptive multi-spectral camouflage
Improve load carriage and footwear systems	Mobility aids, e.g. exoskeleton
Integrated Identification Friend and Foe (IFF) and Blue Force Tracking/reporting	Ability to seamlessly add on technology and interface with networks

The essential and desirable weight reduction goals for the system are shown in Figure 9-4.

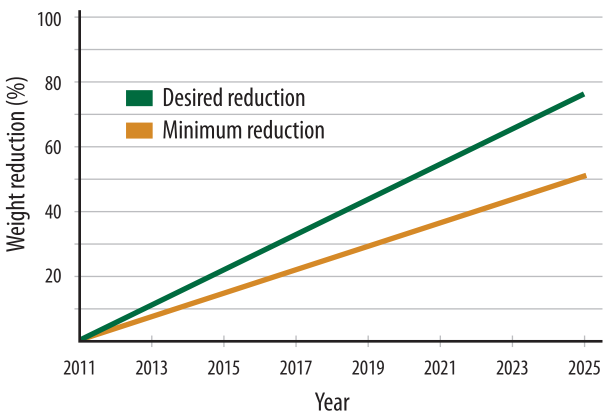

Figure 9-4: Soldier System Weight Reduction Goals

9.5 Technical Domain Specific Drivers

Sixteen specific technology drivers were identified (see Table B-1 of Annex B to Chapter 9 for a full description):

1. Access to technology
2. Bulk
3. C4I integration
4. Ergonomics
5. Durability
6. Material Technology
7. Modularity trade-offs
8. Multi-spectral signature
9. Operator in the loop
10. Power
11. R&D capability in Canada
12. Soldier systems
13. Spectrum of capabilities
14. State of knowledge
15. Threat Level
16. Weight

The threat is the key driver that dominates the survivability capability area and in 2009 the Integrated Soldier System Project (ISSP) prioritized a list of 30 threats facing the dismounted soldier (see Appendix 1). Based on the ISSP Subject Matter Experts reviews, the top four threats faced by dismounted soldiers were as follows (see Table 9-2):

Table 9-2: Top Threats Facing Dismounted Soldiers

Rank	Threat	Risk level
1	Blast Injury (fragments, impact acceleration and overpressure)	High–Very High
2	Ballistic–High Explosive Fragments	High
3	Ballistic–Direct Fire	High
4	Psychological/Physiological	Medium–High
5	Detection of Thermal Signature	Medium

The two themes (16 and 17) of the Soldier System Survivability, Sustainability and Mobility technical domain are summarized below and are available in greater detail in Annex C and D.

9.6 Theme 16: Operational Clothing, Load Carriage and Mobility

9.6.1 Scope

The Operational Clothing, Load Carriage and Mobility theme includes the future operational uniform system, load carriage system and mobility aids.

The clothing system includes:

- undergarments, the uniform itself, and add-ons (e.g., parkas and rain suits), not including specialized protection equipment (e.g. the CBRN over garment);
- a means to distribute, generate and store power, together with connectors to attach electronic systems (e.g., Global Positioning Systems (GPS), IFF tags); and
- handwear and footwear (e.g. socks, insoles, boots, over boots, snowshoes and skis).

The load carriage system includes:

- Modular fighting rigs; and
- Personal rucksacks.

The mobility aids include what the soldiers may use to carry his/her equipment into and during operations, such as:

- Small-unit carriage robots or vehicles; and
- Load carriage assistive options (e.g., exoskeletons).

9.6.2 Objective

The objective of this theme is to improve operational effectiveness through a soldier clothing and equipment system that will better protect the soldier and provide interoperability, multi-functionality and adaptability to the soldier's mission in all environments and weather conditions. This can be achieved by developing a human-centric load carriage system that contributes to self-sustainability and operational effectiveness with increased mission configurability, modularity and mobility. It must provide increased comfort and reduce real and "perceived" weight through enhanced lightweight design and material for better weight distribution. It may include the use of robotic mobility assistance such as an exoskeleton and, in last priority, an external carriage system or robotic mules. It will integrate energy generation and maybe also include harvesting. Furthermore, it will integrate the data, power transmission and required connections.

Figure 9-5 below shows CF's Directorate of Land Requirements (DLR) operational clothing, load carriage and mobility objectives and current related programs, as presented at the technical workshop.

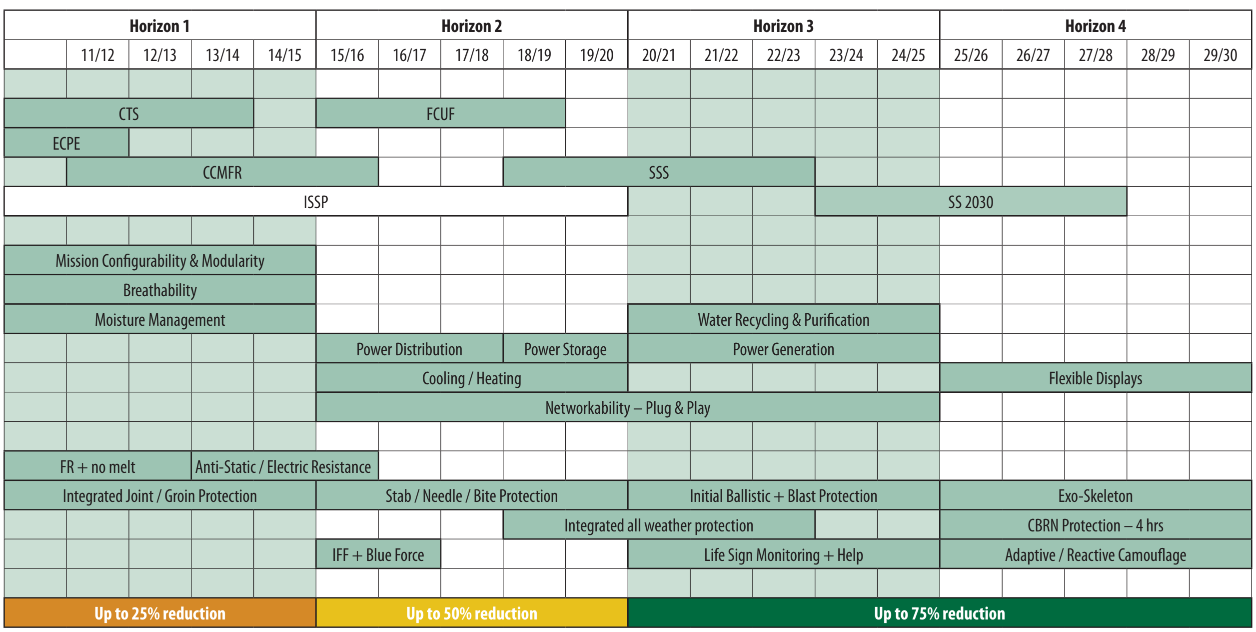

Figure 9-5: DLR Operational Clothing, Load Carriage and Mobility Objectives 2010

9.6.3 Related Challenges and Requirements

Forty-four performance parameters were identified as key challenges needing to be addressed. The challenges clustered around five broad deficiency groupings: weight, material performance, protection, integration and compatibility, comfort and user acceptance.

For a full list of the critical challenges see Annex C to Chapter 9, which provides detailed mid-term (2015–2020) and long-term (2020–2025) performance targets.

Key Mid-term Challenges and Requirements (in alphabetical order):

- 25 percent essential and 50 percent desirable weight reduction
- Improved comfort
- Improved integration
- Improved material performance
- Improved signature management
- User acceptance

Key Long-term Challenges and Requirements (in alphabetical order):

- 50 percent essential and 75 percent desirable weight reduction with added capabilities
- Active thermal management
- Adaptive or multi-function textiles
- Full integration
- Integrated power and data
- User acceptance

9.6.4 Enabling and Emerging Technologies

Twenty eight promising technologies were captured that could address a number of the key deficiencies identified under the Operational Clothing, Load Carriage and Mobility theme. These potential options are detailed in Table C-2 of Annex C to Chapter 9.

Based on this review, only limited options for mid-term (2015-2020) technology options to address gaps in the Operational Clothing, Load Carriage and Mobility theme were identified:

- Energy-harvesting textiles and technologies
- Nano-coatings
- Advanced polymers and elastomers (e.g. for fibres, film, matrix, coating)
- Advanced textile structure (3-D)
- Multi-component textile (coating, membrane)
- 3-D custom fitting (insole)
- Pouch Attachment Ladder System (PALS)/ MOdular Lightweight Load-carrying Equipment (MOLLE)
- Modular Pack System (Load Carriage)
- Exoskeleton and endoskeleton systems for assisting in load carriage
- New camouflage designs

A large number of revolutionary technologies were identified that may resolve deficiencies in the operational clothing area in the long term (2020-2025). The most promising of these revolve around the processes and applications of nanotechnology but their real benefits are still not fully demonstrated. Nano-materials include carbon-based nano-materials, nano-composites, nano-metals and alloys, biological nano-materials, nano-polymers, nano-glasses and nano-ceramics. Nanotechnology has the promise of customizing materials and textiles for the Department of National Defence unique and demanding requirements. Potential long-term (2025+) nanotechnology solutions to the performance gaps include:

- Carbon-based nano-materials (e.g., particles and carbon nano-tubes) for improved strength, electrical energy storage, insulation, semiconducting and conducting properties.
- Nano-fibres and nano-fibrils for improved fabric strength, polymer reinforcement and lighter materials.
- Nano-clays for improved abrasion resistance, chemical protection and fire resistance.
- Nano-ceramics for improved and novel optical, electrical, dielectrics, magnetic, thermal, chemical and mechanical properties.
- Nano-coatings for protective covering, colour-shift coatings, improved abrasion resistance, ultraviolet (UV) protection, CBRNE protection, liquid repellence, etc.

9.6.5 Proposed R&D Focus Areas

Research and development (R&D) requirements for the Operational Clothing, Load Carriage and Mobility theme are grouped under seven focus areas that address generic operational clothing deficiencies. These potential R&D requirements and opportunities are clustered around the following themes:

Priority 1

- Next-generation operational clothing (including outer shell systems using integrated multi-spectral signature management, moisture management and logistic carriage systems, as well as headwear systems, footwear, handwear and combat uniforms);

Heath effects of nano-technologies on human and long-term impacts.

Priority 2

- Advanced materials and processes (including adaptive textiles, electro-chromic materials, micro-encapsulation processes and coatings, smart and nano-materials, and E-textiles);
- Hearing protection (dismounted and mounted) and enhanced hearing (assessment and development);
- Enhanced mobility (including assessment of exoskeletons and development of dermo-skeletons);
- Standards and test methods;
- R&D infrastructure.

Priority 3

- Research tools (instrumentation and simulation) such as 3-D scanning and numerical simulation tools.

More information about the R&D requirements and opportunities for this theme is provided in Annex B to Chapter 9.

As load carriage and footwear are two of the greatest deficiencies, future R&D efforts in these areas will be needed focusing on the form, fit, function, modularity, performance, human factors and comfort aspects in order to maximize user acceptance.

9.7 Theme 17: Personal Protection

9.7.1 Scope

The Personal Protection theme includes ballistic, blast, impact and CBRNE protective systems. The torso and extremity ballistic protective systems include fragmentation vests with ballistic plates, arm protectors and groin protection. The head protective system includes the ballistic helmet shell or shells, helmet liner and suspension system, protective visor, ballistic eyewear, ballistic goggles, nape protector, throat protector, mandible guard and attachment points for or all of these subcomponents as well as items such as night vision goggles (NVGs), headlights, mountable cameras, IFF, and others. The extremity protective systems include arm, leg and joint protection.

9.7.2 Objectives

The objectives of this theme are to:

- reduce weight and bulk of materials;
- emphasize a high level of human factors engineering and user acceptance;
- improve and integrate protection to the various body areas against environmental and battlefield threats;
- maintain thermo-physiological comfort and survival in extreme conditions;
- improve compatibility between and within different clothing components;
- integrate functionality so that fewer layers provide multi-layer protection and increase functionality;
- reduce lifecycle costs by making systems more effective, durable and recyclable, and by buying fewer components for the system; and
- provide scalable and modular protection depending on the threats and the mission.

Figure 9-6 below shows CF's Directorate of Land Requirements (DLR) personal protection vision for the various horizons, as presented at the technical workshop.

Horizon 1					Horizon 2					Horizon 3					Horizon 4				
	11/12	12/13	13/14	14/15	15/16	16/17	17/18	18/19	19/20	20/21	21/22	22/23	23/24	24/25	25/26	26/27	27/28	28/29	29/30
Modular crew				Scalable and modular															
25% lighter with common attachment system, integrated mandible protection, integrated ballistic visor												Integrated CBRN mask							
FPV with limited integrated load				25% lighter vest					Replace vest with jacket with stabilizing collar – 50% lighter										
	Fragmentation protective knee and elbow pads					Fragmentation protective pants							Ballistic crew suit with stabilizing collar – 75% lighter						
															Fully integrated CBRN fragmentation suite				
10% lighter plates									Add-on armour versus Internal Plates – 360 degree protection, 75% lighter						Add-on groin and extremity protection				
				30% lighter plates									Reactive Add-On armour						
Up to 25% reduction					Up to 50% reduction					Up to 75% reduction									

Figure 9-6: Personal Protection Vision Asbstract 2010

Table 9-3: Threat Classification (reference only)

Threat Classification				
Level	Blunt Impact	Fragments	Projectiles	Blast*
Basic	–	1.1 g FSP at 100-300 m/s and low mass fragments (e.g. non-metallic environmental debris)	–	–
Low	30J w/t flat anvil	1.1 g FSP at 300-500 m/s	5.56 ball 7.62 ball	$P_{max} = 1.2$ bar, $\Delta t = 5$ms or $P_{max} = 3.6$ bar, $\Delta t = 1$ms
Medium	60J w/t hemispherical anvil with multiple preconditioning impacts	g FSP at 500- 800 m/s	5.56 SS109	$P_{max} = 5$ bar, $\Delta t = 5$ms or $P_{max} = 12.5$ bar, $\Delta t = 1$ms
High	90J w/t hemispherical anvil with multiple preconditioning impacts	g FSP at 800+ m/s	7.62 steel core 7.62 WC core	$P_{max} = 6.5$ bar, $\Delta t = 5$ms or $P_{max} = 18$ bar, $\Delta t = 1$ms

* Peak overpressures and positive phase durations for an idealized Friedlander overpressure waveform.

For CBRN threats, standard levels are provided in STANAG 2984 while CBRN protection requirements can be found in STANAG 4548. An understanding of the trade-offs of level of protection, human factors requirements, and acceptable injury outcome is still evolving and more work is needed in this area.

9.7.3 Related Challenges and Requirements

Thirty-eight key performance parameters that need to be addressed have been identified. They are clustered around weight, user acceptance, material properties, protection, integration and compatibility, and comfort. A total of 24 high priorities were identified. For a full list of the key challenges see Table D-1 of Annex D to Chapter 9.

Key Mid-term Challenges and Requirements (in alphabetical order):

- Improved aural and ocular protection
- Improved behind-armour blunt trauma
- Improved environmental protection
- Improved extremity protection
- Improved integration
- Reduced weight (30 percent increased mass efficiency)
- User acceptance

Key Long-term Challenges and Requirements (in alphabetical order):

- Active thermo-regulation, full heat management
- Full integrated, modular and scalable armour
- Full integration
- Improved ballistic and impact protection
- Reduced weight (50 percent increased mass efficiency)
- User acceptance

9.7.4 Enabling and Emerging Technologies

A large number of promising technologies were identified that may resolve deficiencies in the Personal Protection theme. These potential solutions are detailed in Table D-2 of Annex C to Chapter 9 and are grouped under seven categories as follows (in alphabetical order):

- Advanced ceramics (opaque)
- Ballistic fibre/fabric
- Blunt impact protection technologies
- Composite materials
- Overpressure protection technologies
- Reactive technologies
- Supporting technologies
- Transparent armour.

Promising technologies include nano-materials, adaptive convective materials, shape memory polymers and textiles, smart or interactive textiles, piezoelectricity, dilatants or shear-thickening, phase change materials and energy absorbing materials. Some of the technologies identified for Personal Protection are similar to those identified for Operational Clothing.

9.7.5 Proposed R&D Focus Areas

R&D needs under the Personal Protection theme have been grouped under five focus areas that address protection deficiencies and requirements as well as specific sub-system needs. These are clustered around the following requirements. A detailed list of R&D development needs and opportunities is available in table D-3 of Annex D to Chapter 9:

Priority 1

- Advanced protective materials.

Priority 2

- Systems design, integration and optimization;
- Threat and injury analysis;
- Test methods and standards.

Priority 3

- Modeling and simulation tools.

Annex A: Soldier Survivability/Sustainability/Mobility Deficiencies

Table A-1: Survivability/Sustainability/Mobility Deficiencies

Rank	Theme 16: Operational Clothing, Load Carriage and Mobility		Theme 17: Personal Protection	
	Operational Clothing (Including footwear & handwear)	**Load Carriage & Mobility** (Including water carriage & sustainability)	**Head**	**Torso and Extremities**
High	N/A	Weight		
High	N/A	Weight distribution		N/A
Medium	Bulk (reduction in range of motion and mobility) Snag hazards	N/A	N/A	Bulk (reduction in range of motion and mobility) Snag hazards
Low (high for head protection)		N/A	Coverage	
High	Limited protection, flash retardancy	N/A	Limited protection, flash retardancy	
High	Limited protection, fire/flame			
High	Limited protection against melt / no drip			
Medium	Limited protection heat resistance			
Low	CBRNE torso	N/A	N/A	N/A
Medium		N/A	CBRNE respiratory system	N/A
Low	Shrinkage	N/A	N/A	N/A
Low	Anti-static	N/A	Anti-static	Anti-static
Low	Electric arc	N/A	Electric arc	Electric arc
Low	Puncture	N/A	Puncture	Puncture
Medium	Integrated protection (knee/elbow, groin)	N/A	N/A	N/A
Medium	Moisture management/ recycling/ (open/closed), water resistance versus breathability (footwear)	Moisture wicking/management and thermoregulation		
Low	Loss of dexterity	N/A	N/A	Loss of dexterity

Rank	Theme 16: Operational Clothing, Load Carriage and Mobility		Theme 17: Personal Protection	
	Operational Clothing (Including footwear & handwear)	**Load Carriage & Mobility** (Including water carriage & sustainability)	**Head**	**Torso and Extremities**
Medium	N/A	Commonality of components (common suspension system, compatibility of attachment systems)	N/A	N/A
Medium	No integrated life preserver (e.g. floatation device)	No integrated life preserver (floatation)	N/A	No integrated life preserver (e.g. floatation device)
Low	Longevity / fading / durability (stretch / tear of fabric)	N/A	N/A	N/A
Medium	N/A	No quick release in emergency situations	N/A	No quick release in emergency situations
High	Comfort (physical and thermal)	Comfort (physical and thermal)	N/A	N/A
Medium-High	N/A	N/A	N/A	Blast mitigation
High	Integration/compatibility (with weapons, armour, load carriage, sensors, clothing and equipment, pockets and buttons)			
Medium	Power / data transmission	N/A	N/A	N/A
Medium	Adaptive multi-spectral camouflage limited to specific environments/terrain			
High	N/A	N/A	Integrated aural protection	N/A

Annex B: Drivers

Table B-1: Survivability/Sustainability/Mobility Drivers/Constraints

Drivers/Constraints	Implications
Spectrum of capabilities	Need a system that provides protection from a variety of threats: ballistic, blast, environmental, etc.
Operator in the loop	The operator is the biggest source of variability in the current system
Weight	Reduce weight of system (note that weight reductions in PPE may be offset partly by weight increases in sensors or other added capabilities)
Bulk	Future systems must be smaller to reduce bulk and optimize soldier mobility and weapon handling performance
Ergonomics	
Visual & heat signature	
Trade-off between protection-wearability-burden	
State of knowledge	Research must be undertaken to unlock the potential of nanotechnology
Material technology	Need better performing materials/fibres/textiles, etc. in smaller, lighter and less bulky packages: • Better textile spinning technologies to spin smaller yarns without breaks • New fabric structures • Lower density material • Smallest structures (fibres, filaments, etc.) • Durable lightweight membranes and polymers
Expected life duration	Future PPE systems must be robust to withstand operational handling/soldier use

Drivers/Constraints	Implications
Power	Future PPE systems may provide a conduit for distributed power and data sources Future power sources must have greater power density
Soldier systems	Future system must link through a soldier network to access other sensors, identification friend or foe (IFF) information networks, etc. Need a system to assess hand-off, data exchange, etc. Soldier systems could also provide centralized or auxiliary power, perform data computation, etc.
Access to technology	ITARS restriction may limit the use of US research, technology, etc. for Canadian projects
Threat level	Protection that is adaptable to the type of conflict
C4I integration (networked enabled soldiers)	Depends on network integration level (communication link)
R&D capability in Canada	A significant barrier to addressing many of these drivers is that Canada has limited R&D capabilities in this area

Annex C: Theme 16: Operational Clothing, Load Carriage and Mobility

Annex C includes the following three tables:

- Table C-1: Challenges/Requirements
- Table C-2: Enabling and Emerging Technologies
- Table C-3: Proposed R&D Focus Areas

Table C-1: Challenges/Requirements

Challenges	Priority	Requirement	
		2015–2020 (Horizon 2)	2020–2025 (Horizon 3)
Clothing and Handwear			
Soldier system integration	High	Integrated C4I/sensing capability (communications, GPS, etc.)	Fully integrated (C4I, sensing, power generation, distribution and storage)
Reduced clothing system weight	High	25 % essential to 50 % desirable reduction with added capabilities	50% essential to 75 % desirable reduction with added capabilities
Thermal comfort • Moisture management • Breathability • Thermal management (cold/heat)	High	Thermally neutral (with minimum weight and thickness) Active thermal management for 24 hours (without re supply)	Thermally neutral (with minimum weight and thickness) Active thermal management for 72 hours
Flame protection	High	Increase exposure time (2 min.) before thermal injury, no melt/drip	100% Increase exposure time with no burn injury
Signature management (multi-spectral: visible, noise, IR, thermal)	High	Increased range before detection (+50% in all spectral bands)	One system for all conditions (adaptive camouflage) range
Comfort (see Human and System Integration Technical Domain)	High	Increased body fit	
User Acceptability	High		
Enhanced integration/ multi-function	High	Reduced number of items in soldier system without reducing capabilities	Minimum number of items
Environment / weather (rain, sand, dust, wind, etc.)	Medium	Integrated all weather protection	Integrated all weather protection

Challenges	Priority	Requirement	
		2015–2020 (Horizon 2)	2020–2025 (Horizon 3)
Enhanced agility/flexibility/ range of motion	Medium	Neutral with added capabilities	Minimum restrictions/constraints
Population fit (biometric)	Medium	100% fit with minimal custom fit	100% with no custom fit
Power generation/ harvesting/storage (see Power/Energy Technical Domain)	Medium	Clothing as a power generation and storage platform	Integrated power generation, distribution and storage
Impact protection	Low	Bump protection for joints	Greater coverage of extremities to reduce blunt trauma
Longevity/fading/durability (e.g. laundering, UV, fuel, abrasion, etc.)	Low	+100% (average)	+200%
Static discharge (see Power/ Energy Technical Domain)	Low	100% static dissipation	100% static dissipation
Enhanced dexterity/tactility (handwear)	Low	+30%	Minimal restrictions/constraints
Puncture/cutting/bite/ stab/slash	Low	Integrated with basic clothing, weight/ comfort neutral	N/A
CBRNE, TIC-TIM protection/ decontamination (limited duration protection)	Low	10 minutes protection for asymmetric threat Integrated in soldier uniform (washable) (safe to dispose) Minimum service-life: same as current uniform Open to closed state in less than 30 seconds	4-hour protection integrated in soldier uniform Decontaminable (safe to dispose)
Footwear			
Form, fit, function	High	Use of advanced body scanner BOSS system (2-D scan) including footwear to size soldier system	Equipment form and fit based on 3-D body scan data
All climate/terrain/ threat rotection	High	Water/wind resistant boots using new materials Improved strength/support weight ratio	Single modular system
Full mission comfort	High	Shock absorption Sole flexibility Foot protection Ankle support Cold/arid/temperate/jungle/mountain operations adaptability	Ballistic protection Limited duration CBRN protection Limited modular blast protection
Improved moisture management/recycling/ (open/closed), water resistance versus breathability (climate control)	High	100% improvement Textile that changes dimensions based on water presence Breathability Lining systems	200% improvement
Integrated load carriage system (all backpacks, water carriage, frag vest/plate carrier, tactical vest)	High	Partial integration	Complete integration
Compatibility with armour system	High		

Challenges	Priority	Requirement	
		2015–2020 (Horizon 2)	2020–2025 (Horizon 3)
Increased user acceptance	High		
Mission-configurable and modular	High		
Commonality of parts (common suspension system, compatibility of attachment systems)	High		
Improved comfort/ adjustability/stability (better load management)	High	No pressure points	
Improved ballistic protection	Medium	Impact, puncture, flame (flash), ballistic	
Modular system construction	Medium	A modular boot system with interchangeable components for terrain and environmental conditions Thermo regulation done via modular component	
Integrated and compatible with energy system	Low	Conduct trade-off analysis	Implement recommendations
Signature management	Low	Multi-spectral	Compatible with adaptive clothing camouflage
Drying time	Low	Less than 4 hours when fully soaked	Less than 1 hour
Securing methodology to foot	Low	Quick lacing and release	Self-tightening
Load Carriage			
Weight reduction	High	25% essential to 50 % desirable weight reduction	50 % essential to 75% desirable weight reduction
Weight distribution	High		Full modularity to allow custom load distribution
Enhanced range of motion	Medium		Unhindered range of motion
Improved safety	Medium	Quick release. Integrated life preserver	
Energy harvesting/ generation, distribution, and storage capability (efficiency/ optimization/ release)	Medium	Incorporate a basic capability	Enhanced efficiency/optimization (see Power/ Energy Technical Domain)
Active and passive thermal regulation	Medium	Improved passive thermal regulation	Integrated active thermal regulation
Hydration	Medium/ low (short term) High (long term)	Improved compatibility of hydration system with load carriage system and enhanced ergonomics	Fluid recycling and purification
Enhanced/assisted mobility	Low	Robotics/exoskeleton as an add-on component	Robotics/exoskeleton integrated in soldier system
Reduced noise signature	Low	70 dB while walking average at 5 meters distance	55 dB while walking average at 5 meters distance

Table C-2: Enabling and Emerging Technologies

Technology	TRL (1–9)	Year for TRL 7	Strength (S)/ Weakness (W)	Critical Barriers/Gaps	TSC Recommended Action
Advanced Clothing Materials and Processes					
Functional textiles (conductive, sensors, network, power/ data transmission, user interface)	6	2014	S: Weight saving, multi-functionalizing, better integration, redundancy W: Durability, EMI, multi-layer integration/connectors	• Cut/sew issues • Printing • Storage • Environmental impact • Magnetic field	Assess/ leverage/ invest
Energy harvesting/ scavenging: flexible photovoltaic films	5–9		S: Technology available, but not adapted to meet military needs W: Resistance, low wattage, medium efficiency	• Limited power generation	Monitor/assess
Energy harvesting/ scavenging: piezoelectric fibres	4	2017	S: (none identified) W:L efficiency, design issue, energy storage	• Limited power generation for weight	Monitor/assess
Energy harvesting/ scavenging: thermo electric film/fibres	4	2020	S: (none identified) W: Low efficiency, design issue, energy storage		Monitor/assess
Processes and application of nanoparticles	1–7	2020	S: (none identified) W: Scale-up, quality, purity, dispersion/migration, stability, potential health issues	• Commercialization • Integration • Availability • Manufacturing • Process at mills	Monitor/invest
Processes and application of nanofibres/ nanofibrils	1–3	2020	S: (none identified) W: Strength, dispersion/ migration, potential health issues	• Commercialization • Integration • Availability • Manufacturing	Assess/invest
Processes and application of nanoclays/ nanocompounds	1–-3	2020	S: Abrasion resistant, chemical protection, fire resistant, etc., no toxicity W: (none identified)	• Commercialization • Integration • Availability • Manufacturing • Process at mills	Monitor/invest
Processes and application of nanocoatings	3–9		S: (none identified) W: Potential health issues, durability	• Commercialization • Integration • Availability • Manufacturing • Process at mills	Monitor/invest
Processes and application of nanocomposites/ nanoceramics	1–3	2020	S: Weight reduction W: (none identified)	• Commercialization • Integration • Availability • Manufacturing • Process at mills	Monitor/invest

Technology	TRL (1–9)	Year for TRL 7	Strength (S)/ Weakness (W)	Critical Barriers/Gaps	TSC Recommended Action
Processes and application of nano-encapsulation /beads	1–3	2020	S: (none identified) W: (none identified)	• Commercialization • Integration • Availability • Manufacturing	Monitor/invest
Bio-sensing textiles/ devices	5–6	2020	S: (none identified) W: (none identified)	• Commercialization • Integration • Availability • Manufacturing	Monitor/invest
Advanced polymers and elastomers (for fibres, film, matrix, coating, etc.)	5–8	2013-2018	S: Used in many soldier systems components and allowing for increased comfort, weight & protection W: Still at fundamental scientific level	• Commercialization • Integration • Availability • Manufacturing • Process at mills	Monitor/invest
Advanced composite materials (metal, ceramic, polymer)	5–8	2015	S: Weight reduction, increased protection W: (none identified)	• Engineers are not being trained in new materials and composites as a required curriculum	Assess/invest
Advanced textile structure (3-D)	9		S: Weight reduction & reduced delamination W: (none identified)	• Manufacturing complexity	Assess
Multi-component textile (coating, membrane)	5–8	2020	S: (none identified) W: (none identified)	• Heat build-up	Invest/ assess
Filtration-adsorption • Powder-beads • Fibre • Textile • Metal organic framework (MOF) • Selectively-perme-able membrane	7–9 (MOF TRL3)		S: Self-detoxifying W: (none identified)	• Absorptive capacity	Assess/invest
Multi-spectral materials (passive, adaptive) for signature management & camouflage	3–9	2015 (visual adaptive) 2020 (thermal adaptive)	S: One type of uniform for all environment W: (none identified)	• Material encapsulation commercialization • Integration • Availability • Manufacturing • Process at mills	Monitor/invest
3-D custom fitting (insole)	9		S: Custom fit Increased comfort, increased durability W: (none identified)	Initial cost	Monitor/assess

Technology	TRL (1–9)	Year for TRL 7	Strength (S)/ Weakness (W)	Critical Barriers/Gaps	TSC Recommended Action
Multi-layers composite technologies	6–9		S: Thermo-regulation using a combination of hollow fibres superposed with other fibres creating surface air channels W: (none identified)		Monitor
Alternate closure technologies (CBRNE)	3–7			• Zippers leak and there is a need for novel closures • Mask-hood interface is the weakest interface and needs improvement	Monitor
Sealing-seaming technologies (CBRNE, weather, sole)	5		Allows joining of the upper without any stitches thereby providing increased water resistance		Monitor
Load Carriage Technologies					
Pouch attachment ladder system (PALS)	9	NA	S: Allow load carriage modularity and configurability W: (none identified)	• Adds weight • Limited to PALS grid	Invest
Rigid / internal frame armour / load carriage	7–9	NA	S: Redistribution of weight to the hips W: Might cause other injuries		Monitor/invest
Modular pack system	9	NA	S: Allow different modular bag options to be attached to a common frame W: (none identified)		Monitor/invest
Enhanced Mobility					
Dermo-skeleton	4–6	2013–2014	S: Applicable to combat tasks W: (none identified)		Monitor/invest
Exoskeleton	5–7	2014–2015	S: Applicable to logistic tasks W: Power requirements		Monitor/assess
Thermal Management					
Man portable micro-climate cooling (evaporating)	6	2015	S: Can provide continuous cooling W. Low comfort, weight, sweat evacuation, multi-layer system integration, needs to be next to skin	• Cooling controlled by environmental conditions	Monitor/assess
Man portable micro-climate cooling (heat-sink materials/systems)	5-(active system) 3-(passive)	2020 (active) 2025 (passive)	S: Minimized stress effect in hot environments W: Energy demand for long duration	• Power requirements	Monitor

Table C-3: Proposed R&D Focus Areas

R&D Focus Areas	Scope/Description (Needs and Opportunities)	Priority Order (1, 2, 3)
Next generation operational clothing	Design and integration of advanced materials and processes in the next generation of operational clothing systems addressing all climates (including the Arctic) for optimized compatibility, modularity, functionalities, usability, and comfort (physical/thermal), including combat uniform, handwear, footwear, and headwear systems, outer shell system using: • Integrated multi spectral signature management using adaptive and reactive camouflage • While incorporating: Improved joint flexibility & protection • Opto-electronic fibres for shell materials • Flexible controls and Interfaces Logistic carriage system (tactical vest, modular pack & webbing) with optimized balance and stability for carrying various loads: • Water, ammunition, food And taking into account: • Moisture management • Heating/cooling • Extraction / drying time • Shape customization And protecting against: • Environment and weather • Impact, laser & CBRNE • C4I detection	1
Advanced materials and processes	Development and assessment (e.g., ageing, performance degradation under harsh conditions) of light-weight multi-function materials and processes addressing the operational clothing needs (i.e. comfort, etc.) • Adaptive textiles • Electrochromic materials • Smart and nano-materials and e-textiles • Phase change and shape memory materials • Novel CB protective materials (e.g., stretchable barriers) • New fabric structures/architectures • Micro-encapsulation process/coatings	2
Hearing protection (dismounted and mounted)	Development/assessment of enhanced hearing protection systems to mitigate impulsive noise such as weapon firings and explosions, integrated with communications system and also providing hearing enhancement (see Sensing Technical Domain) optimized for long duration comfort and performance (e.g. voice intelligibility)	2
Enhanced mobility	Development and assessment of robotic-based soldier mobility aids designed and optimized to mitigate oxygen consume with improved biomechanical efficiency and ergonomic acceptability and allowing increased distance and speed of dismounted movements. Mobility aid options to explore are: • Dermo-skeleton for enhanced combat mobility/endurance, and load-related injury reduction • Exoskeleton for heavy load carrying	2

R&D Focus Areas	Scope/Description (Needs and Opportunities)	Priority Order (1, 2, 3)
Standards and test methods	Development of improved objective metrics, test methods and standards for thermal and physical comfort performance assessment	2
R&D infrastructure	Development of a DND centralized integration facility that will be used for the performance evaluation and optimization of soldier systems equipment under real and/or simulated conditions	2
Research tools (instrumentation & simulation)	Development and/or implementation of novel tools and instrumentation such as: • 3-D scanning data for precise/custom size and shape specification and used for manufacturing of clothing • Instrumented articulated manikin that mimics the movement of the human with skin pressure measurement to study load effects and load distribution on the body Refinement and application of numerical simulations tools such as: • Digital biomechanical modeling for predicting the effect of equipment on soldier performance in a variety of tasks and conduct trade-off analysis	3

Annex D: Theme 17: Personal Protection

Annex D includes the following three tables:

- Table D-1: Challenges/Requirements
- Table D-2: Enabling and Emerging Technologies
- Table D-3: Proposed R&D Focus Areas

Table D-1: Challenges/Requirements

Challenges	Priority	Requirement	
		2015–2020 (Horizon 2)	2020–2025 (Horizon 3)
Weight & Bulk			
Weight reduction (assuming same threat/protection level)	High	Increase mass efficiency of armour materials by 30% (V50/AD)	Increase mass efficiency of armour materials by 50% (V50/AD)
Reduced bulk	Medium	Minimize impact of protective systems on user range of motion and mobility	
User Acceptance/Comfort			
Improved ergonomics (torso)	High	Maximize range of motion and flexibility	Transparent to the user
Improved ergonomics (head)	High	Minimize moment of inertia Minimize off-set of CG Easier, quicker donning/doffing	Minimize moment of inertia No off-set of CG
Fit and comfort (physical and thermal)	High	(see Operational Clothing, Load Carriage and Mobility Theme)	(see Operational Clothing, Load Carriage and Mobility Theme)
Improved stability	High	Improve helmet stability	Eliminate relative motion of visual displays with respect to eye
Field of view (head)	High	Maintain current field of view (horizontal and vertical view)	No obstruction of the natural ambinocular field of horizontal and vertical view
Moisture/heat management and recycling	High	Partial (enhanced breathability) (see torso section)	Complete

Challenges	Priority	Requirement	
		2015–2020 (Horizon 2)	2020–2025 (Horizon 3)
User acceptability	High	(see Operational Clothing, Load Carriage and Mobility Theme)	(see Operational Clothing, Load Carriage and Mobility Theme)
Thermo and moisture regulation	Medium	Improved heat & moisture management	Built-in thermo regulatory system
Compatibility	High	Compatible with the entire soldier system	
Signature Management			
Improved signature management	Medium	Multi-spectral camouflage (see Operational Clothing, Load Carriage and Mobility Theme)	Adaptive camouflage (see Operational Clothing, Load Carriage and Mobility Theme)
Protection			
Aural protection (noise/impulsive)	High	No temporary hearing loss or permanent damage from exposure to small arms fire	No temporary hearing loss or permanent damage from exposure to heavy weapons fire or close proximity to blast
Ocular protection including exposure to solar radiation, continuous wave and pulsed lasers • Luminance transmittance • Optical clarity, distortion and warpage • Prismatic imbalance • Anti-fogging • Abrasion resistance	High	Modular protection against laser threats and solar radiation	
Operationally relevant protection requirement definitions	High	Operational casualty and protective equipment analysis and improved V/L modeling tools	Comprehensive V/L models for the whole body covering the full spectrum of battlefield threats
Small arms protection (head)	Low	None	Modular protection against ball rounds
Small arms protection (torso)	High	Reduced behind armour blunt trauma for a given threat level	
Fragmentation protection	High	Improved extremity protection including against non-metallic fragments	
Coverage (head)	High	Modular/scalable multi-threat protection systems including nape/throat/jaw and eyes	Full coverage against fragmentation, impact and blast threat
Blunt impact protection (head)	High	Double impact energy for same injury risk	Further increase of 30% in energy with no increase in injury risk
Improved over pressure protection (PBI and CNS)	High	Improve mitigation strategies based on validated injury mechanisms	Further optimization of the mitigation strategies
Protection against environmental threats	High	No loss of protection system at +50 °C or -40°C Flame retardant Protection against exposure to wind, sand, dust, salt, sun	100% fire/flame/flash/heat/cold retardant/resistant 100% no melt/drip 100% anti-static/electric resistance Integrated all weather protection Integrated life sign monitoring & tracking (see Operational Clothing, Load Carriage and Mobility Theme)
Extremities and joints protection	Medium	Integrate basic ballistic protection and blunt impact	Optimize ballistic protection with the whole the system

Challenges	Priority	Requirement	
		2015–2020 (Horizon 2)	2020–2025 (Horizon 3)
Blunt impact protection (torso)	Low	Add basic protection to spinal column and joints	Add protection to all extremities
Directed energy weapon protection	Low	Taser defeat	Microwave, laser defeat
Protection against edged weapon	Low	Modular stab and cutting weapon protection to existing body armour and provide modular add-on protection for the extremities/ additional coverage	Protection against stab and edged weapons integrated in torso system
CBRNE/TIC-TIM protection (limited duration protection) (dermal/respiratory/eye)	Medium	Stand-alone short duration head cover with respirator (10 minutes)	Integrated respirator (4 hours)
CBRNE/TIC-TIM protection (24 hours for operations in contaminated areas) (dermal/respiratory/eye)	Medium	Low burden tactical gas mask (TIC-TIM canister) Low breathing resistance Low profile Increased field of view Multi-mission capability	Integrated with helmet system
Integration			
Modularity and scalability	High	Add-on with modular coverage, protection level	Full integrated modular/scalable armour
Integration	High	Enhanced integration with load carriage, combat clothing and power/data system	Full integration with load carriage, combat clothing and power/data system

Table D-2: Enabling and Emerging Technologies

Technology	TRL (1–9)	Year for TRL 7	Strength (S)/ Weakness (W)	Critical Barriers/Gaps	TSC Recommended Action
Ballistic Technologies (Fragments/Bullet Protection)					
Advanced ceramics (opaque)					
Silicon based ceramics	7–9				Monitor
Boron based ceramics	7–9		S: Low-density, high hardness, most efficient against steel core rounds W: High cost, limited capability against tungsten core rounds		Monitor
Alumina based ceramics	7–9		S: Low cost W: (none identified)		Monitor
Low-cost high performance ceramic processing	7–9				Monitor
Complex shape ceramic forming	6–9				Monitor
Ceramics with nano-reinforcement	2–6				Monitor
Nano-ceramics (nano-structures)	2–4				Monitor

Technology	TRL (1–9)	Year for TRL 7	Strength (S)/ Weakness (W)	Critical Barriers/Gaps	TSC Recommended Action
Transparent armour					
Advanced transparent ceramics	5–7		S: Increase in strength, increase in scratch resistance, lighter, thinner visor and BEW materials, better scratch resistance W: Cost, manufacturability	• Need to develop commercially • Need to characterize material behaviour • New ceramics are coming to maturity and are being deployed (prototypes) • Partnerships can reduce time to field transition technologies	Monitor/assess
Advanced glass	5				Monitor
Advanced transparent polymer	5				Monitor
Coating-film (anti-fog, anti-scratch, anti-reflection, laser, UV)	6–9				Monitor/assess
Ultra-hard coatings	6–9				Monitor
Advanced forming techniques	6				Monitor
Ballistic fibre/fabric					
M5 fibre (polyhydroquinone-diimidazopyridine)	6		S: Higher strength and ballistic efficiency W: Access to the technology, maturity, stability, scale-up, degradation	• Manufacturability • Environmental effects on performance	Monitor/assess
Polyethylene	6		S: Lowest mass density, high tenacity W: Matrix adhesion in a composite, structural integrity/stiffness, multi-hit capability, backface deformation		Monitor/assess
Aramid/Para-aramid	9				Monitor
PBO	9				Monitor
Fibre reinforcement (nano or other)	5				Monitor
Fibre treatment	6–9				Monitor
Micro-filament	5				Monitor
Hybrid fabrics	5				Monitor
Advanced textile structure (3-D)	6–9 (e.g., 3Tex)		S: Greater impact resistance, reduced delamination W: Ballistic performance still to be demonstrated	• Compromise between structural and ballistic properties	Monitor
Composite materials					
Advanced thermoplastic	6				Monitor
Reinforced thermoplastic	6				Monitor

Technology	TRL (1–9)	Year for TRL 7	Strength (S)/ Weakness (W)	Critical Barriers/Gaps	TSC Recommended Action
Advanced thermoset composite	6				Monitor
Ultra-high pressure processing	6				Monitor
Optimized matrix- fibre interface	6				Monitor
Hybrid laminates	6				Assess/invest
Overpressure Protection Technologies					
Blast loading decouplers	7–9		S: Attenuation of peak overpressure W: Bulky, heavy, limited flexibility		Assess/invest
Noise cancellation (ear protection)	9			• Ear interface • Signal processing • Algorithm, implementation	Assess/invest
Metallic Foam Structure	6		S: Blast footwear application		Monitor/assess
Blunt Impact Protection Technologies					
Polymer foams/ low-density compressible materials (helmet liner, BABT mitigation)					Monitor/assess
Highly rate/ force-dependant materials (soft to hard) (e.g., D3O, Deflexion)	6–9		S: Improved low energy impact protection, flexible under normal conditions W: Limited to low energy impact, limited empirical evidence		Assess/invest
Shape memory polymer/foam (helmet liner)			S: As a result of an external stimuli such as temperature, can change from a temporary deformed shape back to an original shape W: (none identified)		Assess
Reactive Technologies					
Magnetorheological (MR) fluids	1–5		S: Flexible under normal conditions W: External activation, power demand	• Activation/Response time vs. threat • Ballistic/impact efficiency	Monitor
Dilatants - shear thickening fluid	6–9		S: Flexible, stab and puncture resistance, back-face signature reduction W: Limited empirical evidence for ballistic		Assess/invest
Phase change materials	1–3				

Technology	TRL (1–9)	Year for TRL 7	Strength (S)/ Weakness (W)	Critical Barriers/Gaps	TSC Recommended Action
Interactive textiles	1–5		S: Materials and structures that sense and react to stimuli (e.g., mechanical, thermal, chemical, electrical, magnetic)	• Integration • Standards • Connection • Commercialization	Monitor/invest
Supporting Technologies					
Physical human body surrogate (e.g., head, torso, leg) (frangible and non-frangible)	6	2015–2020			Invest
Empirical, physics based numerical simulation tools	6	2015–2020			Invest
Ballistic instrumentation (e.g. gauges, high-speed imaging, etc.)	9				Invest

Table D-3: Proposed R&D Focus Areas

R&D Focus Areas	Scope/Description (Needs and Opportunities)	Priority Order (1, 2, 3)
Advanced protective materials/systems	Soft, hard and transparent light-weight material systems based on: • Nano-materials • New high performance fibres/ fabrics and composites • Material processing • Advanced ceramics and metals • Advanced transparent materials • Hybridization • Reactive technologies (piezoelectricity, shear-thickening, phase change, etc.) • High performance compressible materials (energy absorbing/managing materials) Capable of defeating current and future threats for the desired survivability/protection level and enabling significant causality/injury and weight reduction	1
Systems design, integration and optimization	Enhanced headwear, torso, extremity protection through: • Material selection and integration • Trade-off analysis • Coverage studies • Human factor engineering • Functionalities integration • Protection vs. other functionality • Anthropometry • Soldier acceptability	1

R&D Focus Areas	Scope/Description (Needs and Opportunities)	Priority Order (1, 2, 3)
Threat/injury analysis	Future security environment Threat analysis and prioritization Injury mechanisms Injury statistics (epidemiology) Injury/incapacitation models and criteria Casualty reduction analysis Behind armour effects	2
Modeling and simulation tools	Vulnerability models • High resolution models • Compatibility with CAD • Comprehensive threat effects, injury and outcome models Structural simulation • Enhanced predictive modeling • Loading models • Constitutive models • High-rate material characterization	2
Test methods and standards	Protection/survivability level requirement vs. threats Physical surrogates for key threats and body areas Measurement tools (optical, x-ray, gauges) Refined methodologies Performance assessment	3

Chapter 10: Human and Systems Integration

10.1 Introduction

This technical domain covers human factors integration to the systems as a key enabler linked to all NATO soldier system capabilities. Human and Systems Integration (HSI) is a technical and management process that seeks to enhance total system effectiveness and minimize life-cycle costs, throughout the entire life cycle of any socio-technical system. This is achieved by implementing the most effective balance of human integration processes from five human-centric areas—in concert with traditional systems-engineering and management processes—to optimize the integration of individuals and teams into sociotechnical systems. These five HSI areas include human factors (HF) engineering, system safety, training, health hazards and personnel (see Figure 10-1).

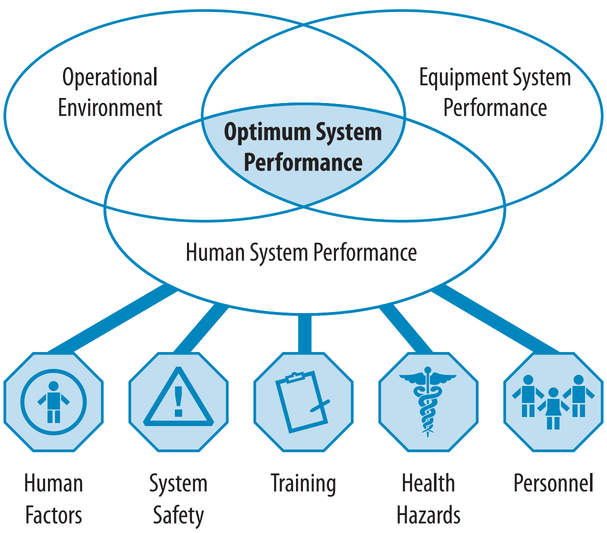

Figure 10-1: Human Systems Integration Model

This technical domain is unique among the Soldier Systems Technology Roadmap (SSTRM) technical domains in that it is not so technology-driven and relies heavily on the use of engineering and management processes to achieve effective integration of humans and systems from the other SSTRM technical domains.

The Human and Systems Integration technical domain has been sub-divided into three themes:

- Theme 18: Physical Integration on the Soldier
- Theme 19: Perceptual-Cognitive Integration on the Soldier
- Theme 20: System Architecture and Interoperability

10.2 Technical Domain Deficiencies

A total of 51 general deficiencies were identified in the Human and Systems Integration technical domain. These deficiencies are detailed in Table A-1 of Annex A to Chapter 10. Fifteen high priority deficiencies are itemized below:

- Insufficient characterization of soldier system users, environments, tasks and conditions;
- Excessive weight and bulk of soldier systems worn, carried and consumed by the soldier;
- Threat protection constraints on soldier system integration;
- Inadequate management of thermal needs (in excess or needed);
- Poor physical compatibility between soldier system items that are worn carried and employed;
- Maintaining the soldier's natural perceptual fields when integrating Command, Control, Communications, Computing and Intelligence (C4I) and protection requirements;
- High mental workload and decision-making demands when integrating new C4I technologies;
- Challenges to achieving and maintaining effective situational awareness (SA);
- Lack of effective and well-integrated user display and interface designs;
- Little to no integration of soldier system voice and data with attached combat vehicles;
- Little to no integration of soldier system power and data with individual weapon systems;
- Little to no C4I network integration with individual soldier systems;
- Lack of effective, adaptive software architecture for individual soldier systems;
- Unreliable soldier system connectors and cabling;
- Lack of Human Systems Integration policies, procedures and guidelines in Canada.

Several of these deficiencies relate to the physical, perceptual and cognitive demands placed on soldiers when integrating the many varied and complex sub-systems in the larger soldier system. This is particularly the case when faced with competing trade-offs for soldier usability among C4I, protective, load carriage, weapons and display/user interface sub-systems. Other deficiencies relate to the challenges of physical and data integration of components within the individual soldier system, as well as external systems (e.g. personal weapons, combat vehicles, and C4I network).

Lastly, based on broad consensus at the SSTRM technical workshop, a deficiency section on HSI processes was added to the discussion of the domain to highlight a major deficiency in the lack of Canadian policies, procedures and guidelines for achieving effective human and systems integration.

10.3 Human and Systems Integration Vision 2025

The SSTRM vision of the Human and Systems Integration technical domain in 2025 is **to significantly enhance soldier and team effectiveness and to minimize overall life-cycle costs by consistent and balanced implementation of Human and Systems Integration, technical and management processes to optimize the integration of individuals and teams into the larger socio-technical soldier system across the five North Atlantic Treaty Organization (NATO) capability areas (i.e. Sustainability, Survivability, Mobility, Lethality and C4I). This will be achieved through the application of Human Systems Integration human-centric processes in five domains: human factors engineering, system safety, personnel, training and health hazards.**

10.4 Overall System Goals (2015–2020, 2020–2025)

To achieve the technical domain vision, near-term goals (2015–2020) and far-term goals (2020-2025) have been identified:

Goals for 2015–2020:

- Quantify the gaps and deficiencies in task performance of the current soldier system.
- Quantify the benefits and impact of HSI intervention across the five NATO capability areas (i.e. Survivability, Sustainability, Mobility, Lethality and C4I) and total system life-cycle cost.
- Develop advanced human system interfaces for seamless integration with human characteristics, capabilities and needs.
- Develop system integration architecture and interface guidelines and standards.
- Develop/improve/disseminate affordable, usable HSI tools and processes to support effective human systems integration by and for the range of stakeholders.
- Promulgate a Department of National Defence (DND) policy mandating the employment of HSI processes throughout the life cycle of all product acquisition and technology development projects having a soldier system element.
- Institutionalize an Army service policy and instruction to support the integration of HSI technical and managerial processes with the systems engineering process and life cycle management of soldier systems and their components.
- Develop or adopt a handbook (including standards) and an instruction document for employing HSI technical and managerial processes in the product life cycle of soldier system components.

Goals for 2020–2025:

- Consistently implement an effective balance of HSI human-centric areas (i.e. human factors engineering, system safety, personnel, training, health hazards) and technical and management processes by institutionalizing HSI training and hiring HSI expertise.
- Optimize integration of individuals and teams into the larger socio-technical soldier system across the five NATO capability areas.
- Enhance and optimize physical, perceptual-cognitive, socio-psychological and system integration of soldier systems to meet training needs, operational demands and to defeat the threats of the Future Security Environment (FSE).
- Provide designs with mature, deployable, operator-state and mission-phase adaptive (intelligent) interfaces and components of the soldier system.
- Provide affordable, fully integrated, appropriately equipped, well-trained soldiers who are able to perform their tasks with minimum degradation under all conditions.
- Train the entire soldier system infrastructure stakeholders to use and maintain the systems.
- Provide ubiquitous systems and processes that support human and systems integration.
- Respond to secular trends in the physical, perceptual, cognitive and cultural characteristics of the soldier population in the design of future soldier systems.

10.5 Technical Domain Specific Drivers

The following drivers were identified for the Human and Systems Integration technical domain:

- Soldier capabilities, limitations and characteristics;
- Physical characteristics of components in the soldier system (i.e. size, weight and shape);
- Soldier system and sub-system performance requirements;
- User expectations for the look, feel and performance of the soldier system;
- Human-system interface integration (i.e. visual and auditory display designs and input device designs);
- Information dependence of the soldier system;
- Power dependence of components, sub-systems and the system as a whole;
- Personal area network concept and associated technologies for sharing information and power;
- Interoperability requirements between the soldier system and other systems (e.g. weapons, vehicles);
- Legacy system integration requirements on the new soldier system for past systems;
- Research and development (R&D) capacity in Canada;
- Management issues for technology accessibility (e.g. cost, availability and trade issues).

The complete list of specific Human and Systems Integration identified drivers is available in Table B-2 of Annex B to this chapter.

10.6 Theme 18: Physical Integration on the Soldier

10.6.1 Scope

The Physical Integration on the Soldier theme begins with the capabilities, limitations and characteristics of the soldiers themselves and all the equipment they carry, wear, use and with which they interact. Any soldier integration effort must accommodate the wide range of soldier differences in size, shape, strength, fitness, skills, abilities, speed, agility, dexterity, thermoregulation, resilience to forces and pressures, handedness, etc. Technologies that inform the HSI process in characterizing soldiers, and that enhance physical integration and performance, without exceeding soldier limitations, are included in this theme.

10.6.2 Objective

Soldier systems will be physically designed and integrated in a way that enhances the physical capabilities of the soldier without exceeding physical limitations that could lead to injury, discomfort, fatigue and reductions in individual performance.

10.6.3 Challenges/Requirements

Key challenges were identified for the Physical Integration on the Soldier theme. These challenges are summarized below according to three groupings: characterizing the soldier and soldiering, minimizing physical burden and improving methods, measures and soldier monitoring. This grouping is kept through the sections of the first two themes. Specific challenges are detailed in Table C-1 of Annex C to this chapter.

- **Characterizing Soldiers**—To support the effective integration of physical items with the soldier, more information is required about the soldier's physical characteristics and tasks. To that end, more knowledge is required about soldier sizing, shape and functionally available areas of the body for mounting and carrying items. To better understand the effect of physical integration on soldier capabilities, more knowledge is required about natural and functional ranges of motion, mobility performance, strength and fitness and soldiering task performance.
- **Minimizing Physical Burden**—To improve the physical integration of items on the soldier, the associated physical burden of these items must be reduced. To that end, it is necessary to reduce weight, bulk and volume. As well, the thermal burden on the soldier of wearing so many physical layers and equipment without adequate ventilation or cooling must be reduced to avoid heat stress. The physical burden of clothing and equipment must also be reduced by improving the fit, accommodation and accessibility of items that are worn, and by improving the customization and configurability of loads to be carried. Finally, the physical burden of soldier systems must be further minimized by improving the usability of controls, attachments, adjustments, etc.
- **Improving Measures, Methods and Monitoring**—Methods of measurement and analysis are required to adequately assess the physical impact of different integration concepts. While some of these methods and measures already exist, there is considerable scope for developing additional valid methods and relating them more directly to user acceptance.

Knowing when a soldier has sustained a physical injury and the extent of that injury, and being able to render immediate medical aid, are becoming important capabilities for the future battle space. To that end, there is a need to improve medical monitoring and remote treatment interventions.

10.6.4 Enabling and Emerging Technologies

Enabling technologies for human and systems integration are detailed in all other technical SSTRM chapters although some key integration technologies are discussed below. Specific enabling technologies are identified in Table C-2 of Annex C to this chapter.

- **Characterizing Soldiers**—New three-dimensional (3-D) photographic and laser scanning technologies are key to enabling the characterization of soldier size and shape for both semi-nude and clothed soldiers. Advances in scanning software also enable complex analyses of function body surface areas. New technologies in real-time motion allow capturing and analysis of complex soldier movements and tasks.
- **Minimizing Physical Burden**—Technologies and methods to reduce weight burden, bulk and volume, improve fit, accommodation and accessibility, improve load customization and configurability, reduce thermal burden, and improve physical device usability can be found in Chapter 7 (C4I) and Chapter 9 (Survivability, Sustainability and Mobility). One area of enabling technologies detailed in Annex C to this chapter includes load-carrying technologies to off-weight the soldier for combat and sustainment loads. These technologies include dermoskeletons, exoskeletons and robotic mules.
- **Improving Measures/Methods/Monitoring**—A key enabling toolset for analyzing and assessing physical burden, accommodation and integration is the new family of virtual 3-D human modeling software. These tools enable the evaluation of complex soldier movement sequences in key tasks, using anthropometrically representative and diverse virtual mannequins. Artificial intelligence is also being combined with virtual mannequins to solve mobility and accessibility problems with clothing, equipment, vehicles and weapons.

10.6.5 Proposed R&D Focus Areas

R&D focus areas related to human and systems integration are also included in all the other SSTRM technical chapters. Specific R&D focus areas for the Physical Integration theme are detailed and prioritized in Table C-3 of Annex C to this chapter. The key elements are summarized below:

- **Characterizing Soldiers**—Considerable scope remains for further R&D to exploit the data captured by 3-D photographic and laser scanning technologies (e.g. software development of usable analytical tools can help translate surface areas, volumes and dimensions into meaningful interpretation and trade-off analyses to model integration concepts and designs).

- **Minimizing Physical Burden**—Considerable research and engineering development is underway in developing load carrying technologies to reduce weight on the soldier (e.g. dermoskeletons, exoskeletons and robotic mules), but considerable scope remains for further R&D to realize the promise of these technologies. Minimization of physical burden is also done on an incremental basis by using novel lightweight material equipment. See Chapter 9 (Survivability, Sustainability and Mobility).
- **Improving Measures/Methods/Monitoring**—Virtual 3-D human modeling software offers considerable scope for improving the analysis of human and systems integration. R&D is needed to develop and improve software-modeling tools for creating valid human models performing realistic soldier tasks and activities. There is also considerable scope for developing virtual models to assess fit accommodation, range of motion and performance aspects of soldier tasks wearing different soldier system ensembles across the range of anthropometric sizes, shapes, strengths and ranges of motion characteristic of the Canadian Forces. The use of artificial intelligence to enable realistic "problem-solving" movements and actions is showing promise and offers considerable scope for creating "smart" virtual mannequin modeling tools to improve the speed and quality of human and systems integration assessments.

10.7 Theme 19: Perceptual-Cognitive Integration on the Soldier

10.7.1 Scope

The perceptual-cognitive integration of the soldier system with the soldier begins with the capabilities, limitations and characteristics of the soldiers themselves. Any soldier integration effort must accommodate the wide range of soldier differences in perceptual abilities (i.e. visual, auditory, tactual and olfactory), memory, decision-making, tolerance to mental workload, intelligence, etc. Technologies that inform the HSI process in characterizing soldiers and enhancing perceptual-cognitive integration and performance, without exceeding soldier limitations, are candidates for consideration in this theme. This addresses as well the information overload on the soldier.

10.7.2 Objective

Systems designed for soldiers will be perceptually and cognitively integrated in a way that optimizes the capabilities of the soldier without exceeding physical limitations that could lead to stress, fatigue, errors and reductions in individual perceptual or cognitive performance.

10.7.3 Challenges/Requirements

Key challenges were identified for the Perceptual-Cognitive Integration theme. These challenges are summarized below according to four groupings: characterizing the soldier, characterizing the task, minimizing perceptual-cognitive burden and improving selection, training and readiness. Specific challenges are detailed in Table D-1 of Annex D to this chapter.

- **Characterizing Soldiers**—To support the effective integration of perceptual-cognitive activities and demands within the soldier system, more information about the perceptual and cognitive characteristics of soldiers and their tasks is required. To that end, more knowledge is needed about the levels and content of soldier knowledge, skills and abilities, soldier perceptual abilities, soldier information processing capacity, soldier memory capacity and soldier perceptual-cognitive performance in high stress environments. It is not enough to generalize information from the general population.
- **Characterizing the Task**—To better understand the requirements for soldier perceptual-cognitive capabilities, and the capacity that remains available for soldier system devices, more knowledge is needed about the demands of soldiering tasks and missions. Different missions, environments and conditions (e.g. day versus night) pose vastly different perceptual and cognitive demands on the soldier, depending on their role and function within a unit.
- **Minimizing Perceptual-Cognitive Burden**—To improve the perceptual-cognitive integration of soldiering and soldier system demands with the capacity and capabilities of the soldier, the associated perceptual-cognitive burden must be reduced. The perceptual modalities employed in soldiering tasks also tend to be the modalities traditionally employed to present soldier system information to soldiers (i.e. visual and auditory modalities). Soldier systems are able to provide the soldier with large amounts of different types of information (e.g. tactical cues, text messages/reports, digital map information, radio communications and tactical battlefield information). This new information competes with the perceptual and cognitive demands of normal soldiering, so these demands must be reduced.
- **Improving Selection, Training and Readiness**—Future soldier systems usage may require a different mix of knowledge, skills and abilities than that which currently exists in the Land Force. New methods will need to be developed to identify recruits who will be successful in the digital soldier system age.

  New soldier system technologies will likely require new methods and means of training soldiers to be effective. As the demands of a complex battle space increase, new methods of achieving, monitoring and maintaining individual psychological readiness in operation will be required.

10.7.4 Enabling and Emerging Technologies

Enabling technologies for perceptual-cognitive capabilities are described in Chapters 7 (C4I) and 8 (Sensing). However, key enabling technologies include perceptual cueing technologies that embed tactical information cues in the perceptual field of a display (e.g. augmented reality visual display, 3-D audio display). Candidate technologies that impart cueing information through vibrotactile perception in the skin have proven to be very effective in soldier system environments. Autonomous decision aids, information filtering and fusion participating to the emergence and consolidation of situational awareness, and COA (Courses of Action) software tools are key enabling technologies for reducing distraction, mental workload and situational awareness errors. Augmented reality displays, coupled with 3-D visualization software, can also enable significant improvements in acquiring situational awareness and its understanding. Technologies for brain-computer interface remain largely untapped and could have substantial benefits for human-systems integration.

10.7.5 Proposed R&D Focus Areas

R&D focus areas related to human and systems integration are also included in other SSTRM chapters. Specific proposed R&D focus areas for the Perceptual-Cognitive Integration theme are detailed and prioritized in Table D-2 of Annex D to this chapter. The key elements are summarized as follows:

- **Characterizing Soldiers**—A significant amount of R&D is necessary to acquire information about the perceptual and cognitive characteristics of soldiers. The results of this research would provide essential input to information systems design, software interface and functionality, training program design and soldier-selection criteria.
- **Characterizing the Task**—Research is required to determine the perceptual and cognitive task demands of different missions, environments and conditions for the range of roles and functions within a unit.
- **Minimizing Perceptual-Cognitive Burden**—R&D is required to identify and develop the most effective strategies and technologies to minimize the overuse of a soldier's perceptual and cognitive resources, while performing regular soldiering tasks. Opportunities exist to exploit new and existing perceptual modalities in novel ways (e.g. vibrational factors to alert and cue) and to determine the best ways and means to achieve perceptual cueing and information integration with low-attentional demands during primary tasks. Further R&D is necessary to reduce demands on memory, decision-making, and acquisition and maintenance of the situational awareness on soldiers through decision aids and situational-awareness support systems.

  Additional R&D is required to investigate and develop technology solutions for reproducing natural and enhanced perceptual abilities among soldiers who have had their natural senses blocked or obscured by protective and display devices and materials (e.g. helmets blocking hearing).
- **Improving Selection, Training and Readiness**—Research into the personnel selection requirements (i.e. knowledge, skills, abilities, traits and aptitudes) is necessary to ensure that soldiers in the future digital battle space can successfully integrate and employ future soldier systems.

  New soldier system technologies introduce new possibilities for individual and collective training. Powerful individual soldier computers operating in a networked configuration at the sub-unit and unit levels provide opportunities for embedded individual training, individual virtualized training, networked team and collective training, individual and collective mission rehearsal, and so on. These are all potentially possible in the field, during transport and on the move. R&D is required to identify which technology solutions and training strategies provide the greatest training benefit for the least overhead, i.e. physical, logistical and financial overhead.

  Research into individual readiness issues, impact and optimization for the future information battle space is currently limited. R&D into ways and means to measure and monitor individual readiness is also in its infancy.

10.8 Theme 20: System Architecture and Interoperability

10.8.1 Scope

This theme includes issues of soldier system integration with external systems (e.g. vehicles, weapons and C4I systems), hardware issues in integration (e.g. cables and connectors), and interoperability of systems.

10.8.2 Objective

Human system integration principles and practices will be applied to the System-of-Systems integration of soldier systems worn or carried by the soldier and external systems that soldiers must occupy or operate. This SoS integration will ensure that the capabilities of the soldier are optimized for all associated systems without exceeding the physical and perceptual-cognitive limitations of the soldier.

10.8.3 Challenges/Requirements

Key challenges were identified for the System Architecture and Interoperability theme. These challenges are summarized below, according to six groupings: vehicle integration, weapon integration, C4I integration, human-to-human interoperability, hardware integration and software integration. Specific challenges are detailed in Table E-2 of Annex E to this chapter.

- **Vehicle Integration**—In the current battle space, dismounted soldiers in combat vehicles have very little voice and data integration with their vehicles or their vehicle crew. Moreover, they have almost no integration once they leave the vehicle. For the future soldier system to be effective, vehicles and their dismounted soldier systems must be fully integrated for voice and data, both within and outside of their vehicle. As well, dismounted soldiers have little or no situational awareness of the terrain and conditions of the battle outside their vehicle prior to dismounting, making the dismounting process more dangerous and uncertain. New technologies offer the potential to improve a soldier's local situational awareness prior to disembarking from their vehicle.
- **Weapon Integration**—Future infantry weapons will be more than just precision effects devices—they will also provide a platform for a significant amount of sensor information, target designation data and target hand-off capabilities. As well, soldier system controls and displays may be co-located on weapon systems. However, there is currently no effective means of sharing power and data between individual weapon systems and the soldier system.

- **C4I Integration**—The future soldier system will be capable of operating its own ad hoc network at the section and platoon level. Integration with the Land Command Support System (LCSS) computer network of command and control is required to significantly enhance the Command, Control, Communications, Computer, Intelligence, Surveillance and Reconnaissance (C4ISR) capabilities and contribution of soldier systems with higher command elements. Similarly, remote sensing devices provide the potential for greatly enhanced quality of the situational awareness but many challenges exist for integrating this capability into soldier system networks.
- **Human-to-Human Interoperability**—Canadian Forces soldiers are required to routinely communicate and interact with military forces and civilians who do not have English or French as their first language and who have different cultural expectations and customs. In this way, language and culture can pose a significant barrier to interoperability between human operators.
- **Hardware Integration**—Hardware integration (cables and connectors) remains a significant and persistent durability challenge in dismounted soldier systems. Current soldier system designs often include a varied mix of connector types and battery types that further complicate integration, interchangeability, configurability and maintainability.
- **Software Integration**—Current soldier systems offer a wide range of software interface designs that may or may not be intuitive and usable for the soldier, and may even be different between software modules and operating systems. This lack of a soldier system software interface standard requires soldiers to learn each unique interface for the devices and modules they use. This creates a significant training burden, slows software usability performance and increases the likelihood of user errors.

10.8.4 Enabling and Emerging Technologies

Enabling and emerging technologies for system integration and interoperability capabilities are described in Chapters 5 (Power and Energy), 7 (C4I) and 8 (Sensing). A recurrent issue in this theme is the need to reliably and securely integrate power and data between components on the soldier, and between the soldier system and other items carried (e.g. weapons) and platforms that carry soldiers (e.g. vehicles). For interfaces on the soldier, enabling transmission technologies include smart fabrics (e.g. electro-textiles, metal rubber and flexible interface materials) and connector technologies such as inductive power and data, and wireless or connection-less personal-area-network (PAN) technologies (e.g. Bluetooth, zigbee, z-wave and Ultra Wideband (UWB). While wireless and inductive transmission and connection of power, data may be attractive in the near term, there are immense challenges in securing these types of technology for the battlefield. These technologies have the capability to deny every effort done in signature management for the soldier and his section (i.e. concealment, deception and camouflage). But at the same time, these technologies are powerful enablers for integrating the soldier system with items that the soldier wears, carries or uses while dismounted and while mounted. So there is then an available area of innovations that beg to be exploited.

10.8.5 Research and Development Focus Areas

R&D focus areas related to human and systems integration are also included in all the other SSTRM technical chapters. Specific R&D focus areas for the System Architecture and Interoperability theme are detailed and prioritized in Table E-2 of Annex E to this chapter. The key elements are summarized as follows:

- **Vehicle Integration**—Considerable R&D effort is required to determine the most effective means of integrating voice and data connectivity and interoperability between dismounted soldier systems and their vehicles for the purposes of communication, situational awareness, target hand-off and command and control. There are several R&D opportunities for pursuing improved local situational awareness for soldiers about the state of the battle and conditions outside their vehicle prior to dismounting. Such R&D will need to consider the number, types and integration of sensor systems outside the vehicle, the best way to present this data to support soldier' situational awareness acquisition, and the decision-support opportunities for guiding soldiers to cover and avoid enemy fire.
- **Weapon Integration**—There is considerable scope for integration R&D to address the links and function allocations between the soldier system computer that is mounted on the soldier and the sensor and display systems on the soldier's weapon. There are R&D opportunities for resolving the best ways and means to share power and data (e.g. wired, wireless, inductive or conductive) on the weapon system, as well as the more fundamental system architecture questions about controls, displays and sensor integration between the two systems.
- **C4I Integration**—Apart from ongoing R&D to resolve the best ways, means and levels for network architectural integration with the LCSS, there is considerable scope for resolving how best to integrate remote sensor systems into small-unit common operating picture.
- **Human-to-Human Interoperability**—R&D is required to determine how best to integrate simultaneous translation technologies and cultural decision-aids into soldier systems.
- **Hardware Integration**—R&D into more effective links and connectors for power and data remains a ubiquitous requirement in soldier systems
- **Software Integration**—A program of R&D is required to determine the most effective and usable soldier system software interface standard that can be applied consistently and widely to all soldier interfaces.

Annex A: Human and Systems Integration Deficiencies

Table A-1: Human and Systems Integration Deficiencies

Rank (High/Medium/Low)	Physical Integration
High	Soldier system characterization (physical) – To effectively design and integrate technologies for the soldier we must have comprehensive knowledge characterizing the physical soldiering environment, and associated task demands, and the physical characteristics and capabilities of the soldier population must be known. There are currently gaps in our knowledge in these areas and we are deficient in communicating and disseminating this knowledge to non-military stakeholders. These gaps include knowledge of the physical environment, physical task demands, user characteristics, user capabilities, and workspace characteristics.
High	Over weight – Soldier systems weight is currently excessive resulting in injury, fatigue, discomfort, and reduced task performance
Low	Bulk – System bulk is currently excessive and reduces personal flexibility, range of motion, mobility, accessibility to confined spaces and openings, and limits task performance. Excessive bulk also affects soldier integration with other equipment, weapons, and vehicles.
Medium	Fit accommodation – Soldiers vary widely in size and shape, and current fit accommodation is not always ideal. Climate and mission demands require a capability to adapt the fit of different clothing, equipment, and workspaces to accommodate this range of demands. Poor fit accommodation results in degraded task performance (e.g. ingress, egress) higher discomfort, fatigue, and safety risk. Size tariffing (wide variability in the population, logistical consideration, too many sizes)
Medium	Load configuration – There is a finite amount of real estate available on a soldier to carry various items of the soldier system load. This real estate can vary depending on the size of the soldier and clothing state. Optimizing load configuration and configurability for size, shape, mission, roles, etc. are significant challenges. Location-specific requirements challenge the integration of components and sub-systems
High	Exposure and threat (integrated protection) demands – Precipitation, dust, vibration, EMF, CBRNE, etc., create protection demands, while we have protection for many of these threats, our current solutions pose significant integration challenges (e.g. ballistic vs. CBRN protection).
High	Thermal management – Thermal management remains a significant challenge for dismounted soldiers and equipment in both hot and cold environments. The addition of high physical workload, impermeable clothing, and heat generating equipment can exacerbate heat demands and moisture management. Thermal demands on equipment or soldiers can dictate integration solutions
Medium	Device usability – Soldiers must be capable of generating sufficient force, control accuracy, dexterity, and tactility required to manipulate a wide range of input and control hardware devices at various locations on and off the body. Often these devices must be capable of being manipulated while wearing handwear.
High	Physical compatibility – Physical compatibility between different items of clothing, equipment, weapons, and vehicles is always a challenge in soldier systems. For each item of clothing, equipment, weapons, etc., soldiers must be able to effectively employ, operate, carry, and handle a soldier system device while wearing combat loads.
High	Sub-system integration – Individual items of clothing, equipment, and weapons must be able to integrate sufficiently well on the soldier so as not to impede soldier tasks and activities, and the effective operation or use of any one item. E.g. clash between facial protection and weapons
Medium	System safety – Safety has always been an important issue for the soldier in terms of clothing flammability, static discharge, POL exposure, etc. The advent of new devices that require batteries, electrical cabling, various radios, and electronic devices introduces new potential safety hazards in terms of flammability, Hazard Electromagnetic Radiation to Ordnance (HERO) detonation, and Hazard of Electromagnetic Radiation to Personnel (HERP), battery safety – combustion, gasses.
Medium	Accessibility – Accessibility includes both donning/doffing and emergency medical access. Soldiers must be able to don and remove their equipment quickly. For example, when suddenly engaged while at rest in a FOB or when suddenly required to move for a mission soldiers must be able to don their equipment and achieve full combat functionality quickly. As well, there are times when a soldier must doff their equipment in an emergency situation (e.g. suddenly submerged in water, vest is on fire). Time is the enemy of a wounded soldier as exsanguination is the highest cause of fatalities. Medical staff must be able to access the injury quickly so the physical integration of clothing and equipment must not impede this accessibility.

Rank (High/Medium/Low)	Physical Integration
Medium	Medical monitoring/intervention – Currently there is no remote means of monitoring the health and medical status of a soldier. New computerized, networked soldier systems can capture physiological data to monitor stress levels, wakefulness, life signs, wound location, etc. for remote triage and faster treatment. Time until medical intervention is often the determinant of survival, especially for exsanguination
Medium	Ergogenic Aids – Soldiering is a physically demanding occupation that can excessively fatigue the soldier and reduce warfighter performance. Physical performance can be enhanced with ergogenic aids including pharmaceuticals, nutraceuticals, diet, and mechanical aids (e.g. Exoskeleton, dermoskeleton). However, little is known about the effects of ergogenic aids on combat effectiveness. Pharmaceutical interventions, even if demonstrably effective, lack organizational support. Nutraceuticals, or nutritional supplements, are unregulated and are available for purchase but lack evidence-based data to support their use. Mechanical aids are neither sufficiently lightweight nor unobtrusive enough for soldier acceptance.
Medium	Detectability – Detection by the enemy typically reduces soldier survivability. The addition of future soldier system devices will result in the soldier emitting new sources of noise, light, heat, and electro-magnetic radiation. These must be controlled and/or camouflaged to avoid enemy detection.
Low	Physical readiness – How do we know when a soldier is physically ready for combat (vigilance, wakefulness, physical capacity)?

Rank (High/Medium/Low)	Perceptual-Cognitive Integration
High	Soldier system characterization (psycho-social) – To effectively design and integrate technologies for the soldier we must have comprehensive knowledge about the psychosocial soldiering environment, and associated perceptual and cognitive task demands, and the perceptual and cognitive characteristics and capabilities of the soldier population must be known. There are currently gaps in our knowledge in these areas and we are deficient in communicating and disseminating this knowledge to non-military stakeholders. These gaps include knowledge of the perceptual-cognitive environment, perceptual-cognitive tasks demands, user characteristics, and user capabilities.
High	Perceptual fields – Integration of clothing, equipment, protection, and weapons can affect natural fields of perception. These include horizontal and visual fields of view and spatialized fields of hearing, proprioception, sense of smell, taste, and tactility.
High	Mental workload – Soldiers are increasingly faced with processing a lot of information in all phases of the spectrum of battle. New computerized, networked soldier systems will provide more information to the soldier to process than ever before. Managing the mental workload demand on the soldier will be critical to maintaining and enhancing his perception, situation awareness, decision-making, task performance, and effectiveness.
High	Situation awareness – As soldiers become more widely distributed in a non-contiguous, non-linear, complex battle space (across the full spectrum of operations and terrain environments), effective situation awareness becomes increasingly important to mission effectiveness and survivability. However, solutions that ensure effective situation awareness remain a challenge. What information should be provided to the soldier? When? In what form? Under what circumstances? How to improve SA?
High	Decision-making – Soldiers are faced with more critical decision-making in today's battle space than ever before. Decisions are often more complex and must be made very quickly. Poor decisions affect mission performance and survivability, and can also have political ramifications.
Medium	Perceptual cueing – Current cueing methods to direct the attention of soldiers to critical information are insufficient (e.g. voice direction, hand signal, etc.). Soldiers work in a very complex environment where the "fog" of war and perceptually diminished environment can result in confusion and disorientation on the battlefield. Digital soldier systems can aid the soldier by orienting them faster and more accurately to features and actions in the battle space through perceptual cueing. By selectively providing cues to the soldier's perceptual sense modalities situation awareness can be enhanced, and decision/action cycles improved, without compromising battle awareness.
Medium	Sensory enhancement – Today's soldier needs to operate under conditions of reduced vision (e.g. low light, night, smoke, from behind cover) and reduced hearing (e.g. vehicle and battle noise) environments. The challenge is how to enhance sensory performance in these conditions without compromising other aspects of soldier performance and effectiveness.

Rank (High/Medium/Low)	Perceptual-Cognitive Integration
High	Display interface design – Display integration remains a key driver in soldier system integration. Current challenge is integrating visual and audio display. Plus these channels are overloaded and we need to exploit other senses. The key to providing soldiers with effective, timely information is the development of visual, auditory, olfactory, and tactual, multi-modal and other novel displays that can provide the necessary information using means that do not detract from the performance of other soldier tasks and activities.
High	Application (software) interface design – Computing technology is becoming ubiquitous in military systems and the soldier systems are no exception. Soldiers have limited time available for training and even less time during operations to figure out how to operate their computing devices and perform information tasks. Key to the effective employment of any future soldier systems will be the usability of the software application interface.
Medium	Remote team information exchange/communications – The capability to communicate information quickly and effectively is essential amongst the distributed soldier team. Current communications is limited to line-of-sight voice and paper. More and more information is becoming digitized (maps, orders, blue force tracking, target designation, etc.) enabling more comprehensive information exchange. Little is known on how best to exploit these technologies to maximize shared understanding and common operational picture under ideal, let alone degraded connectivity, conditions.
Medium	Training (individual and collective) – Successful introduction and achievement of any new technology's potential depends on the soldier having sufficient knowledge and facility with the more complex systems. Currently, training time is limited and training methods are dated. New training methods, approaches and technologies (e.g. embedded, immersive, intelligent agent, on-demand, e-learning), may address the deficiencies but their potential is not well understood.
Low	Personnel selection – While effective human factors design and training are essential, depending on the complexity of any future soldier technologies, there may be a requirement to select soldiers that have the necessary core traits, knowledge, skills, and abilities (KSA) to be an effective user of any new system. This trait and KSA analysis has not been done.
Medium	Individual or personal readiness – Just as high levels of physical readiness are critical to mission effectiveness, there is increasing recognition of the importance of individual readiness or personal readiness. This level of readiness is defined as the culmination of biological, psychological, social and organizational factors that provide the conditions necessary for an individual to expect to perform well, to have skills to do so, and to have the ability to maintain performance even while facing adverse events. However, the factors that influence an individual's level of readiness to consistently perform at a high level are not currently well understood.
Medium	Cultural competence – Comprehensive operations increasingly require military personnel to navigate within systems with diverse cultures and assumptions, as when interacting with members of other militaries, governmental and non-governmental organizations and members of local populations. A key requirement for the future is to gain a more thorough understanding of the psychological competencies and attributes likely to promote the ability to work successfully within complex collaborative environments.
Medium	Ergogenic aids (psychology) – Soldiers are typically required to operate on little or no sleep where conditions can vary from very low activity levels (surveillance) to periods of very high stress (battle). In these very low and high states of activation, soldier perceptual and cognitive performance is reduced. The psychological performance (e.g. vigilance) of soldiers can be enhanced with ergogenic aids including pharmaceuticals, diet, sleep debt management, etc.

Rank (High/Medium/Low)	System Architecture and Interoperability
High	Vehicle integration - voice communications – Currently, soldiers do not have an effective means of communicating with the crew and each other while travelling as a passenger in a noisy LAV.
Medium	Vehicle integration: signal environment hazards – Radio communication is becoming omnipresent and the resultant EMR poses a potential health hazard. For example, the use of radios in the passenger compartment of a LAV is currently prohibited for HERO and HERP reasons.
High	Vehicle integration: network integration (data sharing) – Currently, there is no data exchange capability within the vehicle between soldiers (no radio use), between soldiers and the mounted crew, or between different sub-units on the move (aside from voice communications between leaders). As well, there is currently no solution to ensure that soldiers will have no delays in acquiring GPS and connecting into the network when they depart the LAV.
High	Integration of C2 on the move – Currently, there is no easy, effective means of briefing orders, performing mission rehearsals, or reviewing mission plans while on the move.
Medium	Vehicle integration: local situation awareness – At present, soldiers in the passenger hold of the LAV derive only a small measure of local visual situation awareness around their vehicle prior to disembarking. [Verbally from LAV commander to commander of the dismounts]. Essentially, soldiers disembark "blind" into their dismounted role.
High	Weapon integration: power connectivity – How will the weapon connect to the soldier systems infrastructure for power while minimizing potential safety hazards resulting from cable snagging and mobility restrictions during obstacle traverse? Where will the weapon sub-system power be stored? The key to resolving this issue will rest with the Dismounted Soldier System Architecture and Concept of Employment. There are likely three options: power on the weapon, power off the weapon, or a mix between the two. Which option best meets the HSI requirements and C4I and lethality needs?
High	Weapon integration: data connectivity – How will data be shared between the body-borne system (torso and head-borne) and the weapon-borne system sensors and effectors? How will the system support data connectivity with legacy systems? How would weapon-related processing power be shared between the weapon and the body-borne system? How would the weapon system architecture integrate with the Dismounted Soldier Systems Architecture for Power and Data distribution? Should the data exchange solution between weapon and the rest of the Dismounted Soldier Systems Architecture be separated from the solution for providing power?
High	C4I system integration (network integration) – How will a mounted or dismounted soldier systems be integrated with the LCSS system? How can the dismounted soldier be fully integrated with the rest of the forces? How can the soldier exchange both voice and data information with the chain of command? How could a dismounted soldier be augmented in computing capacity when he connects to a vehicle network?
Medium	C4I system integration (network security) – How will network security be maintained? Who will hold the responsibility for the Dismounted Soldier Systems network security? What kind of security construct is needed at soldier level? What will be the impact of a multi level security posture on the soldier's equipment/architecture and vice versa? How will a soldier using Dismounted Soldier Systems be able to bridge across different security domains?
Medium	C4I system integration (remote sensor integration) – Increasingly, remote battlefield sensors will proliferate in the battle space, including remote cameras, ground sensors, UXVs, etc. How will these be integrated with the soldier systems? (see Sensing Technical Domain for issues of sensor integration)
Medium	Human-human interoperability – Soldiers need to interoperate with coalition soldiers, civilians, NGOs, etc., that speak a language other than English or French, and have unique customs. Often this necessitates the use of local translators embedded with the operational units but these translators are only attached to units or patrols, and individual soldiers typically do not have the means for communicating and relating to these other groups.
Low	System architecture (integration/modularity) – Which soldier system capabilities should be integrated and which should be made modular? Lacking the detailed trade-off analyses.

Rank (High/Medium/Low)	System Architecture and Interoperability
Medium	System architecture (system of systems) – An effective integration strategy for integrating the Dismounted Soldier Systems Architecture into the larger architecture of vehicles and the LCSS is lacking. This architecture must take into account the richness of the technologies available to the Dismounted Soldier Systems and be designed in a way for the soldier to best exploit them in the larger System-of-Systems. Ideally the Dismounted Soldier Systems (DSS) architecture would be capable of adapting to mission demands and capable of accommodating technological growth potential and emerging capabilities. Any DSS architecture must also be consistent with the CF Plan for the future C4ISR Capability Development Plan and strive for commonality of data exchange within the entire System-of-Systems.
High	System architecture (hardware integration) – The most significant hardware integration challenge remains connectors and cabling. This is direct link within the Dismounted Soldier Systems and indirectly to the System-of-Systems Architecture and the general requirements to lower SWaP. What is the best way to integrate the Dismounted Soldier Systems infrastructure to help lower the SWaP and offer a versatile architecture?
Medium	System architecture (commonality) – There are very few standards for system architecture in soldier systems, which results in stove-piped designs, customized solutions, and very limited commonality, even within a given system.
High	Software architecture – Software architecture represents a significant challenge at the Dismounted Soldier Systems level. In HSI terms it will likely be the most expensive lifecycle cost for the system. Innovations (systems and hardware), offering quantum leaps in capabilities, often appear faster than software modifications, or even software innovations, can adapt to keep pace. During the life of Dismounted Soldier Systems we may be able to afford an upgrade in microprocessor, in memory (dynamic and static like mass storage or changes in the data model protocols (i.e. video audio) but it will be more difficult to afford a complete change in Dismounted Soldier Systems main application software based on geographic information system (GIS), that will support the rich context of a Battle Management System (software). The ideal software architecture will be capable of easily evolving and adapting to changes in technologies and remain platform independent for the entire lifecycle of a DSS.
High	DND HSI acquisition policy – Canada does not mandate the inclusion of HIS processes and practices in any DND acquisition policy. The decision to consider and include HSI is solely at the discretion of individual project managers who may or may not be aware of the need for nor benefits of HSI in the system engineering process and total lifecycle management of any acquisition including human operator, maintainers, and trainers. Given the lack of any DND policy on the inclusion of HSI in acquisition programs, HSI application tends to be idiosyncratic and unstructured.
High	HSI service policy/instruction – Canada does not have HSI service policies. To be effective, HSI needs to be applied systematically and comprehensively throughout the lifecycle of any acquisition program in a manner that is generalized across CF but customized to the unique demands and requirements of each of the three services (i.e. Army, Navy, Air Force).
High	HSI handbook/guidelines/standards – Canada does not have an HSI-specific handbook, guidelines, or standards. These reference documents are essential for detailing and standardizing how HSI is employed in any acquisition program, including the when, what, and how of that employment. It is important that HSI itself is integrated into the systems engineering and management process of any acquisition.
High	HSI resources – Shortage of HSI expertise in the soldier systems realm and lack of suitable academic program within Canada. No policy for investment in the HSI domain.

Annex B: Drivers

Table B-1: Human and Systems Integration Drivers/Constraints

Drivers/Constraints	Implications
Soldier capabilities/limitations/ characteristics	Effective human system integration requires extensive knowledge of soldier capabilities, characteristics, and limitations, for all aspects of physiology, biomechanics, anthropometry, perception, cognition, behaviour, etc. This knowledge must also include gender, age, racial, cultural, and generational differences within the soldier population. These capabilities and limitations will become the HSI drivers and constraints in any soldier system design effort.
Physical characteristics of components	The size, weight, and shape of components, sub-systems, and systems have a significant effect on the resultant soldier designs and physical integration within the soldier system. As well, there are limits to the total soldier system weight that can be carried on a soldier and still achieve effective job performance. There are also limits to total size and shape for a soldier system since there is only so much soldier body surface area for locating components in a manner that still enables the soldier to fulfill the performance demands of their job. Population accommodation needs to be 100% to level of 80% acceptance. Location-specific requirements can drive or constrain integration (e.g. GPS antenna).
System/sub-system requirements	The extent and degree of performance required of soldier systems and soldier operators will be a significant driver in the design of any system.
User expectations	User expectations and needs, vice requirements, create gaps that become drivers in future requirements and developments. Risk and weight homeostasis is driving combat supplies and carried loads. Soldier technologies expectations are related to commercial technologies and marketing.
Interface integration	Human-system interfaces (input devices and displays) are a major driver to the design of any soldier system. These devices and interfaces are critical drivers that could well constrain the soldier's senses if not integrated well in the soldier systems since there are many other demands for vision, hearing, tactility, and use of the hands in regular soldiering activities.
Information dependence	If doctrine (e.g. ADO) and tactics rely on information then the requirement for information exchange will proliferate down to the soldier level.
Power dependence	Power capacity is essential to electronic soldier systems and power sources can represent a sizable weight and bulk burden to the soldier, the sub-unit, and the logistical chain. Power density per unit volume and weight, power demands, power management, and operational duration are all design drivers in soldier systems. Power capability affects mission plan.
Personal area network technology	Soldier systems comprise a number of sub-systems that must share power and data. The choice of the ways and means to exchange power and data in the soldier's personal area network is a significant driver in system architecture, composition, and configuration.
Interoperability needs	The extent to which any soldier system may need to interoperate with other systems (e.g. vehicles, weapons, other soldiers with the same system, and other C4I systems) will introduce integration drivers to the design of the system.
Management issues	Canadian access to some technologies will be limited by cost and availability, while others may have IP implications or international trade restrictions.
R&D capacity	Canada has limited R&D capacity to investigate and develop soldier systems solutions. Similarly, Canada's coverage of soldier systems-relevant R&D specialties is also limited. Global collaboration becomes a driver and a constraint.
Legacy system integration	The design and integration of any new soldier system item or technology must necessarily function with other items of clothing, equipment, weapons, and vehicles that still exist in the Army inventory at the time of introduction of any new item. This need for reach-back (backwards) compatibility can be a significant design driver.

Annex C: Theme 18: Physical Integration on the Soldier

Annex C includes the following tables:

- Table C-1: Challenges/Requirements
- Table C-2: Enabling/Emerging Technologies
- Table C-3: Proposed R&D Focus Areas

Table C-1: Challenges/Requirements

Challenges	Priority	Requirements	
		2015–2020 (Horizon 2)	2020–2025 (Horizon 3)
Characterizing Soldiers			
Characterize soldier system size/shape	High	Static full body anthropometry (semi-nude and clothed) data set with 95% predictive power Ability to efficiently and affordably maintain its currency	Static and dynamic full body anthropometry data set with 99% predictive power
Characterize soldier system functional coverage (protection)	Medium	Understand the impact of protection, coverage, bulk, weight, stiffness on task performance and vulnerability to threats	Improve coverage without degradation of task performance
Characterize soldier system range of motion	High	Static ranges of motion with measures of associated resistance under all conditions (including PPE, clothing, workspace, load, etc.)	Dynamic real-time ranges of motion with resistance measures related to joint speed and limit coordination, and task performance
Characterize soldier system mobility performance	High	Mobility performance data cloud for dimensions of load carriage burden: weight, bulk, stiffness, coverage, etc.	Real-time motion and performance results of mobility effects of load carriage burden to assess movement efficiency and performance costs and vulnerability (survivability)
Characterize soldier system task performance	High	Individual performance objective data for key tasks/conditions integrated into models	Team performance objective data for key tasks/ conditions integrated into models
Soldier strength/fitness	Medium	Characterize individual performance objective data integrated into models	Quantify the benefits of alternative strategy for improving
Minimizing Physical Burden			
Reduce soldier systems weight burden	High	-25% burden (metrics TBD)	-50% burden (metrics TBD)
Minimize soldier system bulk/volume (e.g. for increased mobility)	High	-25% (metrics TBD)	-50% (metrics TBD)
Improve system fit accommodation	Medium	95% of all soldiers for all items. 99% of all soldiers for critical survivability items. Minimized logistic burden (optimized the size tariffing)	99% of all soldiers for all items. Affordable, efficient, custom fitting for appropriate items.
Improve soldier's load customization and configurability	High	Understand the modularity/integration trade-offs	Optimize the modularity of the soldier system
Reduce thermal burden	Low (in cold) High (in heat)	-15% in cold -25% in heat	-20% in cold -50% in heat
Improve system device usability	Medium	-25% training time and task performance (errors/time)	-50% training time and task performance (errors/time)

Challenges	Priority	Requirements	
		2015–2020 (Horizon 2)	2020–2025 (Horizon 3)
Improve soldier accessibility (donning/doffing, medical access)	Medium (doffing) High (medical)	-25% time	-50% time
Improving Measures/Methods/Monitoring			
Improve medical monitoring and remote interventions	Medium (both monitoring and interventions)	Medical monitoring at the platoon level with life sign and readiness reporting on request by medics and commanders Manual medical interventions in clothing (e.g. tourniquet) (see the Sensing Technical Domain)	Medical monitoring and triage tracking all the way through the medical management system Remote automated tourniquet and emergency pharmaceutical interventions
Operationalize user acceptance measures (compatibility, comfort, etc.)	Medium	Objective validated test methods for key components of the soldier system	Validated user acceptance models and an efficient way to maintain currency

Table C-2: Enabling/Emerging Technologies

Technology	TRL (1–9)	Year for TRL 7	Strength(S)/Weakness (W)	Critical Barriers/Gaps	TSC Recommended Action
3-D laser anthropometry scanning	9		S: Resolution and detail of information captured is very good W: Static image capture needs to evolve to enable dynamic capture; software for estimating blind surfaces is improving.	• Systems are expensive • Requires dedicated facility	Monitor
3-D photogrammetry anthropometry	9		S: Resolution and detail of information captured is good, more portable and less expensive than laser scanning W: Precision and detail not as high as laser scanning, static image capture needs to evolve to enable dynamic capture, software for estimating blind surfaces is improving		Monitor
Clothed anthropometry modeling	2	2016	S: Much needed for realistic dimensioning especially with the advent of virtual modeling W: technology gap – not a lot of R&D has been done to date	• Modeling clothing to reflect materials and levels of compression is a challenge. • Difficult to define material weight and thickness while material technologies are rapidly advancing	Invest (provide much needed anthropologic data for future designs of equipment, vehicles)

Technology	TRL (1–9)	Year for TRL 7	Strength(S)/Weakness (W)	Critical Barriers/Gaps	TSC Recommended Action
3-D motion tracking & analysis	7–9		S: Imaging/tracking systems are being developed commercially, can be combined with 3-D virtual environment for product development (virtual prototyping), task optimization, and training W: Ability to compile many data sets (not just 1 person) needs to evolve to make analyses more valid	• Correlating 3-D motion tracking to digital human modeling	Invest (current measurement methods for body and joint movement are 2-D planar and static, need to move towards state of the art)
Combat movement performance measurement systems			S : (none identified) W : (none identified)		
Weight/bulk reducing multi-purpose designs			S : (none identified) W : (none identified)		
Weight/bulk reducing materials			S : (none identified) W : (none identified)		
Mission weight management decision-aid software			S : (none identified) W : (none identified)		
Digital mannequin/ biomechanical modeling tools	5 to 9	Depends on modeling requirements	S: Allow for evaluation of spatial requirements, performance, and injury potential before physical prototyping stages, software ranges from high to low fidelity depending on application. W: Software users are reliant on the software designer for developing specific applications, validation of biomechanical inputs (e.g. joint stiffness)	• A software program that "does it all" is not possible due to limitless applications • Incorporating multiple digital human models (analysis of team tasks)	Invest (useful for spatial, muscular force, and injury modeling)
Medical monitoring technologies			S : (none identified) W : (none identified)		
Medical intervention technologies			S : (none identified) W : (none identified)		
Load carrying technologies: Dermo-skeleton	9		S: Ability to reduce loads at joints, potential for soldiers to carry heavier loads. W: ability to transfer load is less when compared to an exoskeleton, level of autonomy (when to be active and when to be passive), requires a level of training by the soldier	• Optimal transfer of power from the system to the soldier • Stabilization of the system on the soldier • Control algorithms for various combat movements	Invest (ability to transfer loads away from the soldier will allow them to reduce their energy expenditure)

Technology	TRL (1–9)	Year for TRL 7	Strength(S)/Weakness (W)	Critical Barriers/Gaps	TSC Recommended Action
Load carrying technologies: Exoskeleton	9		S: Ability to transfer loads away from the soldier, ability to carry heavier loads across longer ranges, reduction in the consumption of energy by the soldier W: Weight of the systems is still too great, long term power solution to the system, unable to produce all soldier movements, requires a level of training by the soldier	• Weight of the system • Long term power of the system • Ability to operate in extreme environments • Adaptable to all soldier movements	Invest (ability to transfer loads away from the soldier will allow them to reduce their energy expenditure)
Load carrying technologies: Robotic mule	9		S: Carries items typically carried by soldiers, operate on own for an extended period of time, gain vantage points that would typically put soldiers at risk, can go over terrain similar to soldiers W: Autonomy to make combat decisions, susceptible to technological breakdowns, responsiveness in critical situations, controlled by an operator	• Larger ranges of motion to traverse rougher terrain • Increase the level of autonomy • System noise.	Invest (ability to transfer loads away from the soldier will allow them to reduce their energy expenditure)
Virtual movement training			S : (none identified) W : (none identified)		

Table C-3: Proposed R&D Focus Areas

R&D Focus Areas	Scope/Description (Needs and Opportunities)	Priority Order (1, 2, 3)
3-D Anthropometry	Characterizing soldier size and shape is essential to relating the design of any soldier system to the range of actual soldier dimensions. Traditional methods have been time consuming and limited for characterizing shape. Three-dimensional scanning systems can provide much faster and richer data with total soldier surface mapping. Relating this technology with other 3-D scanning systems for crewstations, weapons, and general battle space would provide the potential for a much higher fidelity toolset for evaluating internal and external HSI.	1
Clothed anthropometry modeling	Existing anthropometry data sets are for lightly clad soldiers and, while providing good unclothed dimensions, they do not provide realistic dimensioning and shape profiles for clothed, armoured, and equipped soldiers. This has long been a significant shortfall in the available anthropometric data available to soldier systems.	1
3-D motion tracking & analysis	Soldier mobility is a key capability for warfighting. Current measurement methods for assessing dynamic ranges of body and joint movement is typically limited to 2-D planer methods that provide limited insights into task performance and mobility effects of alternative integration designs. Three dimensional tracking systems are now becoming quite sophisticated in terms of the degree of image detail, speed of data capture, and extent of full body representation. Software tools are now being developed to exploit this capability for the purposes of 3-D movies but there is considerable scope for leveraging and developing these technologies for soldier system integration assessments.	2

R&D Focus Areas	Scope/Description (Needs and Opportunities)	Priority Order (1, 2, 3)
Combat movement performance measurement systems	While the injury risk and energy demands of soldier loads is well understood, little is known about the performance effects of soldier integration burdens (e.g. weight, bulk, and restriction to motion). There is considerable scope for researching the dimensions of these burdens as they relate to soldier performance using novel data capture and analyses tools.	1
Weight/bulk reducing multi-purpose designs	One potential solution to reducing the weight and bulk of soldier systems is to design multi-purpose solutions that use single items to achieve more than one function (e.g. ballistic armour batteries). There are numerous research and technology development opportunities for exploiting this concept across the range of associated soldier system functionality and capabilities.	1
Weight/bulk reducing materials	Research into novel materials (e.g. nano materials, phase change materials) should be pursued to minimize weight, bulk, and stiffness demands of soldier system components and sub-systems.	1
Mission weight management decision-aid software	The negative effects of excessive soldier system weight can be reduced by making more informed combat load selection choices during mission preparation. Analytical software tools can be used to assist mission commanders and soldiers to minimize overloading. As well, just-in-time software solutions should also be developed to provide real-time battlefield resupply solutions to avoid the need for soldiers to carry extra consumables and supplies.	3
Digital mannequin / biomechanical modeling tools	Virtual representations of soldiers (mannequins) provides the capability to model different soldier systems performing various soldier movements and tasks in different virtual crewstations, workstation, and combat environments. New developments in software modeling provide the potential for greater realism, performance effects, and functionality. Soldier system evaluation tools and methodologies can then be developed to improve the quality and timeliness of assessments.	1
Medical monitoring technologies	A variety of medical monitoring technologies exists but research into soldier system integration has been limited. There is considerable scope for investigating, developing, and designing alternative hardware monitoring technologies and for developing effective software solutions for alerting/advising soldiers and commanders, triaging wounded soldiers, and integrating patient transport and management within the larger military medical response and treatment system.	2
Medical intervention technologies	The concept of integrating medical treatment and intervention technologies into soldier systems has been around for about a decade but little has been successfully developed and employed. Early, automated medical interventions following injury could have significant benefits for survivability.	3
Load carrying technologies	There is considerable scope for developing, designing, and evaluating load-carrying technologies for soldiers and teams. Examples such as dermo-skeletal systems, exoskeletons, and robotic mules are still developmental technologies that continue to show promise.	2
Virtual movement training	Currently, soldiers are trained in complex movements and tasks through hands-on instruction and repetition. Learning occurs though trial and error, and practice. New technologies in the areas of 3-D tracking and real-time virtual representation provides the potential for virtual training systems where trainees can emulate highly skilled, virtual instructor avatars by matching these skilled movements and postures with the trainee avatar providing tactual and visual cues to accelerate learning. There is considerable scope for researching other ways and means to exploit and develop these technologies for the purpose of soldier training.	3

Annex D: Theme 19: Perceptual-Cognitive Integration on the Soldier

Annex D includes the following tables:

- Table D-1: Challenges/Requirements
- Table D-2: Proposed R&D Focus Areas

Table D-1: Challenges/Requirements

Challenges	Priority	Requirements	
		2015–2020 (Horizon 2)	2020–2025 (Horizon 3)
Characterizing Soldiers			
Characterize soldier knowledge, skills, and abilities in the context of future soldier systems	High	Determine KSAs for future soldier systems	Update
Characterizing the Task			
Characterize soldier information processing demands	High	Characterize current mission demands	Update with experience of future soldier systems
Characterize mission cognitive task analyses	Medium	Characterize current mission and TPPs	Update with experience of future soldier systems
Minimizing Perceptual-Cognitive Burden			
Improve perceptual cueing from information systems	High	Investigate perceptual cueing ways and means	Implement in soldier systems
Detail perceptual field trade space for design integration	High	Determine trade space for existing systems	Update to reflect new technologies from future soldier system
Provide sensory enhancement integration with information systems	High	Investigate enhancement ways and means	Integrate into future soldier systems
Improving Selection/Training/Readiness			
Develop soldier selection criteria for ground technology systems	Medium	Develop and validate selection criteria	Implement criteria in selection of recruits
Enhance training systems and methods for novel soldier systems	High	Investigate and develop novel training technologies and methods	Implement technologies and methods
Improve individual readiness for high information battle space	Medium	Validate measurement tools indicating an individual's level of readiness	Extension of the tools to selection processes and an integrated program of readiness support

Table D-2: Proposed R&D Focus Areas

R&D Focus Areas	Scope/Description (Needs and Opportunities)	Priority Order (1, 2, 3)
Characterize soldier knowledge, skills, and abilities in the context of future soldier systems	Little is known about the range of knowledge, skills, and abilities of existing and candidate soldiers. This information is essential for developing and designing soldier system that can be successfully operated within the capabilities of a sufficient proportion of the soldier population. As well, this information is critical to determining the needs for training systems to bridge the gap between soldier capabilities and soldier system requirements. There is a considerable amount of personnel research required here to achieve the soldier population profiles necessary to support HSI personnel, manpower, and training initiatives for future soldier systems.	1
Characterize mission cognitive task analyses	To be able to design and develop effective soldier information systems it is necessary to know the requirements for information perception, processing, storage, and sharing to perform the complete range of soldier mission. Research into cognitive task analyses is necessary to create a comprehensive, precise model of individual and team cognitive task demands. As well as existing combat missions, future concepts of soldier system/team integration with novel TTPs and CONOPS need to be modeled and CTAs developed to better integrate soldier system designs in future missions.	1
Detail perceptual field trade space for design integration	Significant trade-offs exist between soldier requirements for perceptual fields (vision, hearing, etc.) and the need for information display devices, sensory enhancement technologies, and head/neck protection systems. Precise understanding of these trade-offs is necessary to ensure adequate perceptual performance without compromising the extent, functionality, or performance of other soldier system technologies that compete for the same trade space.	2
Perceptual field replacement technologies	Rather than trade-off soldier system requirements for perceptual fields with other soldier system technologies there is considerable scope for designing, developing, and integrating technologies for replacing natural perceptual fields. For example, an auditory sensor array around encapsulated, protective helmet to reproduce natural spatialized hearing. This concept could also be extended to vision systems and to tactual proximity sensors to expand and integrate soldier sensory perception while maintaining full protection and technology system integration.	2
Characterize soldier information processing demands	SIREQ established the information processing demands of non-computerized soldier tasks and determined the effects of introducing digital enhancements in situation awareness, decision-making, communication, etc., and the associated perceptual and cognitive demands of these systems. Much has changed in 5 years since this research was done. Information processing opportunities and demands will change as the capabilities and limitations of future soldier systems change. Research is required to keep pace with technology developments and to continue to better integrate information technologies to optimize soldier system performance.	1
Perceptual cueing from information systems	Early research in SIREQ confirmed that there was considerable potential for employing novel and varied perceptual display modalities (e.g. visual, auditory, tactual) to cue and inform soldiers about key entities and mission features in the battle space. Considerable scope remains to investigate, develop, and evaluate alternative ways and means to employ perceptual cueing technologies and interfaces in soldier missions.	1
Sensory enhancement integration with information systems	Enhanced soldier sensor systems (e.g. vision and hearing enhancements) have been seen many technology developments in recent years. While soldiers need to employ these enhancements to improve their perception of the local battle space they also need to be able to access and perceive information from their soldier system using the same senses. Research and engineering development/design is necessary to improve the integration of soldier systems information when wearing or using enhanced sensory systems.	1

R&D Focus Areas	Scope/Description (Needs and Opportunities)	Priority Order (1, 2, 3)
Soldier selection criteria for ground technology systems	As soldier system evolve and become more complex, the attributes and aptitudes of soldiers will likely need to evolve or change as well. The selection and training of soldiers needs to keep pace with development of new soldier systems technologies and interfaces. To this end, personnel selection criteria needs to be research and test batteries for selection developed to ensure that soldier recruits match the future technology demands of soldier systems.	2
Training for novel soldier systems	The introduction of novel soldier systems will require the training of new skills and abilities in our soldiers. Since training time is extremely limited, owing to the volume of conventional soldier training requirements, new methods of remote, virtual, and embedded training methodologies will need to be researched and developed. Both individual and collective training with these systems will no longer require co-location of forces or even teams but to achieve this goal will require considerable research and development. As training and experience is gained with these systems by soldiers and teams new knowledge will be gained that will change the way the systems are used, TTPs will adapt, doctrine will change, and training systems will need to evolve and adapt with the knowledge gained.	1
Individual readiness for high information battle space	Optimizing the effectiveness of military personnel will require understanding the factors that impact on their personal readiness. This includes psychological factors, family and social supports, and organizational supports. Although military systems have given increasing attention to this issue, many critical questions remain unanswered. Readiness is associated with critical indicators of effectiveness, such as the intention to stay within a given organization, attrition rates, and turnover. However, although there is some evidence in the literature that readiness promotes individual and group performance, the empirical research in this particular area remains largely underdeveloped. Moreover, it remains difficult to capture the readiness of an individual at a given point in time. This suggests the need for better indicators and measures of individual readiness.	2

Annex E: Theme 20: System Architecture and Interoperability

Annex E includes the following tables:

- Table E-1: Challenges/Requirements
- Table E-2: Proposed R&D Focus Areas

Table E-1: Challenges/Requirements

Challenges	Priority	Requirements	
		2015–2020 (Horizon 2)	2020– 2025 (Horizon 3)
Vehicle Integration			
Vehicle integration – communications	High	Wired	Wireless
Vehicle integration – data networks	High	Wired	Wireless
Vehicle integration – local situation awareness	Medium	Extra-vehicular sensors to in-vehicle display	Intelligent local situation awareness and decision support to soldier

Challenges	Priority	Requirements	
		2015–2020 (Horizon 2)	2020– 2025 (Horizon 3)
Weapon Integration			
Weapon integration – power	High	Wired to torso power supply	Wireless or induction to torso power supply
Weapon integration – data	High	Wired data connection	Wireless data connection
C4I Integration			
C4I Integration – networks	High	Integrate into company-level network	Integrate throughout LCSS
C4I Integration – remote sensors	Medium	Integrate remote sensor networks	Develop intelligent "sentry" system for situation awareness support
C4I Integration – security	High		
Human-human Interoperability			
Human-human interoperability – language	High	Develop sequential translator	Develop simultaneous translator
Human-human interoperability – culture	Medium	Develop cultural decision aid	Integrate with translator
Hardware Integration			
Hardware integration – cabling	High	Identify power/data distribution solution	Integrate distribution system
Hardware integration – connectors	High	Develop novel connector	Integrate connector in systems
Connector commonality	Medium	Identify common connector	Apply common connector to systems
Power supply commonality	Medium	Identify common supply	Apply common supply to all systems
Software Integration			
Software interface standard	High	Develop standard	Apply standard

Table E-2: Proposed R&D Focus Areas

R&D Focus Areas	Scope/Description (Needs and Opportunities)	Priority Order (1, 2, 3)
Vehicle integration – local situation awareness	Currently, soldiers deploy from the back of their LAV vehicle without any real idea of what they will face and typically have very little local awareness of the battle situation, locations of cover, terrain, sight lines, etc. Various sensor integration and display technologies exist or are in development to capture the 360o visual and auditory environment around the LAV and represent these data to soldiers in a manner that provides soldiers with clear local situation awareness. Research opportunities exist in the areas of sensor technology, display technology, spatialized sensor integration, and situation awareness display.	2
Vehicle integration – command integration	During troop transportation in the battle space, commanders will often try to provide a final briefing on their mission, actions on deployment, etc. There is scope for developing/designing command briefing tools and displays that would support mission briefings in transit. As well, there is also scope for developing technologies and capabilities for mission rehearsal, in both individual and team contexts, during troop transport.	1
Weapon integration – power	Power for future, intelligent soldier weapons would likely be provided by distributed power on the weapon and centralized power from the soldier system on the soldier. There are many possible ways and means to develop, design, connect, and integrate this centralized power. Research and design efforts are necessary.	1

R&D Focus Areas	Scope/Description (Needs and Opportunities)	Priority Order (1, 2, 3)
Weapon integration – data	Weapon sensors will capture information for the soldier system and the soldier system will provide information to the weapon system. How will these data sources be connected and the data managed?	1
C4I integration – remote sensors	The development of new, miniature, remote sensor transmitter devices provides the capability for delivering a wide array of multi-modal sensor information to the soldier. To be effective, this considerable volume of sensory information needs to be integrated into soldier situation awareness displays and perceptual cueing systems to provide the soldier with seamless awareness of the local and global battle space. Research needs to investigate software and hardware solutions for achieving this seamless integration.	2
Human–human interoperability – language	Real-time, two-way translation has long been a requirement for foreign theatres of operations and for coalitions with non-English speaking allies.	2
Hardware integration – cabling	The capability to transmit power and data throughout the soldier system architecture remains a significant challenge to system integration. Technologies such as intelligent textiles are promising and pose new opportunities for connectivity and integration design but more research and development is required to ensure sufficient manufacturability and robustness for military operations. Other technologies should be investigated, designed, and developed to address this significant shortfall in capability.	1
Hardware integration – connectors	Power and data connectors have long been a significant point of failure in soldier systems integration. New technology solution should be developed and researched to address this issue. New technologies in power induction methods are promising but more development and research is necessary to achieve sufficient power transfer efficiencies.	1
Connector commonality	Common cables and connectors provide more flexibility, modularity, and field replacement opportunities for soldier systems, as compared to designs that employ different connectors and cables for each architecture linkage. Research is required to determine or design solutions that can provide both data and power, throughout the range of likely requirements and sub-systems, with a single connector solution.	1
Power supply commonality	Soldier systems comprising many different technology components often require a wide array of different power sources (i.e. different battery types). Research and development efforts should seek to produce soldier system designs that can run off of a single type of battery.	1
Software interface standard	Computerized soldier systems provide an interface to the soldier operators through their software display design. Software interfaces that are intuitive and consistent with soldier expectations and experiences with other commercial systems can reduce training, improve interface performance, and minimize errors. To date, however, there is no standard for soldier system software interfaces. Research should be pursued to determine whether such a standard can be achieved and, if so, what the display design and functional characteristics of that standard should be.	1

PART IV: WHAT NEXT?

PART IV: WHAT NEXT?

Chapter 11: Action Plan— R&D Priority Focus Areas

The SSTRM 2011-2025 Action Plan is intended to engage a national collaborative effort to support the development of soldier system solutions for the Canadian soldier of the future. The broad analysis and efforts over the last two years have led to the identification of key R&D focus areas in the SSTRM's 20 themes, grouped into six technical domains.

The Action Plan provides a theme-by-theme summary of the SSTRM R&D priorities focus areas and any gaps in technology standards that need to be addressed to lead to the development of the technology solution.

Maintaining the principles of open innovation and open collaboration, members of the soldier systems community of interest are encouraged to pursue these opportunities through collaborative R&D and by leveraging public and private sector support (including funding), infrastructure and networks of expertise. Individual researchers, companies and organizations will have the opportunity to pursue those R&D projects that provide the best fit with their own business plans and medium to long-term goals. Table 11-1 maps the technical domains against their supporting themes.

Table 11-1: SSTRM Technical Domains and Related Themes

Technical Domains	Related Themes
Power and Energy (Chapter 5)	Theme 1: Power Generation (Fuel Cells and Energy Harvesting)
	Theme 2: Power Sources (Storage)
	Theme 3: Power and Data Distribution
	Theme 4: Distributed Power Management
Weapons Effects (Lethal and Non-Lethal) (Chapter 6)	Theme 5: Weapons Platform (Launching System)
	Theme 6: Ammunition (Lethal and Non-Lethal)
	Theme 7: Weapon-Mounted Situational Awareness and Targeting Suite
Command, Control, Communications, Computer, Intelligence (C4I) (Chapter 7)	Theme 8: Command and Control
	Theme 9: Communications
	Theme 10: Computer
	Theme 11: Intelligence
Sensing (Chapter 8)	Theme 12: Personal Sensing (Body-Worn)
	Theme 13: Weapons-Mounted Sensing
	Theme 14: Crew-Served and Hand-Held Sensing
	Theme 15: Unattended Area Sensing
Survivability/Sustainability/Mobility (Chapter 9)	Theme 16: Operational Clothing, Load Carriage and Mobility
	Theme 17: Personal Protection
Human and Systems Integration (Chapter 10)	Theme 18: Physical Integration on the Soldier
	Theme 19: Perceptual-Cognitive Integration on the Soldier
	Theme 20: System Architecture and Interoperability

Action Plan

Theme 1

Power Generation (Fuel Cells and Energy Harvesting)

Objective

Use fuel cells or energy harvesting to provide the necessary power to sustain the soldier's mission, while minimizing size, weight and bulk.

SSTRM

R&D Priority Focus Areas (in priority)

- Biomechanical and electromechanical energy harvesters
- Multi-junction quantum dot photovoltaic cell
- Micro-reformation with micro balance of plant
- Thermoelectric material improvement
- Alkaline fuel cells
- Reversible hydrogen storage

Description

- In-situ power generation involves the ability to generate power in the field form either logistic fuels or by exploiting the environment. For the SSTRM, fuel cells & energy harvesting were considered the most promising emerging technologies.

Enabling/Emerging Technologies

Fuel Cells	Fuel Cells	Energy Harvesting
• Conventional plate and frame fuel cell at small-scale • High-temperature systems • Micro reformation • Hydrogen generation	• Novel architecture proton exchange membrane (PEM) fuel cell • Micro-scale balance of plant	• Solar, wind, hydro • Pyroelectric, piezoelectric and thermoelectric materials • Electromechanical energy harvesters

Key Challenges/Requirements

Fuel Cells	Fuel Cells	Energy Harvesting
• Respond to different power needs of dismounted soldiers—ranging from 1–40 W • Support up to eight hours of continuous operation > 40% net system efficiency	• System water-submersible • Start-up of less than five minutes at -15°C • Spill-proof recharge and usage	• Efficiency of up to 40% • Weight and bulk < 1.5 kg and 1 L • Less than 50 dB of noise level • Up to 40% of daily required power

Standards Required

• Fuel cell safety/ruggedness test standards		

Action Plan

Theme 2

Power Sources (Storage)

Objective

Optimize electrical power storage and energy density (runtime); improve the form, fit and function of wearable energy storage devices; and create power & data interface standards to permit smart power management.

SSTRM

R&D Priority Focus Areas (in priority)

- Lithium battery with improved cold-weather power density
- Improved charge rate and power density
- Power sources integration
- Novel high-capacity rechargeable battery and safe designs

Description

- The soldier system's electrical power consumption has grown tremendously in recent years and will continue to increase with the addition of new capabilities. This can have a direct impact on load carriage and soldier survivability. A soldier system's increased demand for electrical energy (or capability) is directly proportional to the weight and volume of the storage device (battery) required. The system must also be able to accommodate significant fluctuations in energy demand and challenging environmental conditions.

Enabling/Emerging Technologies

• Li-air for primary • Li/CFx for primary	• Ni-Zn (aqueous, rechargeable) • Li-ion for secondary	• Nano-battery • Ultracapacitor

Key Challenges/Requirements

• Standardized data interfaces • Rechargeable at greater than C3 rates • Energy density >300 Wh/kg	• Should function -40°C to +50°C • Military safety guidelines • Conformable power sources • Fast charge (replacement) capability	• Primary battery service life durability = 5-year minimum storage life • Rechargeable battery service life durability = cycle life >300

Standards Required

• Battery safety test standards	• Form factor standard	• Voltage/current standard

Action Plan

Theme 3

Power and Data Distribution

Objective

Provide a totally wire-free backbone, integrated into the soldier's operational clothing system. This system, adaptable to the soldier's mission, will allow devices to be plugged in, hot-swapped, reconfigured and scaled on-the-fly.

SSTRM

R&D Priority Focus Areas (in priority)

- Power and data distribution test standards
- Power and data distribution infrastructure
- Soldier system connectors
- Novel transport mediums development
- Wireless power/data transmission

Description

- Transport mediums (e.g., novel electronic harness technologies and connectives) allow power generation storage components to connect to power consuming devices. The unification and integration of power and data transport mediums and related connectives (e.g., cabling integrated into fabrics with novel transport mediums) requires a new approach to design and integration, including the use of human systems integration practices.

Enabling/Emerging Technologies

• Electro-textile shielding • Environmental protection of e-textiles	• Fast data transmission through e-textiles • Connectors for e-textiles	• Connector physical characteristics • Connector electrical characteristics

Key Challenges/Requirements

• Electromagnetic compatibility of e-textiles to United States Military Standard (MIL-STD) 461E or equivalent, without compromising fabric qualities that provide light-weight, low-profile, flexibility and wearability	• Environmental compatibility of e-textiles to MIL-STD 810, without compromising fabric qualities and usability, durability and cleaning • Connector standards and solutions compatible with e-textiles and garments (complying with MIL-STDs)	• E-textile backbone electrical architectures that include fast data capacity, modularity and scalability, damage tolerance and redundancy • Connectors with form factors that meet soldier needs • Many competing architectural solutions

Standards Required

• Soldier connector standards	• Electromagnetic integration and compatibility (EMI/EMC) standards related to e-textiles	

Action Plan

Theme 4

Distributed Power Management

Objective

Intelligently manage power at all levels of the system in a manner transparent to the soldier, allowing for a defined level of mission-specific customization by the soldier and the overall reduction of power demand.

SSTRM

R&D Priority Focus Areas (in priority)

- Power reduction technologies: adiabatic computing
- Dynamic power management
- Predictive mission power planning tool
- Power sources and soldier devices simulation models
- Power-aware components

Description

- An optimized distributed power management system can minimize overall power demand and decrease the weight load for the soldier. The power management system controls battery charging among distributed storage elements, monitors battery health and system power demand, and performs energy re-allocation to maximize system availability.

Enabling/Emerging Technologies

• Adiabatic processing • Power consumption of individual hardware components (e.g., chips) and devices (e.g., Global Positioning Systems (GPS), radio)	• Power-aware software components (e.g., library) and software applications (e.g., Battle Management System, communication stack)	• Power-management control protocol • Simulation • Distributed dynamic power management

Key Challenges/Requirements

• Reduce power/energy demand of individual soldier system devices (e.g., C4I sensing) • Power/energy architecture standards	• Energy-efficient clocking design and synchronization mechanism to permit the implementation of adiabatic computing	• Distributed power management system • Power management policies • Power-aware smart devices

Standards Required

• None Identified		

Action Plan

Theme 5

Weapons Platform (Launching System)

Objective

Develop a portable and integrated weapons system for the soldier and the section that increases weapon effectiveness and provides scalable lethal and non-lethal effects against a variety of targets at the desired range/conditions, while minimizing the soldier's physiological and cognitive burden.

SSTRM

R&D Priority Focus Areas (in priority)

- Improved integration and design including electronic ignition
- Human system integration
- Weight reduction
- Advanced material development
- Non-lethal technologies

Description

- The weapons platform is the electro-mechanical device used as an anti-personnel piece of equipment for combat and/or self-defence. It is also used as a pointing device for surveillance. The weapons platform includes power/data/rail interfaces, and may include rifle, fragmentation and non-lethal subsystems.

Enabling/Emerging Technologies

• Programmable airburst fragmentation ammunition • Case-telescoped weapons (LSAT LMG)	• Modular bull-pup and conventional weapons • Electronic initiation	• Power/data rails • Less-than-lethal systems

Key Challenges/Requirements

• Operator limitations • Weight	• Power • Integrated non-lethal capabilities	• Improved performance

Standards Required

• Interface to soldier system for power/data exchange	• Future standard targets definition	

Action Plan

Theme 6

Ammunition (Lethal & Non-Lethal)

Objective

Improve the incapacitation effects of weapons systems at all engagement ranges to manage lethality, provide robust and reliable caseless and case-telescoping ammunition, extend the range of non-lethal ammunition, and provide quantifiable physiological and psychological effects.

SSTRM

R&D Priority Focus Areas (in priority)

- Cased ammunition
- Case-telescoped ammunition
- Improved understanding of incapacitation effects
- Caseless ammunition
- Programmable bursting ammunition
- Non-lethal technologies

Description

- The ammunitions system encompasses all the munitions delivered by the weapons system. This includes high-velocity projectiles (bullets), low-velocity non-lethal projectiles and fragmenting ammunition. It also includes non-kinetic, non-lethal munitions such as conductive energy devices, chemicals (e.g. odorants and calmatives), electromagnetic technologies (e.g. high-powered lasers) and acoustics.

Enabling/Emerging Technologies

- Case-telescoped ammunition
- Lighter weight case materials (stainless steel)
- Caseless ammunition
- Electronic ignition
- Intermediate-calibre rounds (6.5 and 6.8 mm)
- Frangible rounds, blind-to-barrier ammunition
- Short-range training ammunition
- Programmable, air-bursting ammunition
- Improved range non-lethal ammunition

Key Challenges/Requirements

- Improving technical performance of conventional ammunition
- Weight and bulk
- Accuracy, range and incapacitation effects
- Providing programmable bursting munitions
- Improving non-lethal ammunition

Standards Required

- Personal defence weapon ammunition standard
- Green ammunition standard
- Wound ballistic test method/standard

Action Plan

Theme 7

Weapon-Mounted Situational Awareness & Targeting Suite

Objective

Provide a Weapon-Mounted Situational Awareness & Targeting Suite (WM-SAT) system to permit the soldier to accurately engage point and area targets. The system should provide advanced integrated data-link, surveillance and sensor capabilities in a compact, lightweight form.

SSTRM

R&D Priority Focus Areas (in priority)

- Requirements definition
- Human system integration
- Local Battle Management System integration
- Assisted engagement and decision support
- Sensors

Description

- The WM-SAT system is used to accurately detect, aim a weapon for target engagement, point-for-surveillance, target designation and battle management purposes. It includes a family of sensors to accurately detect targets, determine ranges and 3-D coordinates, compute firing solutions, etc. It includes data links to the associated soldier systems and the mounting interfaces to the weapon.

Enabling/Emerging Technologies

- High-density pixel sensors (pixel pitch < 25 microns)
- Short Wave Infra Red sensors
- High-density displays
- Miniature laser range finders
- Integrated fire control systems
- Dual range optic sights

Key Challenges/Requirements

- Weight reduction
- Seamless technology insertion
- Improved accuracy
- Integration
- Improved sensing
- Affordability

Standards Required

- Power/data rail
- Interoperability standard

Action Plan

Theme 8

Command & Control

Objective

Optimize command and control (C2) within and between all echelons of the Army, Joint Forces and coalition partners.

SSTRM

R&D Priority Focus Areas (in priority)

- Human and systems integration
- Virtual reality training (full or partial immersion)
- Augmented reality training

Description

- Command and control processes and supporting technologies enable ground operations to communicate common objectives, coordinate action and manage risk. Efforts to optimize C2 will enhance the flow of timely and pertinent tactical information at the level of the soldier, section, platoon and company levels, and within the Army, Joint Forces and JIMP environment.

Enabling/Emerging Technologies

• Gaming technology • Training simulators	• Embedded instrumentation for in-situ health monitoring and equipment/device status • Mixed-initiative interfaces	• Case-based reasoning (automatic identification of similar situations) • Data exchange standards

Key Challenges/Requirements

• Interoperability and compatibility	• Decision aids	• Full or partial virtual reality training

Standards Required

• None identified		

Action Plan

Theme 9

Communications

Objective

Provide a communications link for voice and data exchange that is low-cost, mission-scalable, securable with low detectability/interceptability, adaptive to frequency/bandwidth/waveform and environmental conditions, and seamless and intuitive.

SSTRM

R&D Priority Focus Areas (in priority)

- Cognitive mesh network radio
- Power and data infrastructure
- 3-D audio radio communication and audio restitution (alarm, cueing, speech-to-text, etc.)
- Biometrics
- Wireless networking for biosensors
- System management radio common interface
- Security and reliability of mobile ad-hoc networks (MANETs)
- Adaptive spectrum analysis and detection capabilities
- Voice data corpus voice recognition systems

Description

- Effective communications requires that all parties have a common platform where they can interact and understand each other. Communications and computer technologies combine to create a pervasive enabling network that supports the information exchange that underpins command and control, intelligence, surveillance and reconnaissance.

Enabling/Emerging Technologies

• Software-defined radio (flexible waveform hosting, multiple site or situation use) • Multi-band, ad-hoc networking radio • Magnetic wave communications • Beam-forming adaptive array (switched or phased)	• Multiple-input and multiple-output (MIMO) antenna technology • Network-monitoring dynamic priority-based allocation • Airborne platform (extended range of communication)	• Ear canal moulding/head scanning technologies • Automatic speech recognition • Speech synthesis • Design of environment adaptive Waveforms

Key Challenges/Requirements

• Data transmission and network technology	• Human and systems integration	• Interoperability issues • Weight

Standards Required

• Interoperability	• Data exchange model	• Cross-domain security

Action Plan
Theme 10
Computer

SSTRM
R&D Priority Focus Areas (in priority)
- Advanced hybridized multimodal interface development and evaluation
- Flexible, customisable interfacing materials and approaches

Objective
Provide a powerful, mission-adaptive, intelligent, securable and ubiquitous computing capability to soldiers that will help maintain and improve their situational awareness while minimizing system physiological and cognitive burden.

Description
- Within the soldier system, computers encompass the electronic systems (hardware, software, servers, connectors/connections and interfaces) required to sense, process and respond to stimuli and commands. Issues in this theme include the implementation and distribution of computer systems within the battlefield environment, system security and associated human interaction and operation.

Enabling/Emerging Technologies

• Service-oriented architecture (Unified Modeling Language (UML), Systems Modeling Language (SysML) • Power consumption optimization and management	• Low-power consumption electronics • Cross-platform operating systems and language • Open source software utilisation	• Wireless small network • Smart Fabric • Brain-computer interface; • Low-power algorithms and waveforms; • Induction power and connections

Key Challenges/Requirements

• Size • Weight	• Power	• Human-machine interface

Standards Required

• Open architecture/software		

Action Plan
Theme 11
Intelligence

Objective

Improve soldier capabilities in every aspect of the information management process, and increase the soldier's situational awareness with tools to support the mental framework required to assess each situation.

SSTRM
R&D Priority Focus Areas (in priority)
- Information collection, management, filtering and retrieval
- NATO symbology—dismounted infantry soldier
- Affordable Cognitive Radio Securable with adaptive range, throughput and spectrum exploitation
- Low-cost selectable-security encryption
- Navigation aiding using multiple techniques to provide navigation in complex environment
- Development of transparent radio ranging layering capability to support navigation and localization
- Sensor integration/processing

Description

- Intelligence encompasses the collection, processing, integration, analysis, evaluation and interpretation of available information for a specific question or area of interest to support a mission. Situational awareness, information assurance and scalable security are only achievable through accurate, thorough, timely, pertinent, relevant intelligence that is integrated into the concept of operations (CONOPS) from the start.

Enabling/Emerging Technologies

- Meta-data tagging standards with ability to subscribe to information/intelligence produced by other government departments and allies
- Collaborative tools to enable rapid information acquisition
- Online analytical processing (OLAP)
- Standardised symbols and icons
- Geographic information systems
- 3-D visualisation software
- Inertial sensor technologies
- Satellite: GPS/Global Navigation Satellite Systems (GNSS)
- Optical light detection and ranging (LIDAR), radio and laser ranging
- Embedded firewalls
- Data encryption/decryption
- CM encryption engine with turnstile computer data source (CDS)
- Context parser for structured data
- Selective security approach
- Active (meaning simultaneous) multi-Biometric security

Key Challenges/Requirements

- Information management and exchange
- Situational awareness
- Security

Standards Required

- None identified

Action Plan

Theme 12

Personal Sensing (Body Worn)

Objective

Develop a low-profile, wearable sensor system that can be integrated into the soldier system and will increase the individual and shared situational awareness, while minimizing physiological and cognitive burden.

SSTRM

R&D Priority Focus Areas (in priority)

- Enhanced vision (night and day)
- Enhanced hearing
- Enhanced interfaces/controls/displays (neural)
- Personal sensor networks
- Enhanced physiological monitoring
- Enhanced embedded threat detection sensing (e.g., Chemical, Biological, Radiological, Nuclear and Explosives—CBRNE)

Description

- Soldiers can wear or carry sensors for a variety of purposes: to monitor their personal health status, to support local situational awareness and to monitor the local environment. The personal sensing system includes sensors, a display/central control unit (CCU)/data network and biometrics. It can also include a health intervention and monitoring system, Battle Combat Identification and individual identification (bio-metrics).

Enabling and Emerging Technologies

• Biosensors • Miniature environmental sensors	• Position sensors (GPS and inertial sensors) • Identify Friend or Foe (IFF) systems	• Advanced vision devices (e.g., fused night vision goggles) • Higher resolution detectors

Key Challenges/Requirements

• Health monitoring	• Situational awareness • Integration	• Weight reduction

Standards Required

• None identified		

Action Plan

Theme 13

Weapons-Mounted Sensing

Objective

Provide a weapon-independent, common fire control system to enable the soldier to accurately engage point and area targets. The device will be capable of providing ballistic solutions for all section and platoon lethal and non-lethal weapon systems.

SSTRM

R&D Priority Focus Areas (in priority)

- Enhanced electro-optical (EO) detectors (night and day)
- Improved weapon sensors integration
- Efficient secured target identification (IFF)
- Weapon platform sensors
- Novel non-EO target sensing

Description

- Electro-mechanical sensors are used to accurately detect, identify and engage enemy targets at maximum ranges. The weapons sensing system includes sensors to accurately detect targets, determine ranges and to provide data to ballistic solutions, logistics, etc. It also includes data and power links to weapon sights, fire control systems and the associated soldier system.

Enabling and Emerging Technologies

• 17 micron pitch Long Wave InfraRed (LWIR) Focal Plane Arrays (FPAs) • Short Wave InfraRed (SWIR) FPAs	• Clip-on thermal and image-intensified (I2) sensors • Light-weight laser range finders • Lead-angle sensors • Shot counters	• Optically and digitally fused sensors • Centralized power

Key Challenges/Requirements

• Operator workload • Improved target detection and identification	• Integration • Situational awareness	• Weight reduction

Standards Required

• Updated performance standards (e.g., updated Johnson criteria for target Detection Recognition and Identification)		

Action Plan

Theme 14

Crew-Served & Hand-Held Sensing

Objective

Develop portable and integrated sensor systems for the soldier and section that will increase target detection and group-served weapon engagement performance, and provide seamless information/data for weapon fire-control systems.

SSTRM

R&D Priority Focus Areas (in priority)

- Integration of other sensors with EO vision sensor (binoculars and group-served weapons sights)
- Enhanced optics and detectors
- Enhanced behind-wall sensing
- Small arms fire localization

Description

- The CS&HH sensing system includes systems operated or carried by more than one soldier, and is composed of electro-mechanical sensors used to detect, classify and identify enemy targets at line-of-sight and beyond line-of-sight ranges (up to one to two kilometres). CS&HH-served sensors provide inputs into weapon fire-control systems and crew-served weapon sights. The CS&HH sensing system also includes see-through-wall sensing.

Enabling and Emerging Technologies

• Handheld thermal imagers • Light-weight extended range thermal sights	• Digital fire-control units (integrated laser range finder, cant-angle sensors, ballistic calculator, etc.)	• Light-weight laser range finders • Optically and digitally fused sensors

Key Challenges/Requirements

• Operator workload • Improved target detection and identification	• Integration • Situational awareness	• Weight reduction

Standards Required

• None identified		

Action Plan

Theme 15

Unattended Area Sensing

Objective

Provide an autonomous, integrated and networked beyond-line-of-sight (BLoS) sensing capability that can enable intelligent data capture, collation, processing and information dissemination for situational awareness and force protection.

SSTRM

R&D Priority Focus Areas (in priority)

- Autonomous navigation
- Sensors for Unattended X Vehicles (UXVs)
- Micro/nano-Unattended Aerial Vehicles (UAVs)
- Unattended Ground Sensors (UGS)
- Operator-machine interface
- Portable Unattended Ground Vehicles (UGVs)

Description

- Electro-mechanical sensors are used to remotely detect, classify and identify enemy targets at line-of-sight and beyond line-of-sight ranges. The area sensing system includes sensors, delivery platforms, data and communication links, and central or distributed information processing units/ stations, including UAVs, UGVs and Unattended Ground Sensors—Static (UGS-S).

Enabling and Emerging Technologies

• Autopilots for mini/micro UAVs • Improved propulsion units for UXVs	• Improved UXV materials (strength)	• Miniature Global Positioning Systems (GPS) and position sensors

Key Challenges/Requirements

• Improved target detection • Classification and identification (sensor resolution and platform/sensor range)	• Improved platform performance (UXV, UGS) • Weight and size reduction	• Reduced operator workload • Integration with soldier systems

Standards Required

• Micro-UAV technology specifications	• Communication/network standards	

Action Plan

Theme 16

Operational Clothing, Load Carriage & Mobility

Objective

Provide a human-centric load carriage and soldier clothing and equipment system to improve interoperability, multi-functionality and adaptability in all conditions. The system will offer increased capability and mobility, be mission configurable, modular and customizable to increase soldier comfort, and reduce "perceived" weight.

SSTRM

R&D Priority Focus Areas (in priority)

- Next generation operational clothing
- Hearing protection (dismounted and mounted)
- Enhanced mobility
- Advanced materials and processes to enhance comfort, durability and protection
- Standards and test methods
- R&D infrastructure
- Research tools (instrumentation and simulation)

Description

- Operational uniform and load carriage systems impact on soldier survivability, sustainability and performance. Among other items, the operational uniform system includes the soldier's undergarments, uniform, handwear and footwear as well as the means to distribute, generate and store power, and to attach electronic systems. The load carriage system includes what the soldier wears and devices used to bring equipment into operations, including robots/vehicles and load carriage assistive devices such as exoskeletons.

Enabling and Emerging Technologies

- Energy-harvesting textiles
- Nano-coatings
- Advanced polymers and elastomers (for fibres, film, matrix, coating, etc.)
- Advanced textile structure (3-D)
- Multi-component textile (coating, membrane)
- 3-D custom fitting (insole)
- Pouch Attachment Ladder System (PALS)
- Modular pack system
- Exoskeleton and endoskeleton systems for assisting in load carriage
- New camouflage designs

Key Challenges/Requirements

- Weight
- User acceptance
- Load carriage
- Protection
- Integration/compatibility
- Footwear
- Comfort
- Modularity

Standards Required

- E-textile test methods
- Enhanced mobility test standard
- Footwear test standard
- Updated Army anthropometry standards
- CBRNE garment performance test standard

Action Plan

Theme 17

Personal Protection

SSTRM

R&D Priority Focus Areas (in priority)

- Advanced protective materials/systems
- Systems design, integration and optimization
- Threat/injury analysis
- Modeling and simulation tools
- Test methods and standards

Objective

Provide an optimal, sustainable, integrated soldier system that offers improved, integrated body protection against battlefield threats and maintains comfort in extreme conditions, improves component compatibility, integration and functionality, and reduces bulk and weight.

Description

- Personal protection systems are vital to soldier survivability and sustainability and include ballistic, blast, impact and CBRN protective systems. Components range from torso and extremity ballistic protective systems (e.g., fragmentation vests, ballistic plates, arm protectors) to head, nape and throat protective systems with attachment points for items such as night vision goggles (NVGs), headlights, mountable cameras and IFF.

Enabling/Emerging Technologies

• Advanced ceramics (opaque) • Ballistic technologies (fragments/ bullet protection)	• Transparent armour • Ballistic fibre/fabric	• Composite materials • Overpressure protection technologies

Key Challenges/Requirements

• Weight and bulk • Material properties • Signature management	• Protection • Integration/compatibility	• User acceptance • Comfort

Standards Required

• Threat levels standards • Torso ballistic injury test method	• Head Behind armour injury test method • Head/CNS blast injury test method	• Jaw/face injury test method

Action Plan

Theme 18

Physical Integration on the Soldier

Objective

Physically design and integrate soldier systems to enhance physical capabilities of the soldier without exceeding physical limitations that could lead to injury, discomfort, fatigue and reductions in individual performance.

SSTRM

R&D Priority Focus Areas (in priority)

- 3-D anthropometry
- Clothed anthropometry modeling
- Combat movement performance measurement systems
- Weight/bulk reducing multi-purpose designs
- Weight/bulk reducing materials
- Digital mannequin/biomechanical modeling tools
- 3-D motion tracking and analysis
- Medical monitoring technologies
- Load carrying technologies
- Mission weight management decision-aid software
- Medical intervention technologies
- Virtual movement training

Description

- The soldier integration effort must take into account the capabilities, limitations and characteristics of the soldiers themselves, and the equipment with which they interact. This involves accommodating a wide range of soldier differences (size, shape, strength, fitness, skills, abilities, speed, agility, dexterity, thermoregulation, resilience to forces and pressures, handedness, etc.). Technologies that can inform the Human Systems Integration (HIS) process have an important role to play in this theme.

Enabling/Emerging Technologies

• 3-D photographic and laser scanning • Scanning software to enable complex analyses of function body surface areas • Real-time motion capture and analysis of complex soldier movements and tasks	• Dermoskeletons • Exoskeletons • Robotic mules	• 3-D modeling software • Artificial intelligence combined with virtual mannequins

Key Challenges/Requirements

• Characterizing the soldier and soldiering	• Minimizing physical burden and improving methods	• Measures and soldier monitoring

Standards Required

• Updated maximum load limits	• Objective-based human factors methods	

Action Plan

Theme 19

Perceptual-Cognitive Integration on the Soldier

Objective

Soldier systems will be perceptually and cognitively integrated in a way that optimizes the capabilities and performance of the soldier, without exceeding soldier limitations.

SSTRM

R&D Priority Focus Areas (in priority)

- Characterize soldier knowledge, skills and abilities in the context of future soldier systems
- Characterize mission cognitive task analyses
- Characterize soldier information processing demands
- Perceptual cueing for information systems
- Sensory enhancement integration with information systems
- Training for novel soldier systems
- Detail perceptual field trade space for design integration
- Perceptual field replacement technologies
- Soldier selection criteria for ground technology systems
- Individual readiness for high formation battle space

Description

- Soldier integration efforts must accommodate the wide range of soldier differences in perceptual abilities (i.e. visual, auditory, tactual and olfactory), memory, decision-making, tolerance to mental workload, intelligence, etc. Technologies that inform the HSI process in characterizing soldiers and enhancing perceptual-cognitive integration and performance, without exceeding soldier limitations, have underpinned advances in this area.

Enabling/Emerging Technologies

• Perceptual cueing technologies • Autonomous decision aids • Situational awareness filter and fusion	• Courses of Action software tools • Augmented reality displays with 3-D visualization software	• Brain-computer interfaces

Key Challenges/Requirements

• Characterizing the soldier • Characterizing the task	• Minimizing perceptual-cognitive burden	• Improving selection, training and readiness

Standards Required

• None identified		

Action Plan

Theme 20

System Architecture & Interoperability

Objective

Provide a system-of-systems integration to ensure that the capabilities of the soldier are optimized for all associated systems without exceeding the physical and perceptual-cognitive limitations of the soldier.

SSTRM

R&D Priority Focus Areas (in priority)

- Vehicle integration—command integration
- Weapon integration—power
- Weapon integration—data
- Hardware integration—cabling
- Hardware integration—connectors
- Connector commonality
- Power supply commonality
- Software interface standard
- Vehicle integration—local situational awareness
- C4I integration—remote sensors
- Human-human interoperability—language

Description

- Integration of the soldier system with external systems (e.g. vehicles, weapons, C4I systems) is vital to the success of the soldier system. Hardware integration (e.g. cables, connectors) and the interoperability of systems are key factors in achieving an effective "system of systems."

Enabling/Emerging Technologies

• Enabling transmission technologies (smart fabrics)	• Connector technologies (inductive power and data)	• Wireless/connection-less personal area network technologies (zigbee, z-wave, ultra wideband)

Key Challenges/Requirements

• Vehicle integration • Weapon integration	• C4I integration • Human-to-human interoperability	• Hardware integration • Software integration

Standards Required

• Integration guidelines		

THE WAY FORWARD

Chapter 12: The Way Forward — Implementation Phase

The Development Phase of the Soldier Systems Technology Roadmap (SSTRM) project built a broad network among industry, academia and government around the needs of the Canadian Forces soldier of the future. A better understanding of the future soldier system requirements by technology-based firms and academia is fundamental to foster innovation in soldier systems. The technology options identified in the SSTRM, if successfully developed and implemented, should help increase the effectiveness of Canada's future dismounted soldiers in a variety of combat environments while helping Canadian industry to better position itself for success in global markets where similar requirements will need to be fulfilled.

This final chapter points the way forward for the SSTRM, with key recommendations for keeping the soldier systems dialogue alive and bringing forward the R&D necessary to address future soldier systems requirements. This chapter is intended to work closely with Chapter 11, which summarizes the technical information provided in Chapters 5 to 10 in the Action Plan.

12.1 Recommendations

The SSTRM Development Phase resulted in the following key recommendations:

a) Establish an SSTRM Management Office (MO)
b) Establish a follow-on project to the SSTRM Development Phase—the SSTRM Implementation Phase
c) Create an R&D proposal process to provide feedback, support and track industry, Academia and Government R&D projects that will generate technology solutions aimed at meeting the needs of the soldier of the future
d) Evergreen the SSTRM by maintaining the knowledge exchange established during the Development Phase to keep the SSTRM community of interest updated on evolving soldier systems needs and related potential technology solutions.

As of the start of the Implementation Phase, the SSTRM partners are:

a) CF
- Director of Land Requirements (DLR);

b) DND
- Director of Soldier Systems Program Management (DSSPM);
- Defence Research and Development Canada (DRDC); and the

c) Canadian Association of Defence and Security Industries (CADSI).

12.1.1 The SSTRM Management Office

On April 1, 2011, DND established a Management Office (MO) for the SSTRM Implementation Phase. The MO plays a central role in facilitating the SSTRM Implementation Phase and in animating knowledge exchange within the Soldier Systems community of interest. Key functions include:

- Facilitating R&D by advocating for proposals seeking innovation funding that have potential to address Capstone Report future requirements (the SSTRM Management Office has no direct funding for proposals);
- Providing a forum for Stakeholder collaboration (Industry, Academia and Government);

1. Technology Network

- Continually updating and articulating medium (5-10 years) and long term (10+ years) Army Requirements to inform Government, Industry and Academia R&D decisions.

12.1.2 The R&D Proposal Process

The responsibility for developing an R&D proposal or offer based on the needs identified by the SSTRM rests with industry and/or academia, who are the proposal proponents. The process for handling these proposals is shown in Figure 12.1

Proposal Review Process

Proposal Template Completed and Submitted to DND
- All proposals are recorded and tracked

Subject Matter Experts from Army, DSSPM, and DRDC Evaluation
- Relevancy to needs
- Time Horizon identification concurrence
- Potential collaboration in similar offers for synergy
- Funding requirements and potential funding avenues relevant to the offer
- Horizontal application of the proposal; potential broader application across the economy

If Supported
- Face to face meetings are arranged to clarify the proposals and provide advice on potential funding programs
- Letter of Support provided to Applicant

If not supported
- Applicant is formally advised

Evergreening of SSTRM

Figure 12-1: The Proposal Review Process

The MO acts as the primary point of contact for companies and research organizations with proposals or offers to address soldier system technology needs. The MO provides feedback to proponents on proposals/offers, and, when requested, provides best efforts to link the proposal/offer with a government innovation support program.

When the MO receives a proposal/offer, the MO responds to the proponents of the proposal/offer within 30 calendar days. A CF/DND subject matter expert provides feedback on whether the proposal has the potential to meet CF's identified needs. If the proposal very closely mirrors CF's future requirements, a letter of support for the proposal and innovative funding assistance will be strongly considered.

For those proposals requesting assistance, the MO:

- Provides guidance to stakeholders trying to identify potential sources of support
- Assists in identifying key contacts
- Informs relevant organizations (e.g., research and funding) of soldier systems opportunities, challenges and key priorities identified in the SSTRM

A range of federal and provincial government innovation programs is in place across the innovation spectrum—from basic research to commercialization (domestic and international). The MO engages with key innovation programs to alert them to the strategic importance of the SSTRM and to the type of R&D proposals that might be expected to come forward during the SSTRM Implementation Phase. In turn, the MO acts as a focal point to assist R&D proponents in determining the type of proposal that might fit within these various programs.

12.1.3 Technology Networks and Evergreening

The networking and partnerships established by participants during and subsequent to the SSTRM workshops were an important aspect of the SSTRM Development Phase. To continue these benefits through the Implementation Phase, CADSI has created a Soldier System Technology Network with MO administrative assistance.

The Technology Networks are open forums to large, medium and small-size companies, academia and research organizations.

In keeping with the systems approach used by the SSTRM, the Technology Networks focus on the domains and themes defined under the Development Phase. The Technology Networks fill the following roles:

- Increase the ability of government, industry and academia to network, make contacts, and develop collaborative projects on a voluntary basis.
- Provide a meeting ground for industry, academia, government (including the CF) to discuss issues, challenges and opportunities of mutual interest with respect to the evolving equipment, clothing and integrated systems needs of the dismounted soldier.
- Assist in the SSTRM Implementation Phase by engaging in exchanges of information and ideas between the user and supplier communities and contributing to the evergreening of the Capstone Report and Action Plan.
- Provide a place where information on government innovation support programs can be exchanged and best practices on proposal writing can be established and shared.

12.1.4 Innovation Collaboration Exchange Environment (ICee)

- The ICee is now managed by DRDC. The SSTRM community of Interest can continue to "populate" the ICee for the sharing of relevant knowledge and open collaboration.

12.1.5 Management Office Co-ordinates

The SSTRM Management Office may be contacted via the following means:

Website

http://www.materiel.forces.gc.ca/en/sstrm.page

http://www.materiel.forces.gc.ca/fr/ctss.page

Email

SSTRM-CTSS@ADM(Mat) DSSPM@Ottawa-Hull

Appendix 1: Threat Table

Prioritized Ranking of Threats*

The revised prioritized ranking of threats faced by dismounted soldiers is detailed below along with their associated risk levels.

Threat Level	Rating
Very High	6
High	5
Medium	4
Low	3
Very Low	2
Negligible	1

* This list of 30 prioritized threats facing the dismounted soldier is based on Table III of the IPCE Technology Trade-off Report dated 19 July 1995 (Reference EE). This table was reviewed by 20 Subject Matter Experts during two focus groups at the Combat Training Centre Infantry School on 17 March 09 and the Canadian Forces Land Advanced Warfare Centre on 31 March 09 to confirm currency. The participants were asked to rate the frequency of the threats faced, the consequences of the threat, and the overall risk associated with the threat.

Rank	Threat	Risk level
1	Blast	5.6
2	Ballistic - HE Fragment	5.5
3	Ballistic - Direct Fire	5
4	Psychological / Physiological	4.4
5	Detection - Thermal / Emissive	3.7
6	Weather - Solar Radiation	3.6
7	Weather - Temperature and Humidity	3.6
8	Fire and Flame	3.6
9	Detection - Acoustic	3.6
10	Detection - Reflective	3.4
11	Electronic Warfare	3.2
12	Biological Attack	3.2
13	Obscurants	3.2
14	Detection - Radar	3.1
15	Mechanical - Blunt Impact and Falls	3
16	Terrain - Immersion	2.9
17	Natural Disease	2.9
18	Directed Energy Weapon - High Power	2.8
19	Chemical - Percutaneous Attack	2.8
20	Sensory - Sonic	2.8
21	Mechanical - Puncture	2.7
22	Mechanical - Abrasion	2.7
23	Chemical - Respiratory Attack	2.7
24	Biting insects and animals	2.7
25	Weather - Wet	2.6
26	Nuclear - Immediate Radiation	2.5
27	Nuclear - Internal Dose	2.5
28	Nuclear - Blast	2.4
29	Nuclear - Beta Burns	2.4
30	Nuclear - Flash	2.4
31	Nuclear - Thermal	2.3
32	Nuclear - EMP	2.3
33	Nuclear - Residual Gamma Radiation	2.3
34	Weather - Wind	2.1
35	Sensory - Directed Energy Weapon Low Power	2.1

Appendix 2: Known R&D Efforts (Canada and abroad)

Power/Energy

Theme 1: Power Generation (Fuel Cells and Energy Harvesting)

Effort/Program/Project	Description	Status	Organization	URL
H2Can Research Network	NSERC and industry funded research network focused on hydrogen storage and generation	active, currently second year of 5 year program	Program offices located at UQTR Hydrogen Research Institute	
NRC Institute for Fuel Cell Innovation	NRC institute focused on fuel cell systems and energy storage			
NRC Institute for Chemical Processes and Environmental Technologies	NRC research institute with experience in fuel cell catalysts and systems			
Canadian Companies	Developing Micro Fuel Cell Technologies		Angstrom Power Inc. (Vancouver) Tekion (Vancouver)	
U.S. Companies	Developing various aspects of Micro Fuel Cell Technologies. Not an exhaustive list		Ardica, Protonex, MTI Micro, Jadoo, Ultracell, SiGNa Technologies, Adaptive Materials, Lilliputian	

Theme 2: Power Sources (Storage)

Effort/Program/Project	Description	Status	Organization	URL
H2Can Research Network	NSERC and industry funded research network focused on hydrogen storage and generation	active, currently second year of 5 year program	Program offices located at UQTR Hydrogen Research Institute	
NRC Institute for Fuel Cell Innovation	NRC institute focused on fuel cell systems and energy storage			
NRC Institute for Chemical Processes and Environmental Technologies	NRC research institute with experience in fuel cell catalysts and systems			
Canadian Companies	Developing Micro Fuel Cell Technologies		Angstrom Power Inc. (Vancouver) Tekion (Vancouver)	
U.S. Companies	Developing various aspects of Micro Fuel Cell Technologies. Not an exhaustive list		Ardica, Protonex, MTI Micro, Jadoo, Ultracell, SiGNa Technologies, Adaptive Materials, Lilliputian	

Effort/Program/Project	Description	Status	Organization	URL
Other Companies	Developing various aspects of Micro Fuel Cell Technologies. Not an exhaustive list		Smart Fuel Cell (Germany), CE Liten (France), MyFC (Sweden), Horizon Fuel Cell (Singapore), Toshiba (Japan), Hitachi-Maxell (Japan)	
Li/CFx	reduce resistance of CFx for higher rates and scale-up to D size		Eagle Picher Energy Products, Surrey, BC	
Li-ion	new materials for positives and negatives, gel-polymer electrolytes, non-flammable electrolytes		Dalhousie U.; Electrovaya, Mississauga, ON; Hydro-Québec, Montréal; NRC, Ottawa; E-one Moli Energy, Maple Ridge, BC	
Ni	nano-particles of $Ni(OH)^2$		INCO, ON	
LiFePO4	improved conductivity		Phostech, QC	

Theme 3: Power and Data Distribution

Effort/Program/Project	Description	Status	Organization	URL
UK DSTL "Reducing the Burden on Dismounted Soldiers" program	Pilot demonstrators for soldier e-textile backbone, plus compatible connectors	Delivers July 2011	Intelligent Textiles Limited	http://www.defenceresearch.co.uk/pdf/dr10_johnhunt.pdf
UK MoD ISSE (Individual Soldier Systems Executive)	"Managing the integration of separate equipment projects into a single architecture to maximize the effectiveness of the fire team".	Nascent, working groups launch Nov 2010	Broad industry working groups	http://www.mod.uk/DefenceInternet/MicroSite/DES/OurTeams/LandTeams/IndividualSoldierSystemExecutiveisse.htm
Connector adapted to E-Textile	Some preliminary efforts or discussion have taken place outside Canada.	Unknown		
Conventional connectors with desirable characteristics	Some effort done in other Nations in relation to DSS development be it government directed or private efforts	Unknown	Amphenol, Deutsch, ITT-Canon	

Theme 4: Distributed Power Management

Effort/Program/Project	Description	Status	Organization	URL
ASAP-TD			DRDC-Atlantic	
Several companies	Several companies are claiming to do this type of R&D but the overall efforts are disjointed. There is a need to have a joint effort to crack this one.			
Virtual Test Bench	The Virtual Test Bed (VTB) comprises a suite of software tools for the prototyping of large-scale, multi-disciplined dynamic systems. It allows proof testing of new designs prior to hardware construction.		University of South Carolina	http://vtb.engr.sc.edu/vtbwebsite/#/Overview

Weapons Effects

Theme 5: Weapons Platform (Launching System)

Effort/Program/Project	Description	Status	Organization	URL
SIPES		Active	DRDC	
OICW – XM29	The XM-29 is a combination weapon, which has the 20mm semi-automatic, magazine fed grenade launcher as its primary part, and the 5.56mm compact assault rifle as its secondary part. Both parts are assembled into the single one-man portable unit, with the addition of the target acquisition / fire control system (TA/FCS), which is an essential part of the whole system.	Paused	Armament Research, Development and Engineering Centre (ARDEC)	http://world.guns.ru/assault/as40-e.htm
XM-25	The XM-25 stand-alone is 25mm gas-operated semi-automatic magazine fed grenade launcher that replaced the 20mm version of the XM-29. The XM-25 was spun off due to the excessive weight of the XM-29 system.	Active and recently fielded	ARDEC, H&K, ATK	
LSAT Case-telescoped LMG	The LSAT light machine gun, of the LSAT (Lightweight Small Arms Technologies) program, is a developmental light machine gun. The program was initiated in 2004, when the Joint Service Small Arms Program (JSSAP) challenged the American defence industry to develop lighter small arms and ammunition[1][4]. The LMG provides a major reduction in weight over legacy weapons, as well as improvements in other areas, such as controllability and reliability.[2] As of 2008, it has two configurations, one that fires polymer-cased ammunition, and one that fires caseless ammunition	Active	Armament Research, Development and Engineering Centre (ARDEC)	
LSAT Case-Telescoped Rifle	The LSAT rifle, of the LSAT (Lightweight Small Arms Technologies) program, is a developmental assault rifle. Design began in 2008[1], four years after the beginning of the LSAT program. Like the LSAT LMG, the rifle is designed to be significantly lighter than existing designs, and is designed to fire lighter ammunition. Like the rest of the program, the weapon extensively uses parallel development. It has designs for polymer-cased ammunition and caseless ammunition, and designs using spring-loading magazines and weapon-powered magazines.	Active	Armament Research, Development and Engineering Centre (ARDEC)	

Effort/Program/Project	Description	Status	Organization	URL
Felin – PAOP (Polyarme Polyprojectiles)	The PAPOP (PolyArme PolyProjectiles, "multi-projectile multi-weapon") is a French project to construct a computerized multi-usage infantry weapon for the FÉLIN system, capable of hitting hidden or protected targets. It combines a 35 mm grenade launcher with a 5.56 NATO assault rifle, both in a bullpup configuration, complete with targeting aids.	Cancelled		
3 GL and MAUL	The 3 GL is an electrically initiated 40mm grenade launcher and the MAUL is an electrically initiated under slung shotgun. Both are based on stacked round technology initiated inductively.	7	Metal Storm	
Individual Serviceman Non-Lethal System (ISNLS)	The Individual Serviceman Non-Lethal System (ISNLS) is an evolving non-lethal weapon concept currently supported by the commercial-off-the-shelf FN303 Less Lethal Launcher. The primary purpose of the ISNLS is to give the individual warfighter the ability to engage targets with non-lethal force at greater distance and accuracy than is currently available. The FN303 Less Lethal Launcher is a compressed air powered semi-automatic launcher designed to fire non-lethal projectiles at established non-lethal ranges. The launcher is made from a durable, lightweight polymer with flip-up iron sights and an integrated Picatinny 1913 rail for mounting red dot sights (included) or other accessories.		US Joint Non-Lethal Weapons Directorate (JNLWD)	
Personnel Halting and Stimulation Response rifle (PHASR)	The Personnel Halting and Stimulation Response rifle (PHASR) is a prototype non-lethal laser dazzler developed by the U.S. Department of Defense. Its purpose is to temporarily disorient and blind a target. The PHASR rifle is a low-intensity laser, and the blinding effects are apparently temporary. It also uses a two-wavelength laser.		US Air force Research Laboratory Directed Energy Directorate, Kirtland AFB	
Dazzler	A dazzler is a directed-energy weapon employing intense visible light, usually generated by a laser (laser dazzler). Dazzlers can operate in infrared when their targets are electronic sensors. Most of the contemporary systems are man-portable, and operate in either the red (a semiconductor laser) or green (a DPSS laser) part of the electromagnetic spectrum.		US Army Research Laboratory, Sensors & Electron Devices Directorate (ARL SEDD)	

Theme 6: Ammunition (Lethal and Non-Lethal)

Effort/Program/Project	Description	Status	Organization	URL
LSAT	See previous description under weapon platform	Active	ARDEC/AAI	
Metalstorm	See previous description under weapon platform		Metal Storm	http://www.metalstorm.com/component/option,com_frontpage/Itemid,79/
eXtended Range Electronic Projectile (XREP™)	TRL 8, S: compatible with 12 gauge shotguns W: max range is 30m Extend effective range to 100m			http://www.taser.com/products/law/Pages/TASERXREP.aspx
Soldier Integrated Precision Effects System (SIPES)	The Soldier Integrated Precision Effects System (SIPES) is a Canadian Research and Development Technology Demonstration Project that will demonstrate the viability, utility and usability of integrated novel and high pay-off small arms related lethal and non-lethal technologies for future, lightweight, small calibre weapon systems which address current capability deficiencies		DRDC/COLT	
Lead-free ammo	Lead free bullets M855A1		ATK Barnes	http://bulletin.accurateshooter.com /category/bullets-brass-ammo/
New US ammo with improved performance – M855A1, SOST (MK 318 and MK 319)	Barrier blind rounds and designed for short barrels	Fielded	Picatinny Arsenal, Crane	
Frangible bullets	Improved training ammunition Controlled Frangibility - Reduced Hazard - No Ricochet - Inherent Accuracy - Increased Velocity - Reduced Chamber Pressure - Decrease Bore Wear			
LWCC			ARDEC/GD-OTS Canada	

Effort/Program/Project	Description	Status	Organization	URL
Improved Flash Bang Grenade (IFBG)	The Improved Flash Bang Grenade (IFBG) is an FY07 development program that aims to improve the effectiveness and safety of currently fielded non-lethal flash bang munitions by eliminating perchlorates in their formulation. Perchlorates are strong oxidizers used in fireworks, explosives, rocket propellant, flash compositions, and other pyrotechnics. When developed, the IFBG will initiate and eject a metal powder payload that reacts with oxygen in the air to create a large, bright, long-duration flash and loud noise. The longer duration of the flash and bang increases temporary incapacitation. The IFBG will support missions such as hostage rescue, room clearing, and other operations in complex urban terrain.		US Joint Non-Lethal Weapons Directorate (JNLWD)	
Airburst Non-Lethal Munition (ANLM)	The Airburst Non-Lethal Munition (ANLM) is a US Army-led program. The ANLM is designed to enable a precision airburst delivery of non-lethal munitions. It is intended for use in area denial and hostile crowd scenarios and is being developed for use with several different weapons, including the MK19 and the M203		US Joint Non-Lethal Weapons Directorate (JNLWD)	
MK19 Non-Lethal Munition (MK19 NLM)	The MK19 Non-Lethal Munition (MK19 NLM) is being developed to provide the warfighter with an area denial, counter-personnel capability. The MK19 NLM fires blunt trauma projectiles in rapid-fire mode. The MK19 Non-Lethal Munition program has made great progress. The ring airfoil projectile was selected as the payload and the program is approaching DoD Acquisition Milestone B. The shell casing of the munition is ejected by the MK19 launcher, and the ring airfoil projectile is launched as a non-lethal, blunt-impact round. The MK19 provides the warfighter with an effective, non-lethal capability.		US Joint Non-Lethal Weapons Directorate (JNLWD)	
Excalibur Exacto				
Lightweight conventional ammunitions (incl. stainless steal, polymer)				

Theme 7: Weapon-Mounted Situational Awareness and Targeting Suite

Effort/Program/Project	Description	Status	Organization	URL
ASAP	The Advanced Soldier Adaptive Power Technology Demonstration Project (ASAP TDP) is attempting to find both a short term remedy as well as a long-term solution to satisfy soldier power requirements.		DRDC	
RTO			NATO	
Soldier Integrated Precision Effects System (SIPES)	The Soldier Integrated Precision Effects System (SIPES) is a Canadian Research and Development Technology Demonstration Project that will demonstrate the viability, utility and usability of integrated novel and high pay-off small arms related lethal and non-lethal technologies for future, lightweight, small calibre weapon systems which address current capability deficiencies		DRDC	
Advanced Fire Control Technology project	The purpose of the project is to demonstrate advanced fire control component technology, determine correct range to moving targets and to further share power within the weapon		Joint Service Small Arms Program (JSSAP)	
Advanced Weapon Sight Technology, Advanced Technology Objective for Demonstration (AWST ATO-D) Program	The FWS could include a light weight clip-on thermal imager for the basic rifleman; a medium weight thermal or fused weapon sight for the squad designated marksman and automatic rifle; and a heavy weight thermal or fused weapon sight with range finder interface and ballistic computer for crew served weapons. The goal of the AWST program is to enhance Soldier capabilities regarding Situational Awareness, threat detection, range performance for target engagement and reduced timelines between target detection and engagement.		Night Vision & Electronic Sensors Directorate (NVESD)	
Aimpoint BR8 and MPS3	Simple, lightweight, robust and affordable fire control system for use in an Automatic Grenade Launcher (AGL).		Swedish MOD	
Dynamic Image Gunsight Optic (DInGO)	The Dynamic Image Gunsight Optic (DInGO) will provide a rifle combat optic that can be rapidly reconfigured for use from short to long ranges that also addresses current reduced training schedules		DARPA	

Effort/Program/Project	Description	Status	Organization	URL
Grenadier Laser Range Finder and Sight	The Grenadier Laser Range Finder (GLRF) is envisioned to be a rifle-mounted laser range finder that aids the Grenadier in quick and accurate range-to-target determination. The objective of the GLRF is to enhance preparation for combat and combat employment of Grenadiers regarding range-to-target determination and first round hit probability. The GLRF is envisioned to be a compact and weapon mountable M320 Grenade Launcher Module (GLM) Day/Night sight and laser range finder with integral multifunction lasers for the individual combat soldier equipped with the M320 GLM.		US Army Night Vision & Electronic Sensors Directorate (NVESD)	
Soldato Futuro Integrated Combat Weapon sight	The Integrated Combat Weapon System (ICWS) development for the Italian Soldato Futuro soldier modernization program is being led by the team of Fabbrica d'Armi Pietro Beretta S.p.A. and Galileo Avionica S.p.A., with supervision of the Italian Army General Staff.		Italian Soldato Futuro soldier modernization program	
Vingsight FCS	The Vingsight is a standalone universal sight unit for all weapons and calibers from 5.56 to 40mm AGL (Fyskse, 2006). The system includes a fire control computer, and an integrated camera and display for enhanced low light capability. Although the Vingsight has been evaluated in live fire trials and customized for 40mm AGL applications, the system may be enhanced by the following potential upgrades.		Vinghog	
Spatially Fused Aimpoint System (SFAS)	The system enables a warfighter to aim a weapon equipped with a Thermal Weapon Sight (TWS) without looking through the sight and without losing the situational awareness provided by his night vision goggle (NVG). The SFAS shall consist of weapon and head-mounted imaging and position sensors, computational hardware and a body-worn power supply. The SFAS shall electronically combine and overlay the TWS image in the correct relative location of the head mounted enhanced vision sensor scene to facilitate rapid pointing and accurate engagement of targets.		United States Marine Corps System Command	

APPENDIX 2

C4I

Theme 8: Command and Control

Effort/Program/Project	Description	Status	Organization	URL
Human Systems Integration	Put in place and optimize affordable, maintainable and sustainable socio-technical systems. Contributes to the development of policy and doctrine for concept development, definition, and acquisition of these systems.		HSI Section DRDC-T	http://www.toronto.drdc-rddc.gc.ca/about-apropos/fact/s05-eng.asp
– SG.102 - Integration of C4I on Soldier Systems – SG.103 - Interoperability for the soldier Systems – SG.123 - Soldier Systems Communications Interoperability		Closed	NATO Industrial Advisory Group (NIAG) studies	

Theme 9: Communications

Effort/Program/Project	Description	Status	Organization	URL
ASAP-TD		Ready to go	DRDC-Atlantic (NRC Montreal road Campus, Ottawa)	
3-D audio on Soldier's system radio	Dr Robert Arrabito (spatial distribution of different voice channel around the head of the user)	Close	DRDC-Toronto (DCIEM)	http://pubs.drdc-rddc.gc.ca/SEARCH/BASIS/pcandid/www/engpub/SDW?M%3D1%26W%3DAUTHOR++%3D+%27ARRABITO%2C+G.R.%27
NATO Wide Band Waveform (WBWF)				
European Secure Software Defined Radio (EU ESSOR)	The strategic aim of the ESSOR Programme is to provide the basis for development and production of Software Defined Radio (SDR) products		Established by six contributing Member States (ES, FI, FR, IT, PL, SE), were signed on 19 December between A4ESSOR (the prime contractor) and OCCAR-Executive Administration (OCCAR-EA)	http://www.eda.europa.eu/genericitem.aspx?Area=Organisation&ID=593
Coalition Wideband Network Waveform (COALWNW) (JTRS JPEO)	Develop a specification for a coalition-wide wideband networking waveform and associated crypto to support a NATO STANAG.		Australia, France, Germany, Italy, UK, Finland, Sweden, Spain	
Mobile Networks			Wireless industry	

Effort/Program/Project	Description	Status	Organization	URL
Cognitive Radio Assisted Mobile Ad Hoc Network (CRAMNET)	Opportunistic Cognitive Radio For MANET With Adaptive Phy And Dynamic Routing Capability	TRL 7	University of Oulu, Finland	http://www.cwc.oulu.fi/home/files/news/CRAMNET_1.pdf http://www.cwc.oulu.fi/public-cwc-giga-2010/CRAMNET_2.pdf
Literature watch	A very rich collection of Cognitive Radio and Software-Defined Radio references University of South Florida	N/A	Wireless Communications & Signal Processing Group (WCSP)	http://wcsp.eng.usf.edu/cognitive_radio_links.html

Theme 10: Computer

Effort/Program/Project	Description	Status	Organization	URL
Electro-Textile		Closed	DRDC-Atlantic / Intelligent Textile / Lincoln Fabrics	

Theme 11: Intelligence

Effort/Program/Project	Description	Status	Organization	URL
DKKN (Distributed Knowledge & Knowledge Needs) Tactical Intelligence Ontology Development	Information is collected in a data cloud via an agent gateway from multiple interfaces. The information can be accessed / pulled from this information cloud through filters, areas of interest using this search engine and output is provided based on relevance		Office of Naval Research	http://www.onr.navy.mil/~/media/Files/Funding-Announcements/BAA/07-026_Briefing.ashx
Symbology task	Defining what the soldiers will see on their screen	2ND iteration of 4	DLR-5/DRDC-Toronto	
Tactical Biometric Collection and Matching System (TBCMS)	The intent is to integrate multimodal (finger print, facial, and iris) collection into a single, lighter, handheld device that meets DoD and FBI biometric tech standards		Naval Innovative Laboratory	
Draper – PNS (Personal Navigation System)	• GPS (Military) • MEMS IMU • 3-axis magnetometer • Baro-altimeter • 3-beam Doppler radar		Draper Laboratory	
Northrop – Soldier Link Navigator	• Pedometer • 3-axis magnetometer • 3-axis Gyro • Baro-altimeter		Northrop Grumman	

APPENDIX 2

Effort/Program/Project	Description	Status	Organization	URL
QinetiQ – MIGRM (MEMS IMU GPS Receiver Module)	• GPS • Civil (Phase 1) • Military (Phase 2) • MEMS IMU • Magnetometer • Baro-altimeter • Zero-Velocity-Update		QinetiQ	
CHI Systems – SUSA (Small Unit Situational Awareness)	• GPS • MEMS IMU • UHF Radio		CHI Systems Inc	
Applanix - DNM (Denied Navigation and Mapping)	• High Accuracy IMU • GPS • Civil • Zero-Velocity-Update		Applanix	
CERDEC/Northrop – APNTFF (Advanced Position/Navigation and Tracking the Future Force)	• MEMS IMU • GPSMilitary • Pedometer (DRM) • Radio ranging		CERDEC/Northrop	
WPI – PPLS (Precision Personnel Location System)	• Radio ranging • Accelerometers		WPI	
Sarnoff – Locatus	• Radio ranging • Ad-hoc network • Deployable nodes • MEMS IMU (foot) • Zero-Velocity Update		Sarnoff	
DHS – Advanced 3-D Locator	• MEMS IMU (foot) • GPS • Baro-altimeter • Magnetometer • Radio ranging • Decentralized navigation • Zero-Velocity Update		Department of Homeland Security	
L3/IEC – M3DL (Militarized 3-D Locator)	• MEMS IMU • GPS (Military) • Baro-altimeter • Magnetometer • Radio ranging • Decentralized Cooperative Navigation • Zero-Velocity Update		L3/IEC	
U. Calgary – PNS (Portable Navigation System)	• MEMS IMU • 3 gyro, 6 accelerometer • GPS • Baro-altimeter • Magnetometer		Geomatics Engineering	

APPENDIX 2

Effort/Program/Project	Description	Status	Organization	URL
"MiPN" – Minimal Personal Navigator	• DRDC Ottawa R&D Prototype • IMU / Magnetometer (foot), 30 g • GPS (shoulder), 80g • Windows XP Tablet PC		DRDC-Ottawa	
RTO Study: All technologies examined	• Inertial Sensor Technologies • Velocity and Distance Travelled Sensors • Heading Sensors • Altitude / Depth Sensors • Time of Arrival / Time Difference of Arrival (Range) • Angle (Bearing determination)		NATO RTO (as cited in 3.4 Navigation Technologies - Bird presentation)	
RTO Study: MEMS Inertial Sensors	MEMS enable solid state inertial navigation systems on a single integrated circuit chip			
RTO Study: Signals of Opportunity	• Exploit any or all available "signals of opportunity" to determine ones position • Cell phone towers • TV transmitters • Wi-fi hot spots			
RTO Study: Laser Imaging	• Can be used to estimate the motion parameters (aid to INS) • Absolute position can be obtained by matching to an existing database			
RTO Study: Integration Technology	• Kalman Filter • Loosely / tightly coupled • Deeply integrated (or ultra-tightly coupled) • New filters for non-linear systems • Particle filters • Sigma-point filters			

APPENDIX 2

Sensing

Theme 12: Personal Sensing (Body-Worn)

Effort/Program/Project	Description	Status	Organization	URL
Health Monitoring:				
CardioNet	Provides an ambulatory cardiac-monitoring service with several signal-processing algorithms that detect ECG abnormalities and transmit all collected information wirelessly to healthcare providers			www.cardionet.com
Human++	Integrates various sensor technologies and "smart" technology into one low-power, highly networked system			www.imec.be/ovinter/static_ research/human++.shtml
Zephyr BioHarness	Monitors current performance and condition using sensors on a strap placed around wearer's chest			www.zephyrtech.co.nz
VivoMetrics' VivoResponder	Examines signs of life to determine when lives are endangered in emergency response scenarios			www.vivometrics.com
HQ Inc.'s CorTemp Thermometer	In pill form, records core body temperature and communicates via RFID			www.hqinc.net
Remote Triage: Heart Rate (ECG), Respiratory Rate	Development of wireless vital signs monitor		US Army	
Biometrics Technologies for Quantifying Operational Performance	A decision support system that will implement Biometrics as tools that aim to assess operational readiness and effectiveness for individual CF operators. The project developments include: a) Biometrics-based automatic assessment of an individual's operational readiness by considering multiple modalities of three-dimensional (3-D) facial images and eye tracking from stereoscopic cameras, electro-cardiogram (ECG) and electroencephalographic (EEG) signals, and b) Data fusion for the above multi-sensor systems.		DRDC-Toronto	
Sensor Tape	The Sensor Tape Program will develop low-cost medical sensor systems to support DoD missions, in particular to measure the cumulative effect of blast exposure. The program will develop a helmet (or body-mounted) blast dosimeter. The system will consist of a patch-like sensor device, and a monitoring unit for communicating with the sensor tape patch.		DARPA	

Effort/Program/Project	Description	Status	Organization	URL
Wearable Fibre Optic-Enabled Chemical Nanosensor Array for Warfighter	Porous-silicon photonic-crystal materials offer the possibility of mounting millimetre-size sensors directly on the distal end of an optical fibre, resulting in a lightweight, low-cost, flexible, micro-scale, probe-like, optical-sensor solution that could be integrated into the fabric of items of kit or used in applications where minimally-invasive architectures are necessary		DARPA	
Solid State Transcutaneous Carbon Dioxide Sensor	The United States Army (The Army) has identified the need for a device that can accurately and non-invasively measure the partial pressure carbon dioxide (PCO^2) that is suitable for use in combat casualties who have hypovolemic shock, acute lung injury, massive resuscitation, and other factors that alter the exhaled or end-tidal CO2 (ETCO2) - PCO2 relationship.		Army-SBIR	
Augmented Hearing				
Universal 3-D head transform/beam form for sound localization				
Detection/Vision				
Lightweight, Wide Field-Of-View Wave-guided Head-mounted Display	Demonstration of a 60-deg x 10-deg field-of-view device. The design is such that it can be readily extended larger fields of view. Moreover, the design is inherently high resolution and compatible with colour, should the latter eventually become a requirement.		Army SBIR	
NightGuard - Real-Time SWIR Hyperspectral Imaging Sensor for Day/Night Operations	ChemImage has previously demonstrated the utility of a SWIR sensor for stationary and on the move (OTM) explosive detection, disturbed earth detection and camouflage concealment and detection. ChemImage proposes the combination of a short-wave infrared (SWIR) hyper spectral imaging (HSI) sensor with active illumination sources to allow for both daytime and nighttime operations.		Army SBIR	

Effort/Program/Project	Description	Status	Organization	URL
Real-Time Vis-SWIR Multispectral Sensor for Day/Night Operations	The 3-D camera technology is a recent imaging technology for multispectral imaging, developed recently at Surface Optics Corporation. This camera system is a compact solid-state staring multispectral imager that captures the information required to generate complete multispectral cubes with each focal plane exposure. The number of bands depends on the number of spectral filters used in a mosaic filter array. The system will use high-density InGaAs focal plane arrays that are now in development. Two fore-optics will be designed for the system for wide and narrow fields of view. The system will include an integrated real-time processor for analyzing and displaying results in real time. The proposed program will produce a preliminary design layout and a detailed system performance analysis.		Army SBIR	
Large Format Dual Band FPA ROIC for Low Flux Environments	The Dual Band Compact Hyperspectral Imager (DBCHI) delivers high performance, co- registered, simultaneous MWIR & LWIR hyperspectral data from a compact, man-portable sensor.		Army SBIR	
Montage	Integration of an uncooled long wave infrared sensor (LWIR) (8-12 microns) with a sensor that operates in the Visible/Near Infrared/SWIR (VNS) (0.4-1.6 microns) spectral range and the integration of this combined day/night focal plane with the type of flat optics demonstrated in the DARPA MONTAGE Program to realize a compact day night rifle sight system.		DARPA	
Adaptive Focal Plane Array (AFPA)	The overall goal of the Adaptive Focal Plane Array (AFPA) program is to demonstrate a high-performance focal plane array (FPA) that is widely tuneable across the relevant wavebands in the infrared (IR) spectrum (including the short-wave infrared (SWIR), mid-wave infrared (MWIR), and long-wave infrared (LWIR) bands), thus enabling "multispectral imaging on a chip."		DARPA	

Effort/Program/Project	Description	Status	Organization	URL
Compact Mid-Ultraviolet Technology (CMUVT)	Warfighters need to be able to detect and identify biological and chemical agents that may be in use by enemy forces. Current detection methods require large, heavy equipment, and a great deal of power. To address these deficiencies, the Compact Mid-Ultraviolet Technology (CMUVT) program is developing the essential heteroepitaxy, waveguides, cavities, contacts, and micro/nanostructures as necessary to enable efficient LEDs and chip-scale semiconductor lasers operating at wavelengths below 275 nm.		DARPA	
MANTIS	The MANTIS program will develop, integrate and demonstrate a soldier-worn visualization system, consisting of a head-mounted multispectral sensor suite with a high-resolution display and a high performance vision processor (ASIC), connected to a soldier-worn power supply and radio. The helmet-mounted MANTIS Vision Processor will provide the soldier with digitally fused, multispectral video imagery in real time from the Visible/Near Infrared (VNIR), the Short Wave Infrared (SWIR) and the Long Wave Infrared (LWIR) helmet-mounted sensors via the high resolution visor display.		DARPA	
Super-Resolution Vision System (SRVS)	The Super-Resolution Vision System (SRVS) initiative will develop and build a field prototype soldier-portable optical system that will demonstrate improved recognition and identification range over existing systems. The key technical innovation is exploitation of an atmospheric turbulence-generated micro-lensing phenomena to generate better than diffraction-limited images.		DARPA	
Quantum Sensors Program (QSP)	The Quantum Sensors Program (QSP) is applying phenomenology from quantum mechanics to improve the performance of military sensors that use electromagnetic radiation.		DARPA	
Advanced Night Vision System (ANVS)	The Advanced Night Vision System (ANVS) program is developing the core technologies for improving our night vision capability in urban operations.		DARPA	
Integrated Multi-Spectral Sensor	The Integrated Multi-Spectral Sensor must be a visible light day imager capable of simultaneously detecting and tracking the laser energy on a target from the following three sources simultaneously and displaying them in context with the surrounding scene.		ONR	
Novel flexible sensor array integrated with a Flex	Flexible sensors		Navy SBIR	

Effort/Program/Project	Description	Status	Organization	URL
Navigation				
Navigation-Grade Integrated Micro Gyroscopes (NGIMG)	The Navigation-Grade Integrated Micro Gyroscope program seeks to attain tiny, low power, rotation rate sensors capable of achieving performance commensurate with requirements for GPS-denied navigation of small platforms, including individual soldiers, unmanned (micro) air reconnaissance platform, unmanned underwater vehicles, and even tiny (e.g., insect-sized) robots.		DARPA	
MEMS Azimuth and Navigation Sensor	Develop and demonstrate a MEMS sensor based azimuth determination and navigation sensor.		ONR-SBIR	
Robust Surface Navigation (RSN)	The Robust Surface Navigation (RSN) program will provide the U.S. Warfighter with the ability to geo-locate and navigate effectively when the Global Positioning System (GPS) is unavailable due to hostile action (e.g. jamming) or blockage by structures and foliage. The RSN program will develop the procedures and technologies for geo- location of stationary assets and navigation of mobile platforms by exploiting signals of opportunity and/or spatialized signals from satellite, airborne, and terrestrial assets.		DARPA	
Visual Measurement-based Autonomous Navigation	Providing Position Location Information (PLI) for individual Warfighters increases their effectiveness, enables much greater cooperation between forces, and provides strategic information to commanders. Current technologies that attempt to provide PLI use Inertial Measurement Units (IMU) and Global Positioning System (GPS). This combination is undesirable due to weight, size, and power issues. To address this critical challenge, Intelligent Automation Inc. (IAI), along with Prof. Carlo Tomasi of Duke University and Boeing Research and Technology (BR&T), propose to develop SeeStar, an accurate and efficient visual navigation system (VNS).		Army-SBIR	
Miniaturization of Sensors on Flexible Substrates	The purpose of this project is to demonstrate nano-ink printing processes for making function specific active sensors and electronics on flexible substrates. The goal is to demonstrate ink formulations and recipes for depositing conductor and semiconductor materials on various flexible polymer and polyimide substrates for use in smart munitions sensors. In this project active sensor electronic systems for intelligent munitions will be developed with an emphasis on antenna and GPS electronics for Medium Range Munitions (MRM).		Army-SBIR	

Effort/Program/Project	Description	Status	Organization	URL
IFF				
Advanced Soldier Sensor Information System and Technology (ASSIST)	The main goal of the program is to enhance battlefield awareness via exploitation of soldier-collected information. The program will demonstrate advanced technologies and an integrated system for processing, digitizing and disseminating key data and knowledge captured by and for small squad leaders.		DARPA	
Counter-Sniper (C-Sniper)	The Counter-Sniper (C-Sniper) program's goal is to detect and neutralize enemy snipers before they can engage U.S. Forces. An objective of the program is to deliver a field testable prototype system suitable for operational experimentation as an integrated part of the DARPA Crosshairs system, already under development. The purpose of the Crosshairs system is to detect enemy bullets, RPGs, and mortars fired at U.S. military reconnaissance platform and to prevent them from striking the reconnaissance platform. The C-Sniper system will enhance this capability by identifying threats before they can fire.		DARPA	
Helmet Mounted Radar System (HRMS) Moving Target Indicator (MTI) radar system.	Demonstrate the feasibility of developing a helmet mounted radar system that uses technology similar to that currently being developed for sense through the wall applications. The Helios Remote Sensing Systems team will develop a miniature, low power, 360- degree field of view Moving Target Indicator (MTI) radar sensor that will alert the soldier to the whereabouts of targets out to at least 25 meters with a goal of 50 meters while operating in harsh environments.		Army-SBIR	

Theme 13: Weapons-Mounted Sensing

Effort/Program/Project	Description	Status	Organization	URL
SIPES				
One-Shot	The One Shot program will develop a field-testable prototype, observation, measurement, and ballistic calculation system, which enable Snipers to hit targets with the first round, under crosswind conditions, up to the maximum effective range of the weapon (RE). The system developed should provide day and night direct observation of the target, measure all relevant physical phenomena that influence a ballistic trajectory, and rapidly calculate and display both the aim point offset and expected crosswind variability (confidence metric) in the shooters riflescope. The system must exploit novel technologies to operate over a range of visibilities, atmospheric turbulence, scintillation, and environmental conditions.		Advanced Sighting System (One Shot)	
Dual Band Focal Plane Array Manufacturing (DBFM).	Large formats, dual band staring FPAs will allow the operator to select to operate simultaneously in the mid-wave infrared (MWIR) and long-wave infrared (LWIR) regions.		NVESD	
Dual Band MWIR/LWIR SLS FPA	This Phase I SBIR effort will develop dual-band mid-wavelength infrared/long-wavelength infrared (MWIR/LWIR) detector technology based on dual monolithic type-II strained-layer superlattices (SLS). The dual-band detector will operate in either MWIR or LWIR mode depending on the applied voltage bias, and will be compatible with the ROICs under development in the MDA FastFPA program.		Navy-SBIR	
Dual Band MWIR and LWIR Switchable Beam Splitter and Filter	Develop liquid crystal based fast speed, high efficiency dual band infrared switchable beam splitter and filter for 3rd Generation Forward Looking Infrared (3rd Gen FLIR). The device can be electronically controlled to change from transmissive to reflective in mid-wave infrared [MWIR (3.5 â“ 5.0 ?m)] and long wave infrared [LWIR (7.5 â“ 12.0 ?m)]		ARMY-SBIR	

Effort/Program/Project	Description	Status	Organization	URL
Strained Layer Superlattice Dual Band Mid-Wavelength Infrared/Long Wavelength Infrared (MWIR/LWIR) Focal Plane Arrays nBn Based Dual-Band Focal Plane Arrays with Type II InAs/GaSb Superlattices PA and Camera Based on Dualband Infrared SLS Photodiodes			Navy-SBIR	
Miniature Laser Designator for Small Unmanned Aircraft Systems	Advanced Scientific Concepts, Inc. (ASC) has developed 3-D Flash LIDAR range finding cameras based on its patented 3-DFPA technology and is producing high-powered compact diode pumped lasers for Flash LIDAR.		Navy-SBIR	
Dual Well Focal Plane Array (FPA) Dual Gain Gating Imaging Sensor	Inexpensive dual-well focal plane array (FPA) imaging sensor that can provide "see-spot" capability for a micropulse laser designator		Navy-SBIR	

Theme 14: Crew-Served and Hand-Held Sensing

Effort/Program/Project	Description	Status	Organization	URL
Through-Wall Sensing Technologies	• Detection and/or localization of motion behind walls – including breathing and heart beat • Imaging of objects behind walls, including: – Detection of persons, arms caches – Information on in-wall structure – Interior room layout SAR imaging concept: • Reconnaissance platform-mounted radar moving in front of a building of interest • Synthetic aperture radar (SAR) processing in the along-track dimension provides high azimuth resolution • Array processing in the elevation dimension provides discrimination in elevation		DRDC - Ottawa	
CPR3	Beeps if motion is detected, no range or location information		Cinside (Sweden)	http://www.cinside.se/upload/090518_CPR3_folder_sv_eng.pdf
EMMDAR	Range information available		L-3 CyTerra (US)	http://www.cyterra.com/products/through-wall.html

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Effort/Program/Project	Description	Status	Organization	URL
Prism 200	2-D or 3-D images of moving people and objects		Cambridge Consultants (UK)	http://www.cambridgeconsultants.com/prism_200.html
SuperVision 1600			Yiwu Tianying Optical Instrument Co. (China)	http://www.nightvisioncn.com/sdp/625512/4/cp-5246844/0/Through_Wall_Rada.html
Xaver 800	• Detection of static and moving objects • Very large bandwidth allows high range resolution • Higher frequencies (3 to 10 GHz) allow greater angular resolution at the expense of greater signal attenuation • 3-D imaging: 4 antenna configuration allows discrimination in both elevation and azimuth		Camero (Israel)	http://www.camero-tech.com/xaver800.shtml
Xaver 400	2-D imaging only		Camero (Israel)	http://www.camero-tech.com/xaver800.shtml
SAR imaging concept:	• Reconnaissance platform-mounted radar moving in front of a building of interest • Synthetic aperture radar (SAR) processing in the along-track dimension provides high azimuth resolution • Array processing in the elevation dimension provides discrimination in elevation • L-band, 2 GHz bandwidth • 15 cm range and azimuth resolution		5 deg resolution in elevation with future 3-D system	
LIDAR	• 3-D imaging of exterior walls and potentially behind windows • To provide context for SAR images and help in wall compensation			
TWSAR	• L-band (0.7 – 2.7 GHz) for better wall penetration, especially concrete • FMCW • Large dynamic range to accommodate 8 inch solid concrete walls • <2 m vertical receive array • 2 transmit elements to be toggled • 8 elements receive array • Receive channel for each element • 16-bit digitization at IF • I/Q digital downconversion • I/Q data collection for off-line processing			

Effort/Program/Project	Description	Status	Organization	URL
High Accuracy Navigation Systems for Low Power UUVs	Develop new technologies or manufacturing techniques to reduce the size, power, and cost of high accuracy underwater navigation system used in large unmanned reconnaissance platforms, remotely operated reconnaissance platforms, and submarines to enable low power UUVs and gliders to navigate in the complex littoral environment.		ONR-SBIR	
Computerized Laser Sight System (CLASS)	CLASS is a full-solution fire-control system which improves the range and performance of direct fire weapons.		CDC	
XM-153 Common Remotely Operated Weapon Station (CROWS)	The Common Remotely Operated Weapon Station (CROWS) provides Soldiers with the ability to acquire and engage targets while inside a reconnaissance platform, protected by its armour. CROWS is designed to mount on a variety of reconnaissance platforms and supports the MK19 Grenade Machine Gun, .50 Calibre M2 Machine Gun, M240B Machine Gun, and M249 Squad Automatic Weapon.			
Ring Sights	Ring Sights (Sussex UK) produces an array of reflex sighting products specifically designed for Cannons, GPMGs, Grenade Launchers, and HMGs		Ring Sights	
Light Weight Video Sight	Utilizes the latest in laser range finding, I2 night vision and ballistic computer technology to assist soldiers in the detection, recognition and first-round engagement of target threats. he laser range finder that provide a fire solution for day/night operations in all weather		General Dynamics Canada	

Theme 15: Unattended Area Sensing

Effort/Program/Project	Description	Status	Organization	URL
SASNet	The Self-healing Autonomous Sensor network (SASNet) is a tiered networking architecture that consists of collaborative sensing nodes, computing and communicating nodes called fusion nodes that form an ad hoc network for extended sensing coverage. The sensor nodes associated with the closest fusion node and form clusters that interconnect through capable fusion nodes to construct a SASNet system. Electro-optical imaging devices and camera system, as resource-rich spatialized nodes, can be cued, providing a near real time imagery for any detection. The management Node (MN) provides the global view of the system for application, for operational control, and for system management. The system offers an agile surveillance system with a focus of improved operational flexibility and usability. The multi-modal sensors are networked and provide early warning to LOS and B-LOS users. The sensor nodes can detect, classify, and identify personnel and vehicles within its coverage area and report to the MN in near real-time. SASNet employs the concept of sensor toolbox allowing for the assigned users to rapidly deploy the system. The sensor toolbox instruments an area of interest where remote surveillance task can be conducted. The toolbox will typically contain: • Multiple sensor nodes, potentially disposable sensing devices supporting multiple transducer per unit (motion, vibration, sound, magnetic field, etc) • One or backup "fusion nodes" that manage the clusters, each consisting of a group of sensors in an area of interest performing a common sensing task. • One or multiple advanced sensor nodes as EO sensors capable of local image analysis. • Handheld device monitoring unit used for configuring the network, composing and sending the network information queries, and monitoring network activities • Camouflage and fixation kit.	In development	Prime Communications Research Centre (CRC)	
Throwable sensor and robot: Recon, RHEX, and other	Hand-throwable miniature wheeled sensor devices	Fielded and in development for the miniature ones	Commercial	

Effort/Program/Project	Description	Status	Organization	URL
Tactical UGS or T-UGS	T-UGS are small ground-based sensors that collect intelligence through seismic, acoustic, Radiological Nuclear and Electro-Optic means. These sensors are networked devices that provide an early warning system to supplement a platoon size element and are capable of remote operation. To an extent T-UGS will detect, track, classify, and identify personnel and reconnaissance platforms within its coverage area and report to the FCS Network in near real-time. T-UGS comprises the following sensor systems: • The Gateway Node, which is a router and data collector that sends information back to a FCS Network equipped reconnaissance platform. • The Intelligence Surveillance and Reconnaissance (ISR) Node, which is the key component that acquires and tracks personnel, reconnaissance platforms and aircraft through seismic and acoustic means. • The Electro-Optic Node obtains information from the ISR node and pans its camera toward the Point of Interest and is able to track and send images through the FCS Network. • The Radiological Nuclear Node is capable of measuring and reporting gamma dose-rate and accumulated dose from a fallout environment in a tactical battlefield situation. Detected radiological events will be transmitted via a detailed spot report through the Gateway Node to an operator on the FCS network.			
Urban-Unattended Ground Sensors (U-UGS)	Used as a surveillance tool during building clearing operations, caves, sewers, tunnels, and other confined spaces. Textron Defense Systems, along with Honeywell, designed this wireless, hand-emplaced system of sensors to be lightweight and low cost. The U-UGS network is capable of taking field-of-view images of intruders in all light conditions and transmit images to the FCS Network where immediate recognition of human intruders can be achieved or using a motion detections only sensor to detect intruders when imaging is not needed.			

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Effort/Program/Project	Description	Status	Organization	URL
Extreme Agility Micro Aerial Vehicle (EA-MAV)	The objective of the study is to explore concepts of an extremely agile, semi-autonomous, micro-aerial vehicle that will provide a small combat unit or a warfighter with organic stand-off capabilities such as increased situation awareness, more accurate target acquisition and identification and precise delivery of precision effects in complex terrain areas like confined areas and urban areas. These capabilities will improve overall mission success and contribute to the reduction of mission risk. The options analysis and results will contribute to the development of the CONOPS using Class I UAVs and provide the technical basis for advising the Canadian Forces in future acquisition programs related to this type of vehicle.	Completed in FY09/10	DRDC Valcartier	
Overwatch Autonomy & Sensor Situational Awareness for the Dismounted Soldier (OASSAS)	To develop an in-depth understanding of the techniques that endow Micro-Aerial Vehicles (MAV) with an autonomous capability to avoid obstacles and self-localize as a risk reduction task to support future MAV acquisition programs under the Integrated Soldier System Project. The strengths and weaknesses of methods will be characterized and will serve as a reference for future requirements validation. New concepts will be validated and will form part of the enduring MAV analysis capability within DND.	Active for FY10/11 to FY12/13	DRDC Valcartier	
FCS SUGV	U.S. Army's Future Combat Systems family of systems/system of systems. According to the company, "SUGV is The Soldier's Robot – deployed by the soldier; operated by the soldier; sensing for the soldier and weighing less than 30 pounds to minimize the risk to the soldier in hostile operations".			
Micro Air reconnaissance platform (MAV) Program initiative	Seeking to develop and test emerging technologies that could evolve into a mission capable flight system for military surveillance and reconnaissance applications. The only requirement was that the dimension of the reconnaissance platform should not exceed 15 cm.		DARPA	

Effort/Program/Project	Description	Status	Organization	URL
Multi-robot Operator Control Unit (MOCU)	The Space and Naval Warfare Systems Centre, San Diego (SSC San Diego) has developed an unmanned reconnaissance platform and sensor operator control interface (Multi-robot Operator Control Unit or MOCU) capable of controlling and monitoring UAVs, UGVs and Unmanned Surface Vehicles (USVs). The MOCU is designed to run on a broad range of hardware and is a portable system utilizing a man portable computer and re-configurable control unit		The Space and Naval Warfare Systems Centre, San Diego (SSC San Diego)	
V-RAMBO wrist display	Wrist mounted display for UxV control (Video Receiver and Monitor for Battlefield Operations) is a manpack Tactical Video Receiver system, enabling dismounted troops to download real-time imagery gathered by UAVs and other aerial or elevated platforms. The video images can be displayed on V-RAMBO´s dedicated LCD wrist monitor, or any other portable display units.		Tadiran Spectralink	http://www.tadspec.com/index.php?id=188
Haptic Actuators	Electroactive polymers can now be used in controllers for gaming devices, allowing users to feel mechanical movements that correspond to actions in the game. One of the most common applications for electroactive polymers is in robots. That's why the technology is often referred to as artificial muscles.		SRI International Artificial Muscle Inc.	
Universities – e.g. Middlesex University's Halo UAV				

Survivability/Sustainability/Mobility

Theme 16: Operational Clothing, Load Carriage and Mobility

Effort/Program/Project	Description	Status	Organization	URL
SIHS TDP	Headwear integration concept	Completed	DRDC Toronto	
CB^{plus}TDP	CB protective combat uniform that provides protection against toxic hazards in a fully functional design, which is lightweight, low profile, and possesses low thermal burden.	Completed	DRDC	
Invisibility cloak	Camouflage		Duke University / Southeastern University (China)	
Invisibility cloak	Camouflage		Lawrence Berkeley National Laboratory/ Cornell University	
Cloaking Device	Camouflage		Karlshue Institute if Technology	
Fractal Analysis	Camouflage		HyperStealth Biotechnology Corp.	
Metamaterial that manipulates visible light	Camouflage		University of St. Andrews	
Microclimate Cooling System	Future Force Warrior		US Army	
Evaporative Cooling Vest	Mustang Survival		Mustang Survival	
Cooling Vest	Heating/Cooling System		Arctic Heat	
Ventilation vest	Heating/Cooling System		Entrak	
Respirators	Respirators with Nanotechnology (filters)		NIOSH/FDA	
Flexible Displays	OLED Flexible Displays for integration into operational clothing		HP, Samsung, Sony, Philips… etc	
Fibertect	Activated Carbon		Firstline Technology	
Intelligent Textiles	Power Plane/ Power Grid		Intelligent Textiles Ltd.	
Intelligent Textiles	Textile Touchpads		Eleksen - ElekTex	
Bio sensing Textiles	Physiological Monitoring		Vivometrics, Zephyr Technologies	
Bio sensing Textiles	Monitoring of biomarkers		University of California	
Integrated Protective Fabric System	Incorporating additional CWA neutralization, increase neutralization in carbon layer, incorporating superloeophobic liquid repellancy in cover		Natick	
CB PPE	Three new uniform concepts: CB Combat Uniform, CB undergarment, Enhanced Flame Retardant Army Combat Uniform		Natick/Defence Threat Reduction Agency (DTRA)	
CB PPE	Two new mask concepts: CB Protective Integrated System, CB Rail Attachment System		Natick/Defence Threat Reduction Agency (DTRA)	
CB PPE	idZ-BS CBRN BDU: Modular Combat Uniform		German Federal Armed Forces	

Effort/Program/Project	Description	Status	Organization	URL
Computer-Aided Engineering for Footwear Design	Finite Element Analysis of foot and footwear interface simulations			
Power Generation			CTT Group	
Swing Phase Exoskeleton for Augmentation of Human Walking	Augmentation of human locomotion has proven an elusive goal. Natural human walking is extremely efficient and the complex articulation of the human leg poses significant engineering difficulties. We present a wearable exoskeleton designed to reduce the metabolic cost of human walking by providing an upward force on the leg during swing phase. This design features a small size and low weight and is localized comfortably on the lower back with only lightweight nylon cables extending to the feet below.		MIT Media Lab	http://www.media.mit.edu/research/groups/biomechatronics
Exoskeleton Development	BLEEX, ExoHiker, ExoClimber, HULC, eLegs, Medical Exoskeleton		Berkeley Robotics & Human Engineering Laboratory	http://bleex.me.berkeley.edu/research/exoskeleton/
Legged Squad Support System (LS3)	The Legged Squad Support System (LS3) program will explore the development of a mission-relevant quadruped platform scaled to unburden the infantry squad and hence unburden the soldier. In current operations, soldiers carry upwards of 50 lbs of equipment, in some cases over 100 lbs, over long distances in terrain not always accessible by wheeled platforms that support infantry. As a result, the soldier's combat effectiveness can be compromised. The LS3 program will design and develop prototypes capable of carrying 400 lbs of payload for 20 miles in 24 hours, negotiating terrain at endurance levels expected of typical squad manoeuvres. LS3 will leverage technical breakthroughs of prior biologically inspired legged platform development efforts. It will develop system designs to the scale and performance adequate for infantry squad mission applications, focusing on platform, control, and human-machine interaction capabilities, as well as secondary design considerations, such as acoustic signature. Multiple technical approaches will be explored, including electromechanical and hydraulic methods of legged actuation.		DARPA, Boston Dynamics	http://www.darpa.mil/tto/programs/ls3/index.html
Knee Stress Release Device (K-SRD)			B-Temia	

Theme 17: Personal Protection

Effort/Program/Project	Description	Status	Organization	URL
Research fields for NRC-SIMS include: nanoscience, chemical biology, diagnostics, laser science, molecular interfaces, advanced materials, and their related technologies.	Single-walled nanotubes (SWNT)		NRC Steacie Institute for Molecular Sciences	http://www.nrc-cnrc.gc.ca/ eng/ibp/sims.html
Nano technology	R&D activities in nanotechnology in Canada are spearheaded by the federal government, provincial governments, as well as universities and national institutes.			http://www.nanowerk.com/ spotlight/spotid=984.php
Nano technology	R&D activities		Department of Defense Multidisciplinary University Research Initiative (MURI)	http://www.defense.gov/news /d20100716muri.pdf
MER Spinel Window Technology	Manufacturing see-through armour. Rugged, c=scratch resistant		MER	http://www.mercorp.com /about.htm
Nano technology	R&D activities		Centre for Nanophase Materials Sciences	http://www.cnms.ornl.gov/
Nano technology	R&D activities		Centre for Nanoscale Materials	http://nano.anl.gov/
Ultra-strong shock absorbing material	NanoMaterials Ltd. is a leading nanotechnology company that develops, manufactures and markets industrial nano-scale additives for lubricants and enhanced composites.		ApNano	http://www.apnano.com/
Smart textiles at industrial manufacturing level	The PASTA project will combine research on electronic packaging and interconnection technology with textile research to realize an innovative approach of smart textile.		PASTA (Integrating Platform for Advanced Smart textile Applications)	http://www.nanotech-now.com/news.cgi?story_id=40651
Nonwovens for Military Combat Clothing Systems	Nonwovens for Military Combat Clothing Systems		USMC – SBIR	http://www.tacticalwarfightergear.com/tacticalgear/catalog/nano_technology_military.php
Nanoscience Institute	R&D program		ONR - SBIR	http://www.nrl.navy.mil/research/nanoscience-institute/
Novel materials and Material Processes Armour Challenge	R&D program		DARPA	http://www.darpa.mil/dso/thrusts/index.htm
SIHS-TDP			DRDC-Toronto	http://www.toronto.drdc-rddc.gc.ca/about-apropos/fact/t29-eng.asp
AMMPHS-TDP			DRDC-Valcartier	

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Effort/Program/Project	Description	Status	Organization	URL
Impact Testing			Biokinetics	
Suspension / Retention Systems				
Dry fibrillar adhesive			Carnegie Mellon University	http://gradworks.umi.com/33/42/3342742.html
Conductive Textiles in Soldier Systems			Intelligent Textiles Limited, London, UK	http://www.intelligenttextiles.com/

Human and System Integration

Theme 18: Physical Integration on the Soldier

Effort/Program/Project	Description	Status	Organization	URL
3-D Anthropometry: BoSS	Photogrammetry for uniform sizing	Active	Canadian Forces	http://www.visimage.cn/UploadFiles/resource/2009817113611.pdf
3-D Anthropometry: VITUS Body Scanning	Laser scanner for fast, non-invasive acquisition of 3-D body dimension	Active	Human Solutions	http://www.human-solutions.com/company/news_press_report_en.php?id=761
3-D Anthropometry: Scanning Services	Head and whole body scanning, providing a point cloud as the final product	Active	3-deling	http://www.3deling.com/
3-D Anthropometry: Research Programs	Universities, Governments private companies doing many types of research	Active	Numerous - there is an international conference on 3-D Body Scanning Technologies	http://3dbodyscanning.org/2010/program.html
Clothed Anthropometry	Suitable allowances for Light, Medium, and Heavy clothing, as well as gloved hand measures.	Not Known	USDOT	
Clothed Anthropometry	State of the art Review	Drafted March 2010	HumanSystems	
Clothed Anthropometry	Various studies involving clothed anthropometry	Active	Natick	http://oai.dtic.mil/oai/oai?verb=getRecord&metadataPrefix=html&identifier=ADA146985 http://www.stormingmedia.us/29/2979/A297953.html
Biomechanical Modeling	Software Program, Development of Digital Human modeling and simulation in the virtual environment	Active	Boston Dynamics – Digital Biomechanics, Dassault - Virtual Human, Siemens PLM – Jack, HumanCAD Mannequin Pro	http://www.bostondynamics.com/bd_digitalbiomechanics.html http://www.3ds.com/products/delmia/solutions/human-modeling/ http://www.plm.automation.siemens.com/en_us/products/tecnomatix/assembly_planning/jack/index.shtml http://www.nexgenergo.com/ergonomics/mqpro.html

Effort/Program/Project	Description	Status	Organization	URL
Biomechanical Modeling	Research Programs – Numerous Applications	Active	– University of Michigan (Automotive Research specialty, and development of JACK) – University of Iowa (Santos) – Virginia Tech – USARIEM – Natick – BMW, Ford, Volvo, Autoliv, Renault, General Motors, – Human Solutions – DRDC / HumanSystems – SEA – NIOSH – TNO (Netherlands) – NASA	http://www.sae.org/events/dhm/index.htm
Biomechanical Modeling Tools	H-Point Machine, used as a key reference point for seated occupants	Active	Humanetics	http://www.humaneticsatd.com/specialty-products/h-point-machine
Biomechanical Modeling Tools	Instrumentation for Ergonomics and Biomechanics - tools such as ErgoImager, data acquisition products, motion capture suits, and pressure mapping	Active	Nexgen Ergonomics	http://www.nexgenergo.com/ergonomics/ergoprods.html
Motion Tracking	COTS Products	Active	Virtsim, NDI Optotrak, Xsens suit	VirtSIM: http://forcesimulation.motionrealityinc.com/ NDI: Optotrak http://www.ndigital.com/ Xsens suit: http://www.xsens.com/en/general/mvn

Effort/Program/Project	Description	Status	Organization	URL
Motion Tracking	Production/Service Companies:	Active	3x3 Designs Acclaim.Net MoCap Studio ActiSystem AnimaZoo - motion capture rental AudioMotion Avatar Motion Capture Studios Biomechanics, Inc. BioVision Home Page Digital Domain Foundation Imaging Giant Studios hOuse of mOves Kinetic Impulse Lamb & Company LocoMotion Studios Madcap Studios Modern Uprising Studios MOTEK site Motion-Capture.Com Motion Capture Site - Graham Bruce nodna - agency for virtual models and characters Performance Capture Studio PIXAR Pyros Pictures Inc. Probe Entertainment Rainbow Studios Red Eye Studio Rearden Steel Studios SIMI Reality Motion Systems TestaRossa Tyrell Innovations Online Vierte Art Viewpoint DataLabs WCM LLC X-Lab # Digital Laboratory (Italy) Z-UP Productions	http://www.visgraf.impa.br/Projects/mcapture/hotlinks.html

Effort/Program/Project	Description	Status	Organization	URL
Motion Capture	Research Groups	Active	3-D Analysis of Human Movement Biomechanics World Wide Centre for Human Modeling and Simulation Centre for Vision, Speech and Signal Processing FASE Project at CWI (the Netherlands) GVU: Animation Lab Human-Computer Communication Research Group at RMIT Imaging Research Centre at UMBC LIG - Computer Graphics Lab, EPFL - MOCA Project MOCA Project website - Motion Capture at Art and Magic Media Research Lab MERL project: Shadow Puppetry Microsoft Research - Human Figure Animation Project Miralab MIT Leg Laboratory Motion Capture Lab Motion Capture Research at VISGRAF Laboratory	http://www.visgraf.impa.br/Projects/mcapture/hotlinks.html
Dermo-skeleton	Knee Stress Relief Device	Active	B-Temia	http://www.b-temia.com/
Exoskeleton	Human Universal Load Carrier	Active	Lockheed Martin	http://www.lockheedmartin.com/products/hulc/
Exoskeleton	XOS	Active	Raytheon	http://www.raytheon.com/newsroom/technology/rtn08_exoskeleton_gen1/
Exoskeleton	Hybrid Assistive Limb	Active	Cyberdyne	http://www.cyberdyne.jp/english/robotsuithal/index.html
Exoskeleton	Exohiker/Exoclimber	Active	Berkeley Robotics and Human Engineering Laboratory	http://bleex.me.berkeley.edu/research/exoskeleton/exohiker/ http://bleex.me.berkeley.edu/research/exoskeleton/exoclimber/

Effort/Program/Project	Description	Status	Organization	URL
Exoskeleton	Berkeley Lower Extremity Exoskeleton	Active	DARPA & Berkeley Robotics and Human Engineering Laboratory	http://bleex.me.berkeley.edu/research/exoskeleton/bleex/

Theme 19: Perceptual-Cognitive Integration on the Soldier

Effort/Program/Project	Description	Status	Organization	URL
Bio-psycho-social model of readiness	This program of research involves the development and validation of a model of individual readiness	Ongoing – completed by March 2012	DRDC Toronto, contracted to HumanSystems	
Comprehensive Soldier Fitness	The program uses individual assessments, tailored virtual and classroom training and embedded resilience experts to provide critical skills to Soldiers, Family members and Army Civilians	Ongoing	U.S. Army	http://www.army.mil/csf/whatiscsf.html

Theme 20: System Architecture and Interoperability

Effort/Program/Project	Description	Status	Organization	URL
None identified to date				

Appendix 3: Current Soldier Systems Standards

The use of industrial and military standards has become increasing important during recent operations in order to provide interoperability between different forces. Standards provide the framework for the exchange of communications including command and control and situational awareness data. Standards also ensure compatibility between equipment systems by defining connections, power and data management, and user interfaces. Additionally, well-defined test standards will ensure that equipment is able to survive harsh operating conditions.

A number of NATO Standard Agreements (STANAGs) have been identified in Table A 3-1 to provide a basic list of standards that are relevant to Soldier Systems. This is not however an exhaustive list as there exists many other standards organizations, including but not limited to, ISO, CSA, CGSB, and IEEE. Other relevant standards should be identified and tracked as part of the next steps.

Table A 3-1: STANAGs Relevant to Soldier Systems

Standard Agreement	Name	Status
Directly related to DSS:		
STANAG 4677	DISMOUNTED SOLDIER SYSTEMS STANDARDS AND PROTOCOLS FOR COMMAND, CONTROL, COMMUNICATIONS AND COMPUTERS (C4I) INTEROPERABILITY (DSS C4 INTEROPERABILITY STANAG)	Draft
STANAG 4619	ELECTRICAL CONNECTIVITY STANDARDS FOR DISMOUNTED SOLDIER SYSTEMS	In Ratification
STANAG 4695	ELECTRICAL INTERFACE SPECIFICATIONS FOR DSS LEVEL 2 POWER INTEROPERABILITY	Draft
STANAG 4694	NATO ACCESSORY RAIL	In Ratification
STANAG 4591	THE 600 BIT/S, 1200 BIT/S AND 2400 BIT/S NATO INTEROPERABLE NARROW BAND VOICE CODER	Promulgated
STANAG 4609	NATO DIGITAL MOTION IMAGERY STANDARD	Promulgated
STANAG 2895	EXTREME CLIMATIC CONDITIONS AND DERIVED CONDITIONS FOR USE IN DEFINING DESIGN/TEST CRITERIA FOR NATO FORCES MATERIEL	Cancelled
Has some influence on DSS:		
STANAG 4545	NATO Secondary Imagery Format (NSIF)	Promulgated
STANAG 4205	TECHNICAL STANDARDS FOR SINGLE CHANNEL UHF RADIO EQUIPMENT	Promulgated
STANAG 4204	TECHNICAL STANDARDS FOR SINGLE CHANNEL VHF RADIO EQUIPMENT	Promulgated

The need for new standards arises with the development of new technologies. Table A 3-2 provides a list of the major areas where deficiencies have been identified. This is an area that requires much attention and will be a major focus of the implementation phase.

Table A 3-2: Summary of Needed Standards

Technical Domains	Themes	Needed Technology Performance Standards/ Specifications, Test Methods, & Guidelines	Potential Sources
Power & Energy	1. Power Generation (Fuel Cells & Harvesting)	– Fuels cell safety/ruggedness test standards	CSA
	2. Power Sources (Storage)	– Battery safety test standards – Form factor standard – Voltage/current standard	CSA NATO
	3. Power and Data Distribution	– Soldier Connector standards – EMI/EMC standards related to E–textiles	IEEE
	4. Distributed Power Management		

APPENDIX 3

Technical Domains	Themes	Needed Technology Performance Standards/ Specifications, Test Methods, & Guidelines	Potential Sources
Weapons Effects (lethal and non-lethal)	5. Weapon platform (Launching system)	– Interface to soldier system for power/data exchange – Future Standard Targets Definition	NATO NATO/TTCP
	6. Ammunition (lethal and non-lethal)	– Personal Defence Weapon (PDW) ammo standard – Green ammo standard – Wound ballistic test method/standard	
	7. Weapon Mounted Situational Awareness and Targeting Suite	–Power/data rail –Interoperability standard	NATO
Command, Control, Communications, Computing, Intelligence (C4I)	8. Command & Control		
	9. Communication	– Interoperability – Data exchange model? – Cross-domain security	DND
	10. Computing	– Open architecture/software	
	11. Intelligence		
Sensing	12. Personal Sensing (body worn)		
	13. Weapon-mounted Sensing	– Updated performance standards (e.g. updated Johnson criteria for target DRI)	
	14. Crew-Served and Hand-Held Sensing		DND
	15. Unattended Area Sensing	– Micro–UAV technology specifications – Communication/network standards	DND
Survivability Sustainability, & Mobility	16. Operational Clothing and Load Carriage	– E–textile test methods – Enhanced mobility test standard – Updated Army Anthropometry standards – CBRNE Garment performance test standard – Footwear test standard	CGSB DND/NATO/TTCP CGSB
	17. Personal Protection	– Threat levels standards – Torso ballistic injury test method – Head Behind armour injury test method – Head/CNS blast injury test method – -Jaw/face injury test method	NATO CSA CSA/NIJ DND/TSWG CSA
Human and Systems Integration	18. Physical Integration on the Soldier	– Updated maximum load limits – Objective based HF methods	DND (e.g. HIS Handbook)
	19. Perceptual-Cognitive Integration on the Soldier		
	20. System Architecture and Interoperability	– Integration guidelines	DNDDAF

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Glossary

Terms	Definition
Adaptive Dispersed Operations ADO)	The Canadian Forces envisages employing highly adaptive land forces dispersed—in terms of time, space, and purpose—throughout the width and depth of the battle space in order to create and exploit opportunities, control the tempo of operations and overwhelm the adversary's understanding of that battle space. The essence of adaptive dispersed operations (ADO) is the ability to conduct coordinated, interdependent, full-spectrum actions by widely dispersed teams across the moral, physical and informational planes of the battle space, ordered and connected within an operational design created to achieve a desired end-state. The fundamentals of ADO, developed from the manoeuvre principles of find, fix and strike, include: • Developing situations prior to contact. • Manoeuvring to positions of advantage. • Influencing the adversary beyond the range of his weapons with lethal and non-lethal capabilities. • Destroying the enemy, when necessary, with precision and area effects. • Conducting close engagement, when necessary, at the time and place of the soldier's own choosing. • Transitioning between operations without loss of focus or momentum. These fundamentals are applied across the moral, physical and informational planes of the battle space. In short, adaptive dispersed operations call for networked and integrated land manoeuvre forces-supporting and supported by Joint, Interagency, Multinational and Public (JIMP) integrated effects-alternatively dispersing and aggregating over extended distances to identify, influence and defeat full spectrum threats throughout the multidimensional battle space. Dispersion, in this context, is in relation to time, space and purpose.
Alarm	An indication from any source that a chemical, biological, radiological or nuclear attack or release other than attack may have occurred (NATO).
Alert	A warning signal of a real or potential danger, such as an air attack (Commander of the Canadian Army). A warning signal of a real or threatened danger, such as an air attack (NATO). The period of time during which troops stand by in response to an alarm (NATO). Readiness for action, defence or protection (NATO).
Area of operations	A geographical area, within an area of responsibility, assigned to a subordinate commander within which that commander has the authority to plan and conduct tactical operations.
Availability	The probability that an item will perform its intended function at a stated point in time or over a stated period in time; or, the probability that an item is in an operable state at the start of a mission, when the mission is called at a random point in time.
Built-In test (BIT)	An integral capability of the equipment that provides an on-board test capability to detect, diagnose or isolate system failures. The fault detection and, possibly, isolation capability is used for periodic or continuous monitoring of a system's operational health, and for observation and, possibly, diagnosis as a prelude to maintenance action.
Commercial off-the-shelf (COTS)	A product that is commercially available to the general public and which requires no special modification or maintenance over its life cycle.
Communications	The transferring of messages or exchanging of information or ideas, through speech, visual or through electronic means.
Communities of Interest (COI)	A group of users who share common information. Unless otherwise specified, COIs include both voice and data communications. A group of users who only share common data is identified as data COI. A group of users who only share voice communications is identified as voice COI.
Compatibility	The suitability of products, processes or services for use together under specific conditions to fulfil relevant requirements without causing unacceptable interactions.
Compatible	Consistent, able to coexist, (with); mutually tolerant; (of equipment etc.) able to be used in combination.
Complex terrain	Terrain whose features impact on line-of-sight, restrict manoeuvre and separate the soldier from the vehicle. Note: In general, urban areas, jungle, mountains and forests are considered to be complex terrain.

GLOSSARY

Terms	Definition
Component	Serves to form, compose, or make up a unit or whole.
Comprehensive knowledge	The mastery of theory and/or facts which usually require extensive training and/or experience to learn.
Connection	A means that brings together, at a common boundary or interface, two links. In the case of an electrical connection (e.g., audio, radio frequency (RF), power), this is done using a connector (male and female). In the case of an electromagnetic connection, this can be achieved through RF signal, in close quarters by inducting a form of RF.
Connector or electrical connector	A device (hardware or software) that joins together (fastens) two pieces of equipment to allow communication to and from the equipment. In other words, the connectors provide the connection.
CONTACT	An indicator of immediate and significant sighting of or fire from the enemy. Initial message is CONTACT WAIT OUT. All radio communication on a COI ceases until the sender of the CONTACT provides a follow-up report. The second message follows a format for provision of When, Where, Who, How and what the reporting command structure is doing about it.
Data	Information represented in a manner suitable for automatic processing. (NATO)
Dismounted soldier	A dismounted soldier typically is an infantryman within a dismounted rifle section. He/she may be assigned specific tasks as a rifleman, grenadier, machine gunner or commander. Other CF members may also be dismounted soldiers, such as artillery Forward Observation Officers and detachments, Forward Air Control Parties, Medical Assistants etc.
Durability	The ability of an item to survive to the end of its "design life" when it is not subjected to "over-stress" conditions.
Electromagnetic interference	Any electromagnetic disturbance, whether intentional or not, which interrupts, obstructs, or otherwise degrades or limits the effective performance of electronic or electrical equipment.
Electronic textile / electro-textile / E-textile	Electronic textiles (e-textiles) are fabrics that can incorporate active and passive electronic devices from simple conductors to a more complex computing platform. Using yarn with different intrinsic capabilities, etching, deposits of different natures to obtain the computational, sensing or, transmission of information that make smart/intelligent textiles.
Failure	The inability of an item to perform within previously specified limits or an intended function. Typically any event that requires corrective maintenance to restore the system to its normal performance standard. Excludes preventive maintenance, but includes any unscheduled (corrective) maintenance activities found necessary during the scheduled maintenance.
False alarm	An indication of a fault where no fault exists.
False alarm rate	The frequency of false alarms/total number of faults detected.
Fault	Any non-conformance that requires unscheduled maintenance action to correct. Note: A fault may exist without prior failure. A failure is the manifestation of a fault.
H / Hr	The time at which a series of events is predicated on for action. Events are chronologically identified as preceding (H-) or following (H+) a key event at a specific time on a specific day. This is a sliding scale that is not necessarily related to a specific time until all facets of planning have been investigated for their impact on the assigned mission and tasks. E.g., H Hour is the specific time when a helicopter lands on an objective in an airmobile operation and the troops dismount to commence operations on the ground. H Hour occurs on D Day.
Haptic	Of or relating to the sense of touch; tactile.
Integrate	Complete (imperfect thing) by addition of parts; combine (parts) into a whole.
Integrated Soldier System (ISS)	The Integrated Soldier System (ISS) comprises all the ISS variants, accessories and ancillaries, and integrated logistics support.
Land Command Support System (LCSS)	The Land Command Support System is the Command, Control, Communications, Computer, Intelligence, Surveillance and Reconnaissance (C4ISR) system used by the CF to provide Army communications in a theatre of operations. The LCSS is a system of systems and includes communications networks for vehicles, mobile headquarters static headquarters, and soldiers. Additionally, the LCSS provides applications and services to support Army operations. The LCSS operates as a SECRET System High network for Canadian national operations.
Lieutenant (Lt)	A rank within the Canadian Forces. In an Infantry unit normally employed as a Platoon Commander.

GLOSSARY

Terms	Definition
Light Armoured Vehicle (LAV)	The primary Infantry transport vehicle on the battlefield. Its integral turret mounted 25 mm gun provides direct fire support to the section when dismounted. The vehicle requires three individuals to operate independently (driver, gunner and crew commander) and can accommodate an additional seven soldiers riding in the crew compartment.
Link	Any elements in a communications system that transport data or power in and out of a system. This can be in the form of hardware, a cable, wire, or electromagnetic in radio frequency. A link includes the connector(s) if needed.
Linkages	The system of links interconnecting different points of the system. This is represented by the soldier infrastructure with all of its wires, cables or radio frequency channel.
Maintainability	The ability of an item to be retained in, or restored to, a specified condition within a specified period of time, when maintenance is performed under stated conditions by trained personnel using prescribed procedures and resources.
Major	A rank within the CF. Normally employed in an Infantry unit as a coy commander but is also employable as a staff officer.
Military GPS device	A GPS capable of tracking and decoding the encrypted military code.
Mission profile	A time-based description of the events and environments an item experiences from initiation to completion of a specified mission. It identifies the tasks, events, durations, operating conditions and environments for each phase of a mission.
Modular Fighting Rig	The MFR is the basic layer of load carriage. In conjunction with the Improved Environmental Clothing System (IECS), the Integrated Clothing Ensemble (ICE), or temperate/arid combat clothing, the MFR provides load carriage for immediate combat needs for a period of eight hours or less.
Module	A group of sub-modules that are physically or electronically linked.
Operating system	An interface between hardware and user which is responsible for the management and coordination of activities and the sharing of the resources of a computer, that acts as a host for computing applications run on the machine.
Power usage policy	A set of rules activated by the power management processes with the overall goal of optimizing the power usage of the system. The policies specify which components, devices or subsystems need to change operating state (e.g., active, sleep, and hibernation) to minimize power usage. Establishing power management policies is a challenge of optimization under constraint.
Reliability	The ability of an item to perform its intended function for a specified interval under stated conditions.
Rucksack	The rucksack may be worn with the tactical vest (TV). The Small Pack System can be secured to the rucksack . In conjunction with the IECS, temperate combat clothing and the TV the rucksack sustains a soldier in combat for a period of 48 hours. The rucksack's inherent additional carriage will allow individual sustainment to be extended to 72 hours.
Section	Light Infantry Battalion sections are made up of eight personnel (1 Sergeant Section Commander, 1 Master Corporal Section 2 i/c and six (6) Corporals/Privates). Mechanized Infantry Battalion sections are made up of ten personnel (1 Sergent Section Commander, 1 Master Corporal Section 2 i/c and eight (8) Corporals/Privates). The section is mounted in a Light Armoured Vehicle-LAV III vehicle. Three persons must stay with the vehicle in order for it to remain operational. Seven soldiers are therefore available for operations away from the vehicle.
Situational awareness (SA)	The combined knowledge of friendly forces, hostile forces, the environment and other aspects of the battle space.
Skilled	The level of proficiency necessary to independently and safely perform duties and tasks.
Soldier system	Everything worn, carried, and consumed for individual use on the battlefield in a tactical environment.
State of Health (SOH)	A figure of merit that reflects the general condition of a battery, a battery pack or sometimes a cell, and its ability to deliver the specified performance compared with its initial specified and measured conditions at manufacturing. The units of SOH are percent points (100% = the battery's condition matches the battery's specifications). SOH takes into account such factors as charge acceptance, internal resistance, voltage and self-discharge, etc. During the life of a battery, the performance or SOH tends to deteriorate gradually due to irremediable physical and chemical modifications taking place due to storage conditions, usage and age until at some point the battery is no longer usable.
Sub-system	A group of modules that contribute to given functions and/or capabilities.

GLOSSARY

Terms	Definition
System element	A member of a set of elements that constitutes a system. NOTE: A system element is a discrete part of a system that can be implemented to fulfil specified requirements. A system element can be hardware, software, data, humans, processes (e.g., processes for providing service to users), procedures (e.g., operator instructions), facilities, or materials.
Target /target area	A geographical area, complex, installation, specific unit, individual or group planned for engagement by fires, information operations or a combination of both, for the purposes of capture, destruction, suppression, neutralization or persuasion. In sum, the object of a particular action.
Training program	All contractor and Department of National Defence work activities and deliverables associated with the analysis, design, development, conduct, and evaluation of individual training and education.
Troop	A term normally used in Armoured or Engineer units and is synonymous with Pl in a structure sense.
User	Person wearing any variant of the Integrated Soldier System Suite.
Verification	Confirmation, through the provision of objective evidence, that specified requirements have been fulfilled
Warning signal	A function signal which operates an audible or visual calling device with a view to attracting attention (NATO).
Weapons system	The weapon and related technologies used by the dismounted soldier. This includes the weapons platform, sighting and fire control system and weapon ammunition. It also includes the operator/user, sensors and other ancillaries that could be part of the weapon or the sighting system.
ZEFRA	A notional country used in the ISSP Use—Case Dismounted Platoon Patrol.