DND/NSERC Discovery Grant Supplement
Defence and Security Target Areas

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I. Autonomous Systems

Context

This research challenge seeks to explore, enhance, develop, and deliver innovative autonomous system solutions and technologies to a vast range of applications providing reliable functionalities and decision making abilities within complex environments in the context of defence, safety and security. Autonomous systems include the different levels of autonomy that are part of the continuum of interactions between environment, humans and machines (from semi to full automation), as well as the various combinations of human-system autonomy that could be required throughout mission duration. The focus is primarily on operational effectiveness and the optimization of capabilities through automation rather than developing robotic platforms.

Research Topics

1. Establishing Trust in Autonomous Intelligent Systems

Projects under this research topic should focus on the development and integration of innovative technologies and methodologies to improve decision making abilities of automated intelligent systems (autonomous/semi-autonomous) in defence and security missions, including understanding and interpreting system and users' intentions (friendly as well as adversary). Research themes could include, but are not limited to, artificial intelligence, machine learning, machine perception, context-awareness, system agility (including adaptiveness, robustness, and resilience), manned-unmanned teaming, as well as identifying the effects of automation on human performance (such as complacency, automation bias, decreased situation awareness) and the extent to which artificial intelligence can mimic human decision making. The objective is to establish trust and confidence in fully or semi-autonomous intelligent systems, and to allow for adequate insight into how autonomous intelligent systems sense and monitor changing environments**,** detect and interpret changes, evaluate and select among courses of action, and respond to expected and unexpected/unpredictable circumstances while dealing with system malfunctions or total failure.

2. Autonomy in Complex and Contested Environments

Projects under this research topic should focus on the development and integration of technologies to improve autonomous systems abilities to deal with unexpected events following from small to significant changes in the situation and with tasks that challenge their sensing, modeling, planning, or movement envelope. Research objectives could include, but are not limited to achieving situational awareness and understanding in unstructured and non-cooperative environments; enabling dynamic and real-time automated decision making under poor environmental conditions; representing and managing complex situations. Complex and contested environments will require smart heterogeneous sensing and a robust anomaly and obstacle detection to ensure the identification of critical elements of the situation with high confidence level; the consideration and management of a diversity of actor's goals (man/machine, simple/complicated/complex) to achieve dynamic planning and execution management of the mission. It will also imply strong time constraints to go through the observe-detect-orient-decide-act process, requiring a high degree of freedom from the different actors (little supervision). The determination of the right level of automation and/or the right allocation of tasks between the actors (human and non-human) for different situations, environments, contexts will be key for the mission success.

3. Countering Autonomous Vehicles (AVs)

AVs (aerial, surface or submarine) or drones equipped with advanced technology can exhibit sophisticated adaptive behaviors, involving a dynamic generation of goals and plans in reaction to changes in the environment. The capability of AVs to adapt their behavior is an important factor for their detection, tracking, assessment of intent, and neutralization. The complexity of recognizing and countering them is significantly increased when they are part of a group.

3.1 Detection and tracking of AVs: Projects under this research topic should focus on investigations of active, passive and other methods of detection of autonomous vehicles, including understanding how vehicle design, configuration, materials composition and operating state and environment affect their detectability.

3.2 Recognizing AVs intent, plans, and activities: Projects under this research topic should focus on tools and techniques to recognize the purpose and mission (e.g., scientific, industrial, or military) of detected AVs, and the targeted plans and activities carried out to achieve their mission. This work addresses the case of single AV as well as groups of and/or swarms of AVs that work collaboratively to achieve their goal.

3.3 Responding to AVs: Projects under this research topic should focus on tools and techniques to plan and coordinate a combination of measure and countermeasure responses to neutralize malicious AVs and AVs whose mission interferes negatively with own mission. The measures and countermeasures used could include, but are not limited to deployment of own autonomous systems.

4. Automation for Optimized Human Capabilities

Projects under this research topic should focus on developing and implementing state-of-the art technologies and methodologies involving the use of robots, autonomous and/or semi-autonomous systems, and teleoperation to optimize human capabilities and performance. For example, enable human operators to sense and act at long range distances and to control several systems concurrently (e.g. as in a swarm configuration). Challenges could include, but are not limited to, human factors of robotics; unmanned systems; vision enhancement; adaptive interface and collaboration; brain-machine interface; haptic interface; virtual and augmented reality; telepresence and latency.

II. Information Management and Data Science for Decision Making

Context

This interdisciplinary research challenge focuses on developing innovative solutions that are primarily concerned with the generation, packaging, analysis, manipulation, classification, storage, retrieval, movement/communication, protection, and the use of data and information for efficient decision making within secure and reliable environments and with assurance of reduced cognitive and systems load.

Research Topics

1. Efficient Management of Distributed Heterogeneous Data/Information (including Internet of Things, open sources and social media)

Projects under this research topic should focus on developing methodologies, techniques and tools to efficiently and effectively collect, manage and store data and information from heterogeneous sources, both from physics-based sensors, including Internet of Things, and human generated sources including open sources and social media. Research themes could include, but are not limited to, data representation research (e.g. development of efficient data frameworks enabling the gathering, codification and storage of multi-modal sensor data for subsequent fusion and data analytics); novel techniques to manage data/information quality for timely, valuable, accurate, reliable and trustworthy decision support; improved information management and sharing (e.g. novel information extraction, filtering, and integration techniques to reduce information overload and maximize onboard processing); concepts and solutions supporting efficient management of distributed heterogeneous and multi-dimensional data, beyond current big data tools; and human-computer interaction techniques supporting real-time information retrieval and question-answering to optimize information exploitation for improved actionable intelligence, reasoning, planning, collaborating, and decision-making.

2. Information Management for Platform Availability and Sustainability

Advances in information management are required to enable informed evidence-based decisions for both real-time and longer term system operational and management decisions of platforms, while moving away from paper based approaches to record-keeping. Some of the inherent challenges to Canadian Armed Forces platform availability and sustainability are: what modelling environment to use; what data to collect and how to collect it; how to efficiently populate the model with the data (telemetry or other means, bearing in mind potential limitations due to operational security); and how to effectively analyze the data and present meaningful results and advice to the user. For large and complex platforms (e.g., naval vessels), the solution to this challenge should inform and enable: operational decisions with real-time platform system capability data and advice; platform maintenance decisions with a timely and cost-effective evidence-based planning capability that improves platform availability and sustainability; platform employment decisions with the current capabilities of the platforms to effectively and safely undertake specific missions; and end-of-life decisions with actual platform system materiel states.

3. Information Fusion in Detection, Recognition, and Classification Processes

Techniques and algorithms are required for integrating and fusing data from sensors (physics-based and human) and media, and extracting the contextual and semantic information from it to provide actionable intelligence for the information consumer. The new techniques will be designed to reduce uncertainty in the detection, recognition and classification processes to establish correspondence/correlation between objects, and to provide semantic descriptions of objects to users to reduce information overload.

4. Managing Uncertainty in the Physical Environment

Techniques are required to quantify uncertainty related to the physical environment (for example uncertainty associated with underwater acoustic propagation and reverberation due to uncertain knowledge of the physical environmental such as oceanography, seabed, bathymetry,…), to translate that uncertainty into risk and performance metrics that will be used to evaluate prospective courses of action in decision-making, to represent and communicate uncertainty, and to reduce the uncertainty (i.e., in situ sampling strategies, data assimilation, and access to open source data).

5. Integrated Analysis of Quantitative and Qualitative Information from Large Data Sets

Projects under this research challenge should focus on the development and integration of methodologies, tools and technologies that will enable the transition from data to information to knowledge. These analytical methods and tools need to be employable to perform integrated quantitative and qualitative analysis on heterogeneous data sets including the combination of quantitative and qualitative factors in a single analysis/visualization process. One of the key issues to overcome is the heterogeneity of information and data sets such as human resources, finance, real property, etc. However, the analysis of data, such as fusion, search for patterns and trends, data aggregation or disaggregation is only one piece of the puzzle. In order to make it usable to directly support decision-making; further analytical methods, methodologies, and techniques (including but not limited to machine learning and artificial intelligence) need to be developed and implemented. This will enable consolidation of information obtained from the initial analysis and aggregation of the original data sets with further contextual information (often from other sources). This may address potential implications of missing, uncertain, or lost information, and will lead to conversion of information into actionable knowledge. Novel methods and techniques are also required for integrated content-based multimedia analytics, in particular from textual and video sources.

III. Decision Making Enhancement in a Distributed Environment

Projects under this research challenge should focus on innovative systems, technologies, methodologies and tools that effectively and affordably optimize human decision support and decision making within collaborative and/or distributed environments, reducing military personnel cognitive burden, and improving decision-making processes for enhanced security and defence operations.

1. Minimizing Information Overload in Networked Operations

Information overload occurs when the amount of input to a system exceeds its processing capacity. Because humans have fairly limited cognitive processing capacity, when information overload occurs, the consequence is likely to be a reduction and degradation in decision quality. Projects under this research topic should focus on the exploration and development of novel strategies, methodologies, techniques and tools to minimize information overload in networked operations and to prevent or reduce decision quality degradation. This challenge, particularly acute in military network-centric operations, responds to the need for increased complex operational effectiveness, enhanced and integrated decision support and near real-time message filtering; and offer the potential for enhancing the development of big data, data analytics and data visualization and analysis tools.

Research themes could include, but are not limited to, applying techniques in artificial intelligence and machine learning to ease the burden on Sonar Operators by characterizing the noise generating source, be it natural (e.g., whales, earthquakes,..), anthropogenic (e.g., ships, oil exploration, military,…) and/or with as much specificity as possible (mammal species, vessel class, vessel name,…); and employing approaches that involve pattern recognition and classification of processed representations of sonar data (e.g., time-frequency spectra of the original time series) that reveal identifying characteristics.

2. Computation for Enhanced Cognitive Performance

Projects under this research topic should focus on enhancing human sensory, mnemonic, and cognitive performance, including the smart use of compact computational devices. Ease of use is an important consideration given the proximal or distal nature of the device or devices. Research themes could include, but are not limited to ubiquitous pervasive computing (ubicomp), portable schemes for augmented reality, enhanced wayfinding, enhanced vision (including extension of the perceivable spectrum), the human factors of large database visualization, and tools to enhance effectiveness in, and interoperability with, different cultures.

3. Collaborative Mission Planning and Decision Making in Distributed Environments

Projects under this research topic should explore concepts and prototype systems for the presentation and consumption of information to support mission planning in a collaborative and potentially decentralized and distributed/dispersed environment. Research themes could include, but are not limited to, personal and shared workspaces (e.g., knowledge walls, augmented or virtual reality,…); methods to visualize combined risks and associated uncertainties; methods for the navigation and display of multiple information layers; concepts for customizable or adaptable information environments; studies on information comprehension; and methods, standards and technologies for effectively inputting, collaborating, and communicating. It should also cover novel approaches to improve the identification of potential actions in complex contexts as well as the integration of courses of action considering different dimensions or perspectives.

Research themes could include, but are not limited to, situational awareness enabling rapid decision-making such as increasing the ability of military and civilian first-responders to make rapid and complex decisions while operating in a decentralized fashion in small teams within their fields of operations. Technological developments in mobile and telecommunications devices will provide increasing depth of information for situational awareness and rapid decision-making. Projects could potentially examine the minimum depth and latency of situational awareness required to enable rapid and effective decision making for such small teams operating on the move.

4. Measuring Decision Quality / Improvement in Complex Systems

Projects under this research topic should develop or identify metrics for measuring decision quality, as well as methods for assessing improvements (changes) in performance in complex systems undergoing Revolutionary Change (i.e., C2 structure and systems being redesigned). Research themes could include, but are not limited to, approaches involving human-in-the-loop (HIL) experimentation and exercise analysis to evaluate new concepts for the assessment of cognitive decision making (CDM) and decision support systems; methods for system-embedded human factors measurements for continuous data capture and analysis that informs future system iterations. It should also address the impact of uncertainty and its representation on CDM; human-computer teams and automation to support CDM; implications of new information (data sources or model outputs) on CDM; and effectiveness of predictive analytics to mitigate uncertainty in CDM.

IV. Advanced Sensing

Context

This research challenge seeks to explore, enhance, develop, and deploy innovative, small footprint, low-power, cost effective, robust, and potentially autonomous sensing solutions of direct interest to defence and security applications within traditional and complex environments.

Research Topics

1. Electro-Optical (EO) Nano-sensors

Projects under this research topic should focus on developing electro-optical (EO) sensors that extend present limits associated with sensitivities, response time, size, cooling, power consumption while capable of being tailored to wide or multiple wide spectral bands from the UV up to the IR. Research themes could include, but are not limited to the development of EO nanosensors that are of interest for defence applications and are usually structured solid materials capable of light-matter interactions on wavelength and subwavelength scales; nanosensors metamaterials having nano-scale structures capable of polarizing, filtering, tuning or focusing the light to enhance the detection signal–to-noise ratio in selected spectral bands of interest.

2. Quantum Sensing / Wide Dynamic Range, Ultra-fast / Ultra-sensitive 2D Transient Detector Array

Projects under this research topic should focus on developing new Lidar detector technology capable of performing true photon counting of spatially/spectrally distributed weak signals while having the size, weight, cooling requirements and power consumption facilitating its integration in Lidar Systems. Research themes could include, but are not limited to designing/developing detector arrays approaching/surpassing these characteristics for the UV/VIS band (350-700 nm) with quantum efficiency of 30% or more and a photon false detection rate of less than 500 kHz for the whole detector array. Subsequent R&D effort should focus on transitioning comparable sensing capabilities toward the SWIR band (mainly around 1.5-1.6 µm). Applications could include, but are not limited to, short-range cloud mapping with Unmanned Aerial Systems.

3. Active Optical Sensing

Projects under this research topic should focus on developing active detection and/or identification of targets of interest to defence and security. Research themes could include, but are not limited to: the use of active laser source, whose return signal is analyzed to extract useful information about the target while discriminating it from its background; the development of laser systems for standoff laser-based sensing and characterization of a target object or the propagation medium; the use of nonlinear spectroscopy, or sources designed to allow spectral, temporal, or amplitude analysis of the return signal; the use of laser as a carrier wave in an acousto-optic or microwave photonic approach; the use of such systems in the detection and identification of explosives and energetic materials, chemical composition of targets, characterization of atmospheric or aquatic propagation as well as the detection and identification of objects in a cluttered environment.

4. Compressive Sensing (CS)

Projects under this research topic should focus on combining compressive sensing, computational imaging and light-field imaging paradigms to achieve revolutionary enhancement of defence and security related imaging and sensing capacity with increased systems resolution, larger field of view, and imaging in complex environment (e.g. imaging around the corner). Research themes could include, but are not limited to, the use of electro-optical and infrared (EO/IR) systems with active, passive, multiband and hyperspectral sensors for reduced CS sensed signal size, resulting in significantly smaller, cheaper, and lower bandwidth sensor devices with increased universality, security, and robustness with progressivity, and scalability; non-line-of-sight imaging; computational imaging; and the development of advanced image reconstruction codes for CS optimization techniques development.

5. Chemical-Biological-Radiological (CBR) Sensing

Projects under this research challenge should focus on the development and integration of innovative technologies and methodologies to improve decision making abilities using advanced sensing in defence and security missions. Research themes could include, but are not limited to: Diagnostics: novel methods for point-of-care diagnostics related to defence-related Chemical Biological (CB) threats; Drug discovery: novel methods in chemistry to rapidly repurpose existing drugs to identify and counter CB threat agents; Novel sensors to address in real-time CBR releases in the atmosphere; Sensor and sensor system net-centric integration for the rapid detection and monitoring of CBR releases in the atmosphere in support of decision making; further understanding of fundamental processes *and biomarkers* of traumatic brain injury and Post-Traumatic Stress Disorder(PTSD.)

6. Long and Medium-Range Detection and Identification of Underwater Explosions

Projects under this topic should contribute to the understanding of, and ability to detect, locate, and identify the source of underwater blast waves propagating in environments where surface and seabed reflections can complicate the signal. Two challenges in this area are: 1) to develop a model of the near-to-mid field region where the blast wave undergoes a transition from a typical positive-phase pressure wave to an acoustic wave, 2) to use not only the blast wave signal, but also subsequent bubble pulse oscillations to further resolve the explosive source characteristics. A better understanding of how environmental factors such as bathymetry, seabed composition, surface waves, surface ice, and even temperature variations in the water column can affect the wave propagation in the transition region and can lead to improved discrimination and identification of underwater explosive sources. In addition to elucidating the propagation phenomena, the development of new underwater sensor array technology with extremely high dynamic range, and signal processing techniques can also provide a means of improving this unique type of signal detection.

V. Resilient Networked Systems

Context

Projects under this research theme focus on an opportunity for innovation in technologies, methodologies, architectures, tools and processes addressing resilient, self-aware, self-healing, energy efficient, secure and reliable cyber hardware/software networked systems. Topics of interest include: trust-worthy, autonomous, self-aware, adaptive, fault-tolerant, and intrusion sensitive methodologies for wireless radio and sensor networks and highly networked systems; efficient energy conservation in highly congested, faulty, and scalable networks; operations in spectral denied environment; and development and deployment of low-cost platform early warning systems within traditional and harsh environments including space.

Research Topics

1. Intrinsic Resiliency to Cyber-Attack

Projects under this research topic should focus on the development and integration of technologies to improve cyberphysical systems resiliency to attack to ensure the safe and trustworthy operation of software-dependent systems. The research challenges could include, but are not limited to, novel design/architectural/engineering approaches to build cyber robustness and resiliency from the outset; approaches to understand how to construct secure and trustworthy systems; threat comprehension comprising an understanding of effects on the entire system as well as subcomponents; system resilience via techniques to mitigate the effects of a cyber-attack on core system functions; and system robustness via techniques to reduce available vectors of attack through software hardening and reliability testing against attack.

2. Operating in a Spectrum-Denied Environment

Projects under this research topic should focus on developing new techniques and technologies that would enable robust military capabilities that currently require the use of the electromagnetic spectrum (such as communications, command and control, threat detection, target detection, identification and localization, PNT (positioning, navigation, timing), etc.) to continue to be effective in the face of an increasingly congested, contested and competitive electromagnetic (EM) spectrum. Research themes could include, but are not limited to:

addressing the accessibility and usage of the EM spectrum that becomes congested by the ever-increasing number of commercial and private users, and their increasing bandwidth requirements; ensuring military operational spectrum operations in the presence of jamming; addressing spectrum “ownership” that is also highly competitive in the sense that ever larger bandwidth allocations are being reserved for specific commercial or public use; and focusing on vulnerabilities of systems that depend on the use of spectrum, such as tactical radios, satellite communication links, Radar and GPS. Research themes should also include new technologies and approaches allowing various military functions to be performed with the use of significantly less spectrum or preferably without the use of EM transmission/reception at all, or with the use of spectrum without interfering with or being interfered by other users.

3. Space Domain Awareness

Projects under this research topic should focus on developing new technologies that enable space domain awareness. Awareness may be achieved through ground or space–based detection, tracking, and if possible identification and characterization of objects in space considering signatures in both the RF and non-RF portions of the EM spectrum, particularly in or near earth orbit, as well as characterizing the physical environment itself. Research themes could include, but are not limited to, characterization of natural/man-made, friendly/adversarial space assets as well as space debris and naturally occurring objects such as near-earth asteroids; identification of potential space related threats for enhanced capability and space assets management. Research themes could also include, but are not limited to, space operations vulnerabilities and resiliency to space hazards (space weather, debris, …), space assets vulnerability and protection against adversarial intent (cyber, kinetic, electromagnetic, …) and the safe and secure transfer of information in this environment.

VI. Explosive Hazard Avoidance

Context

There exist a vast array of optical and laser spectroscopic techniques for chemical trace detection that show potential for use as means of positively detecting trace quantities of vapours or particulate associated with explosive hazard, yet there are no commercially available instruments suitable for general-purpose, stand-off explosive detection within a mobile platform in a Route Clearance scenario. Projects under this research theme focus on the development and deployment of explosive detection systems with desired sensitivity and detection ranges necessary for general military use in the field environments, in particular the detection of observable trace explosive contamination, that may be on the order of micro to nanograms (µg–ng), and may be representing residues transferred in the manufacture, storage, or handling of explosives.

1. Laser-Based Stand-Off Explosives Detection

Projects under this research topic should focus on the development of advanced active optical spectroscopy methods, such as non-linear Raman, highly non-linear techniques, and other novel light sources and detection strategies, that would enable practical demonstration of the long range, high sensitivity, high specificity requirements for military stand-off explosive hazard detection.

2. Frequency Agile Compact High Powered Radio-Frequency (RF) Sources

Projects under this research topic should focus on the development of a frequency agile compact high powered RF source that can be installed on existing military vehicles without compromising the vehicles' existing functions or integrity. The research challenges could include, but are not limited to, the use of radio-frequency directed energy weapons (RF DEW) that has been shown to be effective in causing some UxVs to malfunction, and some improvised explosive devices to pre-trigger; fielding practical RF DEW systems to address the lack of a frequency agile compact high powered RF source; and exploration of vehicle-delivered explosive devices that have become more likely given the rapid commercialization of uninhabited air and ground vehicle systems (UxVs).

3. Highly Directional and Compact Harmonic Radar Antenna

Projects under this research topic should focus on the development of compact directional antennas that are capable of operating on multiple transmit and receive frequencies with circular polarized electromagnetic energy. The research challenges could include, but are not limited to, development of devices that are compact and light weight for implementation in a handheld platform with the possibility of being used as UxV payload for standoff explosive hazard avoidance; use of advanced harmonic radar technologies in the detection of explosive hazards;

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addressing the limiting factors to the performance of harmonic radar (frequency, polarization dependence) in the detection of the explosive hazards.

VII. Next Generation Systems, Materials, and Signatures

Context

The research challenge seeks to develop next generation materials, cutting-edge experimental techniques and theoretical modeling tools to increase the understanding and development of next generation ballistic resistant and protective materials. The research could also focus on the design and development of next-generation systems and materials targeting a wide range of functional and structural applications underpinning current and future challenges in defence and security.

Research Topics

1. Toughened Transparent Materials against Blast, Shock and Impact Loading

Projects under this research topic should focus on the development and integration of materials and technologies to improve the performance of transparent systems (monolithic or multi-layers) against high velocity blast, shock and impact loading in applications such as vehicles, face shields and security glass. These include, but are not limited to, the design, development and fabrication of advanced engineering materials and innovative technologies/treatments/coatings to enhance physical/mechanical characteristics while maintaining or improving the transparency of the material system. Factors that could be considered may also include light weight, through-thickness performance, resistance against degradation of performance and/or transparency due to environmental factors, and performance after multiple, repeated impacts.

2. Numerical Simulation and In-Situ Measurements of High Velocity Impact Phenomena

Projects under this research topic should focus on the development of advanced tools and numerical models to better understand and predict the behavior of materials and systems under high-velocity impact loading. This will include, but not be limited to, the development of experimental techniques, in-situ measurement tools; and numerical modeling to accurately simulate the behavior of materials under high velocity penetration. Models should also apply to different materials, such as Rolled Homogenous Armour (RHA) steel, brittle materials (ceramics, glasses), and fibre-reinforced composites. Considerations should be given to multi-hit scenarios, and the characterization of variables such as Depth of Penetration (DOP), break up time, particles shape and velocity.

3. Effect of Sea State and Ship Motions on Ship Signatures

Projects under this research topic should focus on advancing the knowledge and understanding, and the development and validation of modelling and simulation tools to predict the effect of various factors, such as ship speed, heading, sea state and ship motions on a vessel's signatures (acoustic, infra- red, magnetic, radar cross-section). This will include, but not be limited to, the development of predictive tools for determining the radiated noise due to propeller cavitation, bow slamming, and other sources of ship noise, all while the ship is sailing in moderate to heavy seas that produce ambient noise in the undersea environment and possibly cause the propeller to leave the water; the consideration of change in vessel profile and infra-red and magnetic signature due to motion and surrounding sea state environment; and the potential coupling of several physics models – linear or nonlinear seakeeping panel methods, propeller performance prediction software and propeller cavitation prediction software, and structural noise predictions. A specific challenge related to acoustic noise is the requirement for a numerical capability to predict the structural vibrations of naval platforms (including external fluid loads) in the so-called mid-frequency range – above the existing nominal upper range of the finite element method and below the existing nominal range of energy-based methods.

4. Towards Attaining Zero Ship Emissions in the Arctic

Projects under this research topic should focus on achieving a zero pollution footprint such as for vessels operating in the Arctic environment through the elimination of engine exhaust emissions, the reduction of the risk of hull damage and effluent leakage, and the means to dispose waste on-board without discharge. This may include the development of numerical models for steel rupture under dynamic ice loads and shipboard sensors that can detect and characterize sea ice and glacial ice, including ice coverage, size and thickness. While this challenge is relevant to all types of vessels, the RCN will be operating the Arctic Offshore Patrol Vessel (AOPV) in the Arctic environment where strict pollution regulations are in place. A further aspect of the challenge are techniques to cleanse vessel components and systems (e.g., hull, cooling system, intake valves...) prior to entering the Arctic from other environments. (For reference, the AOPV is diesel electric with two 4.5 propulsion MW (induction) motors, and four 3.6 MVA generators).

5. Mitigating the Impact of Corrosion on Naval Vessels

Projects under this challenge should focus on corrosion protection measures, designs that prevent corrosion, and corrosion detection methods, the latter including the early detection of corrosion in remote or difficult to reach places and under tiled or coated surfaces. This also includes the development of numerical tools that can predict corrosion location and severity over time for specific platform designs, including the influence of coatings and other corrosion prevention methods, and maintenance and repair strategies. Despite decades of research and advances such as cathodic protection, the Royal Canadian Navy (RCN) has stated that their number one problem in sustainment of their Fleet is corrosion; it causes costly repairs and operational delays. As all current and future RCN vessels are constructed of steel, for this challenge it must be assumed that this is the material that is subject to corrosion.

6. Next Generation High Functionality, Low Burden Protective Materials for "Extreme-Performance" CB Defence Protective Ensembles

Projects under this research topic should focus on advancing the development of "smart" materials that will alter their state in response to a trigger from various external stimuli, for example, toxic chemical/biological/radiological challenges to the body, changes in the external environment, variations in physiological set-points or activity related demands for more functionality. Such materials, when incorporated into wearable systems, should significantly enhance the protection (inhalation and percutaneous), physiological management and task performance/ease of wear (single layer materials versus multi-layer) for users in a chemical/biological/radiological hazard environment. Consideration should be given to smart materials in the technology areas of selective permeability, changeable porosity, reactive constituents, high surface area sorbents, phase change and super-repellent coatings (non-C8 fluoro-chemistry).

7. Quantum Invisible Military Protection Materials

Quantum effects related to atom delocalization and zero-point energy (Casimir effect) in some materials can be significantly enhanced regarding the response of materials to dynamic blast and shock loading. These enhanced quantum effects generally associated with ultrafast mechanical energy absorption through changes of internal chemical bonds, making materials with exotic and often incredible mechanical properties to withstand dynamic blast and shock without failure. This may lead to quantum military protection materials against thermomechanical extremes such as blast, shock and impact. Combined with the reorientation arrangements of molecular long axes to control light paths, the gradations of refraction indexes from positive to negative ranges create invisible-cloaking for quantum invisible military protection materials. Advanced simulations using quantum solid-state chemistry computation are required to capture this research challenge on incorporating material complexity into quantum effects of ultrafast energy absorption and leveraging quantum knowledge derived from simulations and experiments to the engineering design and experimental synthesis of strong lightweight quantum invisible military protection materials.