DEFENCE R&D DÉFENSE

# TECHNOLOGY INVESTMENT STRATEGY 2002

## For The Evolving Global Security Environment

Defence Research and Development Canada
Recherche et développement pour la défense Canada

Canada

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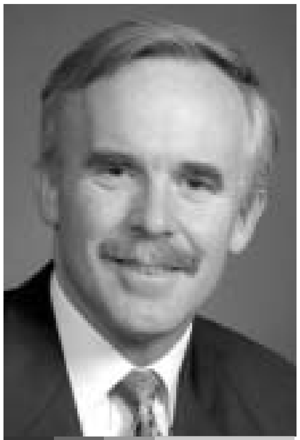
# A MESSAGE FROM THE CEO



I am pleased to present an update of the Technology Investment Strategy (TIS) for the evolving security environment. The previous Strategy published three years ago did not have the full benefit of developments resulting from Defence Strategy 2020 and Strategic Capability Planning. Furthermore, we are in a better position to take into account the implications of the Revolution in Military Affairs (RMA) and the move towards a Concept Development and Experimentation (CDE) capability for the Canadian Forces (CF).

Defence Research and Development Canada (DRDC) is focused on the R&D capabilities in critical technology areas of importance to future CF operations. Our TIS is based on 21 R&D Activities that span the defence technology spectrum, including sensors and information systems, combat systems and human systems, as well as modelling and simulation and systems concepts. The updated TIS better reflects technologies that are integral to the RMA, including information technology and sensors, as well as projected advancements in areas such as nanotechnology, biotechnology, material sciences and power sources.

The TIS outlines the R&D required to develop the Science and Technology (S&T) capacity needed for future defence and national security. It represents a strategy for the R&D that we will do in-house. We will draw on industry, the universities, other national partners and our allies to leverage the additional capabilities we need to carry out a defence R&D program based on Service Level Agreements with our Department of National Defence (DND)/ CF Client Groups. We will provide the capabilities required by the CF in new and innovative ways and strive to make a major contribution to enhanced Canadian security and the operational effectiveness of the CF in a growingly unpredictable world.

Our commitment will continue to be to our CF client as a responsive, innovative and efficient member of the defence team.

**L. J. Leggat**
*Chief Executive Officer and*
*Assistant Deputy Minister*
*(Science & Technology)*

# EXECUTIVE SUMMARY

Three years ago, the Department of National Defence published a Technology Investment Strategy (TIS) outlining the Research and Development (R&D) required to develop the S&T capacity required for future defence and national security. The TIS took into account the strategic direction provided by Defence Strategy 2020 and the new approach of Strategic Capability Planning. Now changes in the security environment and refined departmental strategic planning have advanced the need to revisit and update the Strategy.

The TIS is based on 21 R&D Activities that span the defence technology spectrum. In this document, the rationale for each Activity is described in terms of Technology Trends, Threats and Opportunities. Each Activity is then further described in terms of a number of Strategic Objectives that outline the research and outcomes projected to result from the research. Those R&D Activities, as well as the Strategic Objectives for each Activity are listed below.

**Command and Control Information Systems (C2IS) Performance and Experimentation**

(A) Harmonization of distributed simulations for interoperability with C2IS

(B) C2IS synthetic environments and modelling to facilitate experimentation

(C) Metrics and experimentation for optimum C2IS

**Information and Knowledge Management (IKM)**

(A) Advanced techniques and architectures for more effective sharing of information and knowledge

(B) Knowledge modelling, discovery and creation for improved situational awareness

(C) Visualization and geo-spatial systems for enhanced understanding of spatial- and time-related knowledge

**Communications**

(A) Military bandwidth on demand

(B) Robust, reliable, secure, fixed and mobile multimedia communications capability for the warfighter

(C) Intelligent management of network resources for the integrated battlefield

(D) Communications enablers for distributed systems

**Human Factors Engineering (HFE) and Decision Support Systems (DSS)**

(A) Modelling and Simulations (M&S) to determine the most effective roles for humans in future systems

(B) Human-computer interaction to improve situational awareness

(C) Real-time situation analysis automation technologies for decision-making

(D) Computer-based decision aids and process modelling for decision support systems

(E) Intelligent collaborative planning for integrated force management and execution

(F) Human Systems Integration (HSI) tools for systems design and project development

**Command Effectiveness and Behaviour**

(A) Methodology for improving leadership development skills

(B) Problem solving, bounded reasoning and reasoning under uncertainty for training and informed decision-making

(C) Strategies for command stress and coping

(D) Solutions to enhance team performance

**Autonomous Intelligent Systems (AIS)**

(A) Methods for AIS to perceive their environment

(B) Methods for AIS to interact with their environment

(C) Information sharing among distributed, networked, intelligent systems for collective intelligence, cooperation and collaboration

**Sensing (Air and Surface)**

(A) Acquiring and exploiting environmental knowledge for target discrimination and recognition

(B) New and improved sensing technologies for detection, tracking and classification of difficult targets

(C) Advanced techniques and tools for automated target and feature recognition

(D) Optimal techniques and architectures for multifunction sensors and multisensor systems

**Underwater Sensing and Countermeasures**

(A) Affordable distributed sensors and actuators for future Underwater Warfare (UWW) systems

(B) Sensing and modelling of ocean and seabed properties for future (UWW) operations

(C) Data fusion and resource management for timely provision of the underwater warfare tactical picture

**Space Systems**

(A) Development of processing and exploitation techniques and applications for space-derived intelligence, surveillance and reconnaissance data

(B) M&S of Space Systems for concept development, evaluation and analysis

(C) Multi-static/multi-functional radar electro-optical/(EO) and hyper-spectral sensing for intelligence, surveillance, targeting and reconnaissance

(D) Advanced materials and power sources for the space environment

(E) Concepts, techniques and algorithms for the surveillance of space

**Electro-Optical (EO) Warfare**

(A) Integrated threat warning for survivability in digital battlespace

(B) Soft-kill laser systems to counter EO-IR guided missiles

(C) Plug & Fight architecture for mission configurable, self-defence systems

**Radio Frequency (RF) Electronic Warfare (EW)**

(A) Development of EW R&D priorities to counter emerging threats

(B) Development of technologies and techniques to improve EW system capabilities

(C) Development of systems for automated situation interrogation, assessment and response for effective operations in the future EW environment

**Network Information Operations (IO)**

(A) Protection and assurance of information for dynamic coalition networks

(B) Real-time situation assessment for Network IO

(C) Automated network discovery, assessment and tool development for network exploitation

**Precision Weapons**

(A) Propulsion technologies for optimum energy management of low observable air vehicle systems

(B) Delivery control techniques and systems for improved weapon system performance

(C) Target acquisition and discrimination for improved weapon effectiveness against time critical targets

(D) M&S to improve the effectiveness of weapons system platforms

**Weapons Performance and Countermeasures**

(A) Novel materials and energy release processes to enhance the performance of weapons

(B) Concepts for developing and deploying increased lethality and non-lethal weapons systems

(C) Countermeasures for improved survivability

(D) Sustainable training and technologies to maintain availability of DND training facilities

**Emerging Materials and Biotechnology**

(A) Functional materials for transducers, actuators and smart structures

(B) Substitution of conventional materials for improved mechanical and chemical performance of materials

(C) Synthesis of materials by molecular manufacturing techniques for high performance military applications:

(D) Biotechnology for the environmental protection of CF personnel

(E) Advanced power sources to meet the demands of future military platforms and personnel

**Signature Management**

(A) Underwater signature prediction and reduction for improved survivability and sensor effectiveness

(B) Surface and air signature prediction and reduction for improved survivability and sensor effectiveness

(C) Methods to integrate and optimize total platform signature management

(D) Susceptibility assessment and mitigation for effective deployment of countermeasures

**Platform Performance and Life Cycle Management (LCM)**

(A) Reliable computational fluid dynamics for complex vehicle configurations and extreme flows

(B) Structural modelling for the insertion of advanced materials technology and life cycle management of military platforms

(C) Advanced materials technology and modelling for improved LCM of military propulsion systems

(D) Modelling of operational limits and safety for military platforms to enhance operational effectiveness and survivability

**Multi-Environment Life Support Technologies**

(A) Adaptive life support technologies for improved protection against operational and environmental challenges
(B) Countermeasures to sustain and enhance human performance in adverse environments
(C) Remotely monitor, register and transmit vital physiological, cognitive and behavioural signals for "anticipatory" life support control systems

**Operational Medicine**

(A) Devices, procedures and treatments for casualty management and diagnostics
(B) Produce new therapies, personal health monitoring systems and diagnostic aids
(C) Prevention and treatment of both endemic and weaponized disease

**Chemical / Biological / Radiological (CBR) Hazard Assessment, Identification and Protection**

(A) Hazard assessment and consequence management for enhanced decision-making
(B) Detection, identification and diagnostics to overcome asymmetric threats
(C) Individual and systems protection for advanced CBR countermeasures

**Simulation and Modelling for Acquisition, Requirements, Rehearsal and Training (SMARRT)**

(A) M&S enablers for developing future force concepts and identifying future capabilities
(B) Systems engineering and advanced acquisition concepts to modernize defence processes
(C) Human Factors of SMARRT for human-in-the-loop and representation of human behaviour
(D) Virtual models for optimization of platforms as integrated weapons systems

# INTRODUCTION

The key objective of DRDC is to ensure that the CF of the future remains technologically prepared and relevant in a defence environment that will see increased focus on interoperability with allies, technology-driven warfare and new "asymmetric" threats. The challenge for the Agency over the next 5-10 years is to develop the S&T capacity to enable the CF to deal with the evolving global security environment while ensuring interoperability with our allies.

One of the major S&T drivers is the RMA, which is being enabled by the integration of rapidly advancing technologies: long-range precision capability; sensor technologies; low observable technologies; and information and systems integration technologies.

On the other hand, asymmetric threats are emerging that will require responses. We will develop defensive measures and counters to information and biological/chemical attacks, and be in a position to anticipate, respond to and neutralize terrorist attacks on the military and civilian infrastructure. The national security environment is also changing as the safety and security risks facing modern societies expand with new health hazards, climate change, bio- and cyber-terrorism, and vulnerability of critical infrastructure.

We are responding to these challenges by implementing the TIS, which focuses the future R&D capabilities in critical technology areas where DRDC can make a difference. We will then draw on our allies and national partners to leverage the additional capabilities we need to carry out a defence R&D program that responds to the Capability Goals of the CF.

Since the original development of the TIS almost three years ago, changes in the security environment and DND's strategic planning have advanced the need to revisit and update the Strategy. DND and the CF have developed a strategic outlook in the form of *Defence Strategy 2020*, which maps out a strategic decision-making framework for the CF to guide defence planning for the years ahead. It identifies both the challenges and opportunities facing DND and the CF as they adapt to change in a rapidly evolving, complex and unpredictable world. The "Proactive Innovation" force development option chosen to achieve this vision of *Defence Strategy 2020* marks a definite intent to take advantage of emerging technologies to provide capabilities required by the CF in new and innovative ways.

This updated TIS outlines the R&D required to develop the S&T capacity required for future defence and national security, taking into account the strategic direction provided by *Defence Strategy 2020* and the new approach of Strategic Capability Planning. The updated Strategy also better reflects technologies that are integral to the RMA, including information technology and sensors, as well as projected advancements in areas such as nanotechnology, biotechnology, material sciences and power sources. Research objectives for M&S, IKM, and AIS have been sharpened, and research in

CBRD, weapons countermeasures and Network IO have added impetus in responding to terrorist threats.

The TIS is based on 21 R&D Activities that span the defence technology spectrum, including sensors and information systems, combat systems and human systems, as well as M&S and systems concepts.

An annex to this document contains the linkages between those R&D Activities and the Capability Goals of DND/CF expressed through the Canadian Joint Task List.

Teams of S&T workers in our laboratories will perform the 21 R&D Activities. The core competencies of these laboratory teams, along with the S&T facilities and linkages to other S&T performers, will be aligned with the TIS and in place by 2005, to enable R&D outputs that generate new defence capabilities targeting *Defence Strategy 2020* objectives in the 2010 to 2020 timeframe.

Detailed plans, including human resources and S&T facilities requirements, are now being developed for implementing the TIS. Significant progress has already been made but there are still significant capacity gaps to be filled.

## R&D Activities

- Command and Control Information Systems Performance and Experimentation
- Information and Knowledge Management
- Communications
- Human Factors Engineering and Decision Support Systems
- Command Effectiveness and Behaviour
- Autonomous Intelligent Systems
- Sensing (Air and Surface)
- Underwater Sensing and Countermeasures
- Space Systems
- Electro-Optical Warfare
- Radio Frequency Electronic Warfare
- Network Information Operations
- Precision Weapons
- Weapons Performance and Countermeasures
- Emerging Materials and Bio-Technology
- Signature Management
- Platform Performance and Life Cycle Management
- Multi-Environment Life Support Technologies
- Operational Medicine
- Chemical/Biological/Radiological Hazard Assessment, Identification and Protection
- Simulation and Modelling for Acquisition, Requirements, Rehearsal and Training

## Command and Control Information Systems (C2IS) Performance and Experimentation

### Definition

C2IS Performance and Experimentation addresses new approaches, frameworks and architectures to manage the evolution of information systems for Command and Control (C2) applications. R&D in experimentation will reduce risks and guide innovations on C2IS theories, methods and tools, and it should lead to new and useful insights into the design, development and evolution of C2IS. Advances in measurement techniques from quality of service to measures of effectiveness will guide the development of new architectures and functionalities.

### Trends, Threats and Opportunities

Organizations are increasingly relying on information systems to automate processes and make decisions. Changes to the international situation have raised the importance of effective C2IS as Canada has been a partner in numerous missions throughout the world, often at short-notice and in unforeseen locations with unexpected coalition partners. Information Technology (IT) investments are significant and the risk of failure is high.

*Mast-mounted radar assists in C2.*

Complexities in information systems development and evolution can be overwhelming, and may be amplified through a feedback effect resulting from organizational complexity, user buy-in, differing security standards, multiplicity of business demands, interoperability between systems, constant organizational evolution, legacy systems, Commercial Off The Shelf/Government Off The Shelf, (COTS/GOTS) exploitation and technological difficulties. For coalition operations, interoperability is a key requirement and can only be achieved through unambiguous sharing of required information. This requires open, flexible and interoperable information infrastructures among the national systems. While certain problems related to interconnectivity may be solved by code changes, some information systems (or systems of systems) may saturate or may be impossible to interconnect if the architecture is not properly defined. It is also essential to predict and evaluate the efficacy of potential architectural configurations.



Our approach calls for a rich experimentation framework that will contribute to the exploration of innovative concepts and efficient technologies for joint and single service warfighting capabilities. Because of the rapid development of computer technology, R&D must be carried out to build workable, reliable, robust and efficient C2IS. Consideration is to be given to military users, analysts and developers, as they will interact with real and experimental C2IS systems across varying environments, partners and command levels.

## Strategic Objectives

(A) **Harmonization of distributed simulations for interoperability with C2IS:** Investigate and advance distributed simulation technologies to cope with competing approaches and increasing complexities of C2IS. Develop and align technical standards, procedures and implementation strategies of Command, Control, Communications, Computers and Intelligence (C4I) and M&S. Improve the interoperability between C2IS and simulation environments (e.g. HLA) to ensure that real and experimental C2IS are well integrated in order to facilitate the introduction of advanced C2IS techniques and tools, including the investigation of multi-platform C2IS issues.

(B) **C2IS synthetic environments and modelling to facilitate experimentation:** Investigate and advance C2IS modelling and synthetic environments to improve experimentation with C2IS. Modelling examples include commander, weapon or sensor behaviour, as well as communication and information system infrastructures to model netcentric warfare operations and to carry out the required experiments. Synthetic environments supporting a C2IS may include a virtual ship or aircraft, a virtual command post, a virtual battlefield, etc. Such a synthetic framework will link decision support tools, information and knowledge management tools, models, simulations, other real hardware/software equipment, visualization and people into a common representation of the C4I world.

(C) **Metrics and experimentation for optimum C2IS:** Develop metrics and experimentation environments to identify, quantify and measure the benefits of optimal information systems. Improve fidelity, resolution and reliability in modelling C2IS across all hierarchical levels. The impact of the human-in-the-loop concept, especially in decision-making, is especially difficult to model given that decisions are made under many degrees of uncertainty in the scenario, the model and the outcome. While the correlation of measures with processes requires considerable insight into the C2IS environments, such measures of merit will allow choices between competing solutions to be made with confidence.

# Information and Knowledge Management (IKM)

## Definition

R&D in IKM techniques, architectures and systems will support the knowledge creation process while ensuring effective collection and sharing. Information Management is a distributed process that includes transforming, classifying, indexing and linking data elements in context for exploitation. Knowledge Management is a collaborative and integrated approach to the creation, capture, organization, access and use of an enterprise's intellectual assets. Knowledge Management is used to turn an organization's intellectual assets (both explicit and tacit knowledge) into greater productivity, new values and increased competitiveness.

The aims are twofold. The first is to enhance the Canadian Forces capability to achieve information superiority through dominant battlespace visualisation. The second aim is to support the management of corporate information and knowledge across DND by ensuring that they can be captured, shared, exploited and expanded for future growth, innovation and responsiveness within a distributed/collaborative enterprise architecture.

## Trends, Threats and Opportunities

Defence organizations are faced with information "overload": large amounts of data from improved instruments and sensors coupled with complex results from computer M&S. The amount and complexity of information creates challenges, not only in the collection and processing tasks, but also in managing and understanding the information. Finally, the ability to apportion relevance to the information creates "knowledge".

*Advanced IKM systems are vital to information-based warfare.*

The doctrine of information and knowledge superiority has become the basis for structuring C2 architectures and operations. Battlespace superiority and operational effectiveness are threatened by poor information. The organization must learn from experience and apply that knowledge judiciously to fulfill its mission. On the corporate front, information and knowledge within the organization are powerful assets that must be properly managed to retain value. Inability to adapt and innovate will impede the integration of new information technologies and management practices into the organization's business process.

Recognizing that information superiority is key to both business and defence, IKM advances will exploit the similarities between business knowledge management and military information-based warfare.



## Strategic Objectives

(A) **Advanced techniques and architectures for more effective sharing of information and knowledge:** Investigate and advance techniques and architectures for more effective sharing information and knowledge across the enterprise's distributed and heterogeneous information systems. This activity will benefit knowledge creation and workflow integration in both the corporate and military operational environments.

(B) **Knowledge modelling, discovery and creation for improved situational awareness:** Investigate and advance knowledge creation and discovery techniques through which we collect and process information to gain sufficient situational awareness to be able to project possible future courses of action or trends with confidence. Investigation of these techniques will offer improvements in knowledge management applicable to both corporate and military environments. Since both technology and human operations are involved, the investigation must include research and modelling of business process and human knowledge representation in meaningful and intuitive ways for the navigation, storage and retrieval of information, and for the building of adapted consumer profiles and task-oriented workspaces.

(C) **Visualisation and geo-spatial systems for enhanced understanding of spatial- and time-related knowledge:** Investigate and advance techniques for multi-dimensional information management, analysis and visualisation to enhance the understanding of spatial and time-related knowledge. These techniques should also facilitate the discovery of knowledge in complex environments. Particular emphasis will be given to reducing operator workloads by introducing trusted intelligent assistants.

# Communications

*Soldier checking communications.*

## Definition

Communications R&D addresses the robust and seamless movement of information between a source and one or more recipients to support effective command and control. The R&D is concerned with technologies and techniques that ensure the robust, efficient and secure transport of information; the interconnection fabric that provides the seamless exchange of information; and the protection of the information from exploitation and disruption.

## Trends, Threats and Opportunities

Governments, military organizations, industries and even individuals throughout the world are increasing their dependency on sophisticated interconnected information systems in order to carry out their business in a timely and efficient manner. In addition, dramatic bandwidth explosion in the commercial world is putting tremendous pressure on the evolution of military communications, both terrestrial and satellite, and networking on the digital battlefield.

As communications technologies in the commercial sector continue to evolve rapidly, there is a risk of missing key opportunities that may be critical to addressing military communications priorities. The ubiquitous global communications networking trend reflects the increasing demand, dependency and requirement for “access to information wherever and whatever it is”. This emerging global network will provide a versatile environment for military operations, business, training, education, culture and entertainment. Military organizations rely heavily on secure and reliable communication systems which are equally available to adversaries to exploit for their own command and control, or to devise countermeasures to CF operations.

The Communications R&D Activity addresses the exploitation and adaptation of current and future civilian standards and technology for military use, and the development of unique military technologies. Commercial technologies under development that have military relevance include protocols for internetworking over various communications media, wired and wireless networks, distributed systems, personal communications systems (terrestrial and satellite) and wideband wireless communications systems (terrestrial and satellite). Unique military communications R&D comprises the development and implementation of highly protected satellite communications, increased throughput for military wireless communications in specific frequency bands and mobility and protection of military networks.

The opportunities to be exploited include rapid technological evolution in fields of digital signal processing, networking, microelectronics, micro electro-mechanical systems and M&S. There are particular opportunities in areas where the commercial market is setting the pace of standards, technologies and services. These opportunities will provide commanders with robust, mobile, affordable, secure, interoperable and reliable communication services, enhanced intelligence and information content that they need to fully exercise their C2 function.

## Strategic Objectives

(A) **Military bandwidth on demand:** Develop technology, tools and techniques for the on-demand delivery of robust and efficient bandwidth for the 2020 battlespace. The objective includes development of techniques to enhance coalition interoperability and communications channel capacity, through exploitation of advances in digital signal processing (e.g. software radio), microelectronics, micro electro-mechanical systems and antenna technologies.

(B) **Robust, reliable, secure, fixed and mobile multimedia communications capability for the warfighter:** Develop and implement technology, tools and equipment to ensure robust, reliable, secure, fixed and mobile multimedia communications capability for the warfighter. This objective includes provision of new military services such as integrated voice and data, priority/pre-emption, etc. and M&S to establish and meet high Quality of Service demands.

(C) **Intelligent management of network resources for the integrated battlefield:** Develop tools and protocols for adaptive management of distributed network resources. The work includes R&D into monitoring, control and scheduling of network resources, consisting of a large number of autonomous and intelligent systems.

(D) **Communications enablers for distributed systems:** Develop communication technologies and tools for the effective employment of battlefield-distributed systems. The R&D objective is to ensure the performance of distributed systems over bandwidth-limited, high latency, high error rate channels, as well as to address the strain they will have on future communications systems.

# Human Factors Engineering (HFE) and Decision Support Systems (DSS)

## Definition

HFE R&D addresses system readiness and performance by achieving compatibility among people, their equipment, machines and working environments to ensure effectiveness, safety and ease of use. HFE is a core competency of HSI, which expresses human capabilities and limitations in forms that are compatible with the design and development process. DSS R&D addresses improved performance through the investigation of computer-based tools and capabilities for supporting the two main phases of the decision-making process:

1) recognize the situation; and
2) decide on the action.

## Trends, Threats and Opportunities

Among the more difficult requirements of military personnel is the need to make fast, accurate and informed decisions under complex conditions in both combat and peacekeeping zones. The emerging future global network will provide a powerful and versatile environment for "access to timely and accurate information by fusing information wherever and whatever it is". Advances in threat technology, the increasing tempo and diversity of open-ocean, land, air and littoral scenarios, as well as the volume

*Simulators create environments to assess human capabilities.*



and imperfect nature of data to be processed under time-critical conditions, pose significant challenges to future C2 operators.

Other challenge areas include presenting this information to the decision-maker in a comprehensive and psychologically meaningful way in order to enhance situation awareness and to assist the decision-making process by identifying, selecting or evaluating potential courses of action in response to anticipated or actual threats to the mission, and then implementing the appropriate actions once a decision has been made. New technological opportunities (e.g., neural networks, artificial intelligence, advances in display and human: computer interface technologies) as well as recent research within the

Command Effectiveness and Behaviour R&D Activity must be developed in concert in order to ensure coordinated solutions.

New equipment specification, selection, design, development and the fielding of effective equipment and systems for future military operations is becoming more complicated in an era characterized by rapid technical breakthroughs. Military coalitions and mixed civilian-military operations revealed that existing C21S generally fail to properly support collaborative decision-making in complex and dynamic environments such as contingency situations. Increases in the level of automation, coupled with the need to reduce personnel, necessitates the following:

1) the appropriate functions to be performed by humans in advanced military systems;
2) methods for dynamic re-allocation of function and for allocating responsibilities among the members of a team;
3) human attention;
4) the display of system information and the provision of feedback; and
5) the design of error-tolerant systems.

HSI will focus on developing tools and techniques to assist in the application of HFE to high-technology equipment, and on the trade-offs that have to be made between selection, training, manning levels, design for ease of use and safety and health hazards. A broad range of technology opportunities in systems engineering, M&S, sensors and display technology and design technologies will need to be exploited.

## Strategic Objectives

(A) **M&S to determine the most effective roles for humans in future systems:** Develop effective roles for humans in future systems and predict operator workload and performance. The enabling technologies include advanced forms of operator task analysis and constructive simulation, as well as experimentation and real-world surveys.

(B) **Human-computer interaction to improve situational awareness:** Conduct research into the display of information using audio, visual and other sensory modalities in two and three dimensions to improve operators' abilities to assimilate, understand and query complex displays and to interact with advanced computer-based systems. The R&D will develop theories and models of human-computer interaction and include intelligent agents.

(C) **Real-time situation analysis automation technologies for decision-making:** Develop situation analysis tools and techniques which, in turn, assist in the development and display of the tactical picture including higher levels of abstraction than elemental track plots, supporting the projection of this picture, and mental simulation for the purposes of resolving situation uncertainty, forming explanations of events, generating expectancies for the future and evaluating courses of action. The enabling technologies are: data/information fusion; reasoning under uncertainty (Bayes, evidential, possibilistic); expert systems; multi-agent and knowledge-based systems; and cognitive engineering.

(D) **Computer-based decision aids and process modelling for DSS:** Develop comprehensive models, methods, approaches and concepts to be embedded within DSS to understand the military decision-making processes. The technologies to be investigated are: multi-criteria decision aids; group decision theory; expert systems; uncertainty management; cognitive engineering; multi-agent, rule and case-based reasoning; and knowledge-based systems.

(E) **Intelligent collaborative planning for integrated force management and execution:** Develop adaptive intelligent systems to assist the dynamic synchronization and management of military force activities (including real-time re-tasking and re-targeting) and operations throughout the battlespace. Some of the enabling technologies to be investigated are: intelligent control; blackboard; resource bounded reasoning; anytime algorithms; concurrent problem solving; evolutionary computation; expert systems; cognitive engineering; and multi-agents.

(F) **HSI tools for systems design and project development:** Develop a compatible suite of effective tools and supporting information for the conduct of HSI activities to express human capabilities and limitations in ways that are compatible with the system design process, and to explore the interactions and trade-offs between selection, training, manning levels, design for ease of use and health and safety issues. Some of the enabling technologies to be investigated include anthropometry, Computer Assisted Design (CAD) and constructive and virtual simulation. Information from research in Health Hazards, System Safety, Life Support, Training, etc. will be exploited.

# Command Effectiveness and Behaviour

## Definition

This research domain encompasses all of those behavioural factors that affect the ability of military personnel to perform in cognitively and emotionally challenging situations. It includes the ability to lead, to work in teams, to cope with stress and to observe, understand, decide, act and react. This domain focuses directly on psychological and social-psychological factors that affect command effectiveness and behaviour.

## Trends, Threats and Opportunities

Among the more difficult requirements of military personnel is the need to make fast, accurate and informed decisions under conditions that are exceptionally difficult and stressful. The 'spectrum of conflict' is widening and the CF is involved in operations that are more complex, more politically sensitive and more prone to failure than at any time in its

*CF troops engaged in OPERATION ANACONDA.*



history. To address these challenges, an investment in psychological and social-psychological research must be made. This should include enhancing the inherent decision-making capabilities of humans by first researching and then introducing novel education and training programs. The ability to exploit new technological opportunities (e.g., neural networks, artificial intelligence) will also benefit from research in team decision-making, and in trust and confidence in advice that will be a focus of this research area. It is critical that this domain be developed coincidentally with other technological research in order to ensure coordinated solutions to CF concerns.

The CF will continue to operate, in a world arena that involves varying environmental, political and moral conditions, all of which pose unique human challenges for sustaining cognitive performance and emotional health. Indeed, the trend in recent years has seen a rise in the number and type of CF operations, despite a general reduction in total force complement. In any military operation, the best leverage for success is a healthy, psychologically fit, motivated and bright CF member who believes in the mission and has the necessary resources to carry it out. However, the ability for CF personnel to maintain optimal psychological performance in the face of these challenges may be compromised unless substantial support is offered. Recent awareness of the importance of psychological factors in industry and government organizations has stimulated research in many areas of the social and cognitive sciences. There is an opportunity to apply this research to the military context as well as an opportunity to develop new psychological theories and techniques specific to solving military problems.

This entire research domain is consistent with the CF's recent strong commitment to support its most valuable asset: its personnel. A shrinking budget and an expanded operational mandate ensure that this CF commitment will continue well into the future. The opportunity for research in this area, as well as the potential for performance improvement, is great.

## Strategic Objectives

(A) **Methodology for improving leadership development skills:** Study, assess and contribute to the improvement of leadership skills in the CF. Efforts will centre on isolating the common elements among all leadership theories and determine the military conditions under which each is most suitable. The technology to be applied to achieve this objective is research methodology specifically developed to study human performance and capability. This effort will be coordinated with the CF's new Leadership Centre and the Royal Military College Military Psychology and Leadership department.

(B) **Problem solving, bounded reasoning and reasoning under uncertainty for training and informed decision-making:** Explore problem solving and decision-making theories for use in training and the design of decision support systems. Develop methods for assisting reasoning under conditions of uncertainty as well as under conditions where resources and time are critically restricted. This R&D objective can make significant contributions to Knowledge Management and Artificial Intelligence.

(C) **Strategies for command stress and coping:** Study command stressors, assess their effects and suggest coping strategies for effective decision-making and leadership.

(D) **Solutions to enhance team performance:** Understand the social-psychological conditions that facilitate the establishment of common intent – how it is communicated and how it is shared. The objective includes the enhancement of team performance in joint and combined operations; as such operations are becoming the norm.

# Autonomous Intelligent Systems (AIS)

## Definition

AIS are automated or robotic systems that operate and interact in the complex unstructured environments of the future battlespace. Key R&D issues include the capabilities of such systems to perform complex tasks through the perception and understanding of unstructured environments with minimal human direction and oversight as well as the ability to learn, adapt and share information between platforms and their sensors and to achieve collective intelligence and enhanced system effectiveness.

*Scout vehicle with a laser scanner.*

## Trends, Threats and Opportunities

Robotic systems will be fully exploited in the future battlespace (e.g., micro-robots for surveillance and target identification and robotic weapon systems). They can improve lethality, mobility, effectiveness and survivability both on the tactical battlefield, in peacekeeping and in urban operations. Primary tactical roles include early sensing and shaping of the battlespace prior to and during force deployment. Developments in autonomous systems will also allow reduced crew for most platforms. Robots or remotely controlled platforms, such as unmanned combat air and land vehicles, will be prevalent on the battlefield of 2020.

Robots can assist (automation, lifting), replace (dirty, dangerous or tedious tasks) or complement (multi-spectral sensing, information processing and task reporting) the human. Unmanned vehicles, operating as sensor or weapons platforms can increase situational awareness, extend effective engagement ranges and reduce crew exposure. AIS can have the capability to sense their environment multi-spectrally and perform parallel data collection of a scene to add fidelity to surveillance. Although humans currently make better decisions about the situation, AIS, when effectively implemented, can provide complementary capability.

It is expected that developments in the civilian commercial sector (robotic systems, computer technologies, etc.) and like developments in the international R&D community will potentially lead to effective collaborations. Additionally, because of the strong commonality between Unmanned Air Vehicle (UAV), Unmanned Ground Vehicle (UGV) and Unmanned Underwater Vehicle (UUV) technologies, cross-pollination of technology issues such as interoperability and compatibility will be an advantage. Operation in the land environment provides the greatest challenges to mobility and machine learning, and the greatest opportunities and requirements for automated, cooperative and collective intelligence gathering and information sharing among robotic systems. Throughout, the focus will be on data fusion and the development of cooperative, intelligent systems, for various platforms, rather than on the development of specific new platforms.

### Strategic Objectives

(A) **Methods for AIS to perceive the environment:** Develop methods by which robotic systems can measure/sense, interpret and classify their environment and identify opportunities, threats and challenges.

(B) **Methods for AIS to interact with their environment:** Develop algorithms, software and hardware to control the automated/robotic system's behaviour as it responds to a changing environment.

(C) **Information sharing among distributed, networked, intelligent systems for collective intelligence, cooperation and collaboration:** Develop adaptive learning based on collective intelligence for intelligent systems to cooperate on shared tasks through individual effort with minimal direction. The aim is to develop intelligent systems that collaborate to accomplish missions (a collection of tasks) which they are otherwise unable to perform individually, demonstrating higher order behaviours (higher levels of intelligence and autonomy) to perform higher-level mission assignments and tasks. In the land environment, collective intelligence achieved through swarms of interacting, mission specific sensors and platforms will be pursued.

## Sensing (Air and Surface)

### Definition

Sensing is carried out to detect, recognize, locate and monitor all targets and features of interest (including our own assets) within a specified area. This Activity encompasses several technology areas, among them electromagnetics, electro-optics and acoustics. In order to be of military use, the data gathered by the sensors must be processed to extract information on target identity and state (coordinates, velocity, acceleration, etc.).

## Trends, Threats and Opportunities

With the advent of precision-guided weapons, the importance of accurate and timely information will grow. The threat will also become harder to detect (low observables, camouflaged, foliage penetration, mines, etc.). Missions will evolve in the new type of warfare the CF will face in the future, where adversaries are better equipped because of the widespread availability and affordability of various technologies. Effective and balanced responses will be required in support of peacekeeping operations and in new operational realities such as military operations in urban terrain. The threats in urban environments are expected to grow in importance and to include mines and Improvised Explosive Devices (IEDs).

*The Pirate sensor system.*

Enormous developments occurring in solid-state technology for both the civilian and military markets have tremendously improved the size, weight, power consumption, reliability, affordability and functionality of available sensor systems and their associated processing systems. In the future, sensing will be accomplished by aided or automatic target detection, recognition and geo-location. Also, the outputs from the different sensor streams may be fused as required to further improve the detectability of various targets. In the past, sensors and target identification or recognition algorithms were treated separately. In future smart sensor systems, they will be seamlessly integrated in such a way as to transform sensor data directly into information.

Smart sensing, in the present perspective of integrating detector and target detection and recognition systems, is the fundamental building block for the establishment of the 3D digital battlefield. New sensors systems, tightly coupled to algorithms and platforms, will be developed to respond effectively to the threats in these new operational environments. Although some of the required technology will be advanced by the commercial sector, as evidenced by the exponential increase in computer power and the proliferation of high-performance, miniature and inexpensive sensors, there exist a full range of focused opportunities that exploit areas that are unique to the military. They are: military target signature and background synthesis, full spectrum sensing through camouflage and for low observable targets, targeting for precision weapons, tactical autonomous remote surveillance systems, sensors with increased resistance to dazzling or with reduced retroreflection cross-section, sensor diversity and disparity management and exploitation for the detection of targets of specific military interest.

## Strategic Objectives

(A) **Acquiring and exploiting environmental knowledge for target discrimination and recognition:** Develop on-scene and remote/standoff sensors, propagation models, target signature models and geo-positioned real or synthetic background databases or models in order to optimally differentiate targets from background, in the full spectrum of environmental situations. Characterize targets of interest, backgrounds and atmospheric conditions, in order to specify and predict the performance of weapon and surveillance systems. Validate these models by conducting a detailed measurement program.

(B) **New and improved sensing technologies for detection, tracking and classification of difficult targets:** Improve advanced sensor systems in terms of size, cost, performance and functionality to cope with evolving military requirements. Exploit adaptive sensing modes and integrated processing, and implement these to optimize performance against difficult targets (buried mines, IEDs, cruise missiles, camouflaged and concealed targets, etc.). Develop new adaptive sensors, such as for through-wall sensing, for increasingly important urban operations. Improve and further exploit active and passive hyper-spectral EO/IR imagery systems, as well as high bandwidth, multi-frequency, polarimetric and interferometric Synthetic Aperture Radars (SAR) for improved Intelligence, Surveillance & Reconnaissance (ISR). Develop surveillance sensors with reduced retroreflectivity for covertness and enhanced platform survivability.

(C) **Advanced techniques and tools for automated target and feature recognition:** Develop reliable Automatic Target Recognition (ATR) for the efficient use of sensor data in support of operations capable of dealing with a huge volume of sensor data, exceeding the operator's ability to effectively exploit it in a timely manner. ATR has long been identified as a potential technological breakthrough that would create a revolution in ISR because of its potential for fully autonomous remote systems and for non-cooperative combat Identification Friend or Foe (IFF). Enable multifunction sensing and multiple sensor fusion relying on massive computing power coupled with sophisticated algorithms for advanced signal/data/image processing. Develop on-board target cueing and on-board processing of collected data into information, precise geo-location and co-registration of all sensor views. Develop rapid and continuous visualization tools.

(D) **Optimal techniques and architectures for multifunction sensors and multisensor systems:** Develop techniques and architectures to improve interconnectivity and reconfiguration in a smart sensor web addressing the problem of using multi-function or complementary sensors for target detection, tracking, classification and recognition. Develop specific algorithms for cueing individual sensors, adapting their performance parameters and fusing their output. At a higher level, elaborate sensor management strategies and concepts of operations to select an appropriate sensor mix so that the limitations of individual sensors can be overcome, and the combined sensor coverage and resolution can be rapidly optimized and reconciled.



# Underwater Sensing and Countermeasures

## Definition

This Activity combines aspects of R&D in sensors and actuators, assessment of the undersea environment and data fusion that contribute to situational awareness and targeting in Underwater Warfare (UWW), including Anti-Submarine Warfare (ASW), Torpedo Defence (TD) and Mine Countermeasures (MCM). All mobile and fixed systems are considered, whether conveyed by naval vessels, aircraft or autonomous vehicles, and whether deployed for the long term or, rapidly deployed, for a short term.

## Trends, Threats and Opportunities

Traditionally, maritime deployments have been open-ocean operations against nuclear submarines. Since the thawing of the Cold War, operations have shifted to new areas where the dominant threats are the elusive conventional submarine (with associated torpedoes), mines (moored, bottomed or buried) and land-based weapons. This trend is expected to continue, and demands UWW capabilities that are beyond what we have in-hand or are immediately available from our allies. Underwater Sensing includes the detection and tracking of surface, air and undersea vehicles and weapons, including mines. Acoustic, magnetic, electric, electro-magnetic and optical (principally IR) (and possibly pressure, seismic, chemical, environmental and oceanographic) sensors are all exploited in this activity.

In addition to the multi-platform integration of conventional ASW sensor systems, the conduct of future UWW will require affordable networks of federated sensors, perhaps of inferior individual sensor-level performance to current sensors, but of much greater system-level performance, capable of fully-automated first-level detection, classification, localization and tracking. Communication technologies, data fusion, decision aids and knowledge management will be key to achievement of this capability. Significant advances are also required in the "dry end" (hardware, software and algorithms).

*The HMCS Windsor, a Victoria-class submarine.*



Work in Underwater Sensing will address: hardware (sensor systems, transducers, actuators and data acquisition systems); the physical characteristics of the operational environment (environmental assessment and modelling); and processing (detection, classification, identification, tracking, sensor positioning and UWW IKM). Concepts will be validated and demonstrated by concept demonstrators in the hands of military operators.

Where possible, the entry into service of networked and distributed systems will enable improved-capability UWW operations without the need to replace entire systems as they age. Development of networked and distributed systems will allow technology insertion to advance the operational performance of a system against new threats. It will be possible to replace obsolescent equipment incrementally, thus avoiding 'mass rust-out', with its periodic catastrophic effects on LCM budgeting.

## Strategic Objectives

(A) **Affordable distributed sensors and actuators for future UWW systems:** Develop new sensor technologies (acoustic, electromagnetic and optical) as well as transducer and actuator technologies (e.g. MCM influence sweeps) to cope with future UWW threats – whether submarines, torpedoes or mines. New technology incorporating new designs and new materials will be developed to permit the construction of low-cost distributed and expendable sensors and countermeasures to address the performance deficiencies of current UWW systems.

(B) **Sensing and modelling of ocean and seabed properties for future underwater warfare operations:** Develop new sensing and modelling technologies to provide rapid, accurate, wide-area, high-density and cost-effective environmental measurements for future UWW operations. The performance of naval and airborne sensors, weapons and countermeasures will be improved by obtaining better information on ocean and seabed properties. Sensing technologies will be developed, either *in situ* or remote, that include both special-purpose sensors and existing sensors in operational sonar systems. Modelling techniques will be developed that combine new environmental sensor information, data from existing databases and physical models to provide information required by sensor processing systems, operators and platform command staff.

(C) **Data fusion and resource management for timely provision of the UWW tactical picture:** Develop more effective algorithms and sensor-specific information management for timely provision of the UWW tactical picture to the operator because better sensors alone will not address current deficiencies. Sonar-level and target-level information will be integrated across multiple platforms and systems to achieve successful detection, identification, localization and tracking of vehicles, torpedoes and mines, particularly in shallow-water (littoral) operations.

# Space Systems

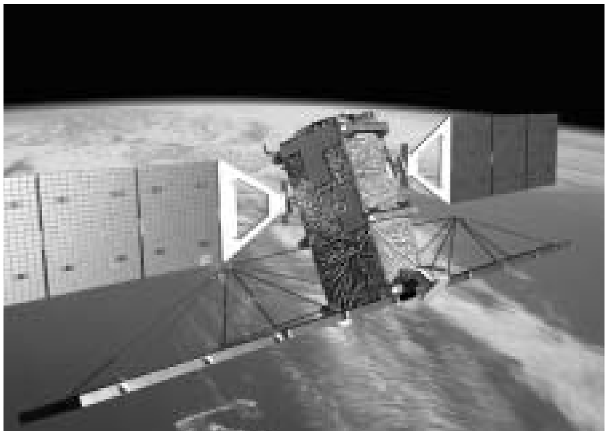
## Definition

Space Systems R&D includes the development of concepts, technology, components, systems and data exploitation capabilities to support surveillance of space from both ground and space-based sensors; surveillance from space, which includes remote sensing, multi-source intelligence collection, and moving-target detection and tracking; and early warning and defences.

## Trends, Threats and Opportunities

The 1998 DND Space Policy reiterated the 1994 Defence White Paper statement that space has emerged as an *"increasingly important component of the global security environment"*. Space is considered by some to be the fourth medium of warfare, now critical to the successful prosecution of military operations. Space superiority is a fundamental tenet of US strategy, which has important implications for interoperability in coalition operations.

The 1998 Space Policy paper stated that *"a comprehensive space capability is fundamental to effective force projection in regional crises, rapid response under conditions of uncertainty and instability, high mobility with minimized forward presence, and maximum efficiency using space to support operations"*. This Policy was validated in Strategy 2020, Objective 3 on Modernization: *"Re-focus defence R&D on the operational needs of the Department capitalizing on leading edge technologies, … especially in the areas of space,*



*RADARSAT II*
*(Provided courtesy of MacDonald Dettwiler and Associates Ltd.)*

*remote sensing, telecommunications and information management"*. Canada's ability to contribute to space systems for surveillance and warning could provide options for burden sharing in North American defence.

It is expected that advances in technologies such as microstructural materials and nanotechnologies, will lead to new components for space that will have a higher performance to cost ratio. For example, the use of these components could improve the sensitivity of sensors, improve the efficiency of power systems or reduce the weight of space structures. Use of these components, such as Transmit Receive (T/R) modules, in Space Systems should reduce the cost of many space missions or may lead to new capabilities in ISR. It is also expected that improvements in algorithms and processing of space data will lead to better exploitation of the resource and new applications.

Since it is unlikely that Canada will develop an independent military space capability, our space technology investment strategy will feature collaboration with the Canadian Space Agency and with allies such as the United States and the United Kingdom.

One of the main uses of satellites is communications. Military satellite communications is not considered here. It is however included in the TIS R&D Activity for Communications.

## Strategic Objectives

(A) **Development of processing and exploitation techniques and applications for space-derived intelligence, surveillance and reconnaissance data:** Develop new processing and exploitation tools to assist in obtaining relevant information from space-based sources, and develop applications for this information.

(B) **M&S of Space Systems for concept development, evaluation and analysis:** Develop and evaluate new system concepts for military space-based surveillance and earth observation, and evaluate their operational effectiveness and military utility through high-fidelity M&S of various space-based radar, EO/IR and multi-source systems. The military utility of current and potential future systems will be evaluated. The research will include mission design, orbit and constellation analysis, estimation of probabilities of detection, investigation of tracking algorithms and simulation of the performance of various signal processing algorithms and Command Control, Communications and Intelligence (C3I) architectures. Contribute to space systems concept development by investigating tasking and cueing techniques and Command, Control Communications, Computers and Intelligence (C4I) concepts for multi-platform global Intelligence, Surveillance, Targeting and Reconnaissance (ISTAR).

(C) **Multi-static/multi-functional radar/EO and hyper-spectral sensing for intelligence, surveillance, targeting and reconnaissance:** Develop system concepts, techniques and technologies for space-based multi-static and multi-function radar, multi-spectral EO/IR, multi-source surveillance and remote sensing. Signal processing algorithms will be developed to account for ionospheric propagation effects, high-speed satellite motion and earth limb and cold space background effects. ISTAR applications include wake detection, mapping, wide area surveillance and automated target detection, classification and identification.

(D) **Advanced materials and power sources for the space environment:** Exploit DRDC's nuclear science capabilities to contribute to the development of devices capable of surviving the high-intensity, high-energy radiation environment of space. Investigate electronic and optronic components, nanostructures and Micro-Electro-Mechanical Structures (MEMS) using environmental simulation, testing, analysis and space experiments.

(E) **Concepts, techniques and algorithms for the surveillance of space:** Support Canadian contributions to the Space Surveillance Network by developing techniques for surveillance, reconnaissance, tracking and identification of objects in earth orbit.

# Electro-Optical (EO) Warfare

## Definition

EO Warfare is aimed at denying adversaries the use of the EO spectrum while protecting its use by friendly forces, with the overall objective of increasing the self-defence capabilities of CF platforms in all military operations. This activity includes EO Support Measures (EOSM) to search for, intercept, identify, locate and track EO sources, EO Countermeasures (EOCM) to prevent or reduce an enemy's effective use of the EO spectrum and EO Protection Measures (EOPM) to defend EO sensors and personnel against enemy lasers.

## Trends, Threats and Opportunities

New weapons and surveillance and target aquisition (STA) systems based on EO technology are being fielded by major and secondary powers on land, sea, air and space military platforms. Some of these systems are proliferating to terrorist groups and pose a serious threat to the CF in war environments or in operations other than war. Between 1973 and 1993, 89% of aircraft reported lost to hostile actions in the world were shot down by IR missiles. Man Portable Air Defence (ManPAD) missiles, based on laser beam rider technology, are difficult to detect and allegedly immune to countermeasures.

The biggest opportunity will result from the development of higher-speed computers and digital signal processing, achieving larger bandwidths and dynamic ranges, faster response time and larger signal handling capacities. It will also make it possible to implement sophisticated artificial intelligence algorithms to analyse the data, extract information and develop tactics in response to multiple threats in a timely manner. Smart sensors will detect and identify multiple threats in complex situations, including stealth and clutter. Passive and active detection techniques will be fused to provide high spatial, spectral and temporal resolutions.

Technology opportunities include broadband optical detectors with high quantum efficiencies, large focal plane arrays, micro-optical systems and low-cost fibre optics. The potential synergistic effect of integrating EOSM and EOCM systems with other sensor and weapon systems will become increasingly important as threats become more complex. The integration of EOSM with other sensors will dramatically assist in threat detection, identification and tracking. Similarly, the integration of EOCM systems with weapons systems and other mission systems will substantially improve the survivability of platforms and enhance their effectiveness.

Frequency agile and tuneable lasers using chemicals, non-linear materials, semi-conductors and crystals operating at longer wavelengths are being developed by all advanced nations. Advantages of lasers include light-speed, surgical, multiple-shot and all-aspect delivery. Lasers offer the potential of a paradigm shift in defence technologies for the 21st century, both in offensive and defensive roles. These lasers, of moderate to high power,


*Coyote surveillance system camera.*

will be used for surveillance and target designation; active and passive target discrimination; robust infrared countermeasures; passive and active standoff detection; platform self-protection and offensive capabilities in tactical engagements.

## Strategic Objectives

(A) **Integrated threat warning for survivability in digital battlespace:** Develop comprehensive, real-time, affordable warning systems for accurate detection, identification, localisation and tracking of multiple threats in order to initiate effective tactical manoeuvres, deploy countermeasures or cue directed-energy jamming devices. Data from independent sensors (IR, active imaging, laser-illumination, UV, etc.) must be coordinated and fused to enable the detection of low-level signatures in a high-clutter background over long ranges. This ties into the joint digital battlespace for enhanced situational awareness and efficient mission planning, IFF, targeting and Battle Damage Assessment (BDA).

(B) **Soft-kill laser systems to counter EO-IR guided missiles:** Develop moderate-power laser systems, constructed as phased arrays of electronically steerable diode lasers, to counter multiple diverse EO/IR threats in a timely and effective manner. Passive and active imaging technologies are being developed for target verification, aim point designation and maintenance, and for close-loop countermeasures assessment. This objective also includes the development and experimental validation of analytical tools for target vulnerability assessment and military effectiveness analysis. There will also be development of novel EOPM to defend CF personnel and equipment against laser weapons.

(C) **Plug & Fight architecture for mission configurable, self-defence systems:** Develop closed-loop, low-cost, mission-configurable, "Plug & Fight" defensive aids suites that are seamlessly integrated with the operator machine interface, weapons and other mission systems. Research is required into threat signature measurement and prediction, countermeasures performance and prediction, IR propagation phenomena and system architectures for specific mission systems and threat combinations.

# Radio Frequency (RF) Electronic Warfare (EW)

## Definition

EW achieves electromagnetic spectrum dominance through Electronic Support Measures (ESM) to intercept, identify and locate sources of electro-magnetic energy; Electronic Countermeasures (ECM) to prevent, hinder or degrade an opponent's effective use of the electromagnetic spectrum; and Electronic Protection Measures (EPM) to protect personnel and equipment from attacks of EW systems and RF weapons that degrade or destroy combat capability.

## Trends, Threats and Opportunities

*Electronic Intelligence (ELINT) sensors are a key warfare technology.*

Radar and communications signals are becoming increasingly complex, adaptive to the environment, and difficult to intercept. Modern missile threats, traveling at higher speeds, lower altitudes, and with smaller radar-cross sections, possibly using a combination of active and passive homing, and operating in dense signal environments, will result in shorter available reaction times and require improved combat subsystem integration and greater automation in response. Advanced countermeasures will be needed against new multi-mode guided missile seekers and imaging radar seekers during their terminal phases. New techniques will be required to counter targeting and surveillance radars, denying acquisition and suppressing subsequent missile launch, and active and passive homing threats.

Digital receiver research, including software signal processing, offers the most promise for significantly improved threat detection and recognition, warning and avoidance, targeting (target acquisition and homing), tactical force deployment and other command and control processes. Multifunction radar ESM receivers will provide precise signal parameter measurements. Digital receiver technology in Communications ESM may prosecute traditional Combat Net Radios and Wireless Communications Systems, processing signals using an evolving array of communications standards and protocols, providing the means to locate and track mobile users. Communication ESM assets must operate "on-the-move". Distributed ESM (netcentric) sensor networks will increase precision and shorten reaction time. Platform and integration constraints will require development of conformal (phased array) antennas. Active ECM, such as RF signal jammers, blind and seduce missile seekers, and confuse and deceive communications, reconnaissance, surveillance and targeting systems. Passive measures, such as chaff, seduce missile seekers from friendly platforms and distract acquisition radars.

The evolution of digital RF memories and wide use of digital signal processing will allow more flexible and tailored ECM response. Improved understanding of threat systems, and increased use of computer-based M&S, will enhance EW capabilities. Directed energy weapons, high power microwaves and electromagnetic pulses may be used to disable or physically disrupt electronic systems. EPM will improve system robustness against attacks by modelling and measurement of RF effects on electronic equipment and by developing shielding. It will reduce platform vulnerability to radar detection and RF guided missile attack by modelling and measurement of the radar cross-section, and by supporting RF signature reduction research. Integration of the total EW function, including the EO/IR components, with weapon systems and other sensors across multiple platforms, will lead to more effective, rapid and informed responses to threats.



## Strategic Objectives

(A) **Development of EW R&D priorities to counter emerging threats:** Forecast new conventional and asymmetric RF threats (either communications systems, or sensors or high power weapons), based on intelligence reports, advances in radar, telecommunications and relevant enabling technologies, analysis and experimentation. Formulate new R&D priorities and approaches for the development of EW techniques to detect, characterize and counter these threats. Apply increasingly capable M&S tools to assist in threat engagement assessments.

(B) **Development of technologies and techniques to improve EW system capabilities:** Develop new technologies and techniques for EW systems that will respond to broad multi-dimensional threat emitter parameter sets with high precision and resolution. Exploit the flexibility of digital signal and data processing techniques for new, programmable, adaptive EW systems to enable "surgical" responses to, and suppression of, targeted opponent systems, while minimizing effects on non-target emitters. Develop techniques for specific (radar and communications) emitter identification and engagement, for shielding against RF weapons, and to optimize the effectiveness of own defensive systems.

(C) **Development of systems for automated situation interrogation, assessment and response for effective operations in the future EW environment:** Develop EW systems that can autonomously (automatic, aided and assisted) interrogate the RF environment, adjust to changing engagement priorities, undertake threat assessment and apply adaptive response mechanisms. This will be achieved by integrating a priori information with data from multiple, distributed and networked sensors (EW and other sensors), by using processes derived from artificial intelligence and automatic feedback control, by deploying specialized autonomous vehicles and by optimizing operator monitoring and control procedures.

# Network Information Operations (IO)

## Definition

Network IO R&D addresses the defensive and offensive measures that may be applied to digital information networks, including their component equipment, their software and the data they hold and transport. This R&D exploits IT to develop new techniques to deter hostile network activity, detect intrusions, recover from attacks, exploit the networks of an adversary and engage the enemy in cyberspace.

*Scientist at work in the Information Operations section.*

## Trends, Threats and Opportunities

The world is witnessing an explosive growth in the use of the Internet. As available bandwidth and connectivity increases to meet the demands of both fixed and mobile users, more and more applications will be found for this technology. The rapid evolution of IT is the enabler that is driving the increasing exploitation of the Internet. The use of the Internet has evolved from a carrier of simple messages to become a significant part of the critical national infrastructure. There is increasing global dependence on this technology for the transfer of huge amounts of critical and private information.

The Defence Information Network (DIN) and many other military private networks are exposed to, and take advantage of, these same technology trends. A feature of this rapid change is heavy reliance on COTS systems that often have poor security features. The continually evolving threat of soft attacks on the information networks used by DND and the CF requires R&D to be performed so that the security of these networks can be assured and CF operations can be optimized. Security, in terms of both information content and connectivity has, therefore, become a topic of prime importance.

In an environment where commercial interests dominate much of the infrastructure development of this vast information web, security is not necessarily accorded the priority required in military activities. This lack of security has resulted in a growing number of threats from individuals and groups, such as “hacktivists”, who are politically organized and who know how to exploit security weaknesses.

The heavy national and CF dependence on both fixed and mobile information networks makes these networks attractive targets for groups that might wish to exert pressure or attract attention to their causes. In addition, there are implications for military operations in cyberspace between nation states where much larger and consistently applied resources have the potential to undertake espionage and cause major damage to critical national infrastructure. The growing sophistication of these threat agents is matched only by the wide availability of sophisticated software tools. The relatively small investment required to have a significant impact identifies information warfare as one of the serious asymmetric threats that are now a focus of the RMA.

Opportunities may exist to influence the security specifications of new systems in this rapidly evolving environment. There may also be the opportunity for DRDC, through its R&D activities, to influence COTS products, before the systems become mature. Through its research, DRDC can identify to the CF, opportunities for better and more secure network operations and influence CF capabilities and doctrine. There are opportunities for DRDC to leverage its modest resources through collaboration with other government departments, industry and allies.

## Strategic Objectives

(A) **Protection and assurance of information for dynamic coalition networks:** Develop tools and techniques that will allow the CF and DND to use commercial and open systems to exchange information securely among themselves in joint operations and among chosen coalition partners in combined operations. The scope of this effort ranges from fixed to mobile to fully ad-hoc networks and ranges from local-area, tactical applications to wide-area strategic applications.

(B) **Real-time situation assessment for Network IO:** Develop tools and techniques that will improve CF and DND capabilities to monitor their networks continuously for soft attacks. This will include methods for detecting and understanding intrusions and attacks on fixed and mobile networks, and for modelling and visualizing network states.

(C) **Automated network discovery, assessment and tool development for network exploitation:** Develop automated tools and techniques to discover, assess and exploit the state of the information networks of a potential adversary in support of CF operations. An understanding of these techniques is also needed to enable the development of appropriate defences for one's own network.

# Precision Weapons

## Definition

Precision Weapons provide the capability of accurately and rapidly engaging (high-value) targets with reliability, from short and long stand-off distances for mission accomplishment, while at the same time minimizing collateral damage. The R&D concentrates on the technologies to assess and improve the effectiveness of precision weapons and to determine the CF's vulnerabilities to such weapons.

## Trends, Threats and Opportunities

Technological advances will continue the trend towards weapons having increased range, autonomy, precision and lethality, and a wide range of delivery systems. More precisely, weapons will fly at longer ranges and at higher velocities (in the hypervelocity regime), where novel propulsion technologies will be needed. Automatic target acquisition and recognition capabilities will be aboard the missiles and they will be equipped with communication links and integrated to the battlespace for battle damage information and assessment. Autonomous unmanned vehicles (for the air, land as well as underwater environments) will be used as precision weapons for future missions deemed too dangerous for conventional systems.

It is expected that in 2020, the CF will make increasing use of a long-range, precision strike capability. This will require R&D in sensors, processing technologies, propulsion and guidance

*Evaluation of grid fins for missile aerodynamic control.*

and control. Innovative technologies like pulse detonation engines need to be investigated because of their potential important pay-off in effectiveness as compared to more conventional propulsion means. New aerodynamic phenomena peculiar to very high and very low velocities will have to be understood. Non-traditional configurations such as waveriders, non-circular cross sections, lifting bodies and stealth shapes will need to be looked at for the upper velocity regime. MEMS for air vehicle drag reduction and aerodynamic control offer interesting possibilities and will be investigated.

Launch, guidance and control development for this new class of weapons will have to be paced with parallel advances in electronics, information processing techniques and other related fields. Smaller and more integrated sensors will be required for target acquisition and discrimination under all environments, and they will ensure that the best performances can be achieved day and night for all target types. Because a weapons system builds on a wide range of technologies, it is essential that these developments be properly integrated to make these platforms capable of delivering – very precisely and with minimal collateral damage – a wide range of payloads against rapidly moving time critical targets located at very long range.

To analyze and optimize the precision and performance of weapon systems, M&S will be essential to evaluate the performance of each sub-component, their interaction when integrated in the overall system, their mission effectiveness, as well as their linkage to other sets of data (geo-spatial, operational scenario) and to the integrated battlespace.

## Strategic Objectives

(A) **Propulsion technologies for optimum energy management of low observable air vehicle systems:** Develop innovative propulsion devices for small payload and short-range applications, and more efficient, more energetic propulsors and propellants for hypersonic and long stand-off applications. Emerging propulsion technologies include liquid/solid fuel ramjets, variable flow ducted rockets, scramjets, pulse detonation engine high-density fuels, endothermic fuels, composite motor cases, rocket motor energy management and low observables.

(B) **Delivery control techniques and systems for improved weapon system performance:** Develop advanced trajectory control systems such as reaction jets, lattice fins for improved maneuverability and increased agility of air vehicles. Non-traditional weapon configurations such as waveriders, non-circular cross sections, lifting bodies and stealth shapes will be investigated for precise delivery of payloads.

(C) **Target acquisition and discrimination for improved weapon effectiveness against time critical targets:** Develop multi/hyperspectral sensors, coupled with sensor fusion, to ensure a superior capability for target recognition, discrimination and acquisition. Also, techniques will be developed for the integration of artificial intelligence for autonomous target acquisition by missiles and for on-board processing of data for battle damage information and assessment into seeker and guidance and control subsystems of precision weapons.

(D) **M&S to improve the effectiveness of weapons system platforms:** Develop M&S techniques to optimize the precision and performance of weapon systems, by analyzing the integration of each sub-component into the overall system, and evaluating their mission effectiveness by allowing the selection of options in a realistic environment. M&S will also be used to plan, train and rehearse for future joint and combined (international) operations in a virtual interoperable environment.

# Weapons Performance and Countermeasures

## Definition

Weapons Performance and Countermeasures focuses on the phenomena taking place when a weapon interacts with a target. These effects can be examined from a weapon perspective (lethality), from a target or platform perspective (vulnerability) and from the standpoint of weapon system detection.

## Trends, Threats and Opportunities

Future combat platforms/systems will be light, highly maneuverable, potentially uninhabited and will require weapon systems to match the needs of the 2020s. They will have to operate in a variety of combat environments, including urban operations, which is likely to be amongst the most demanding in terms of finding the targets and of reducing collateral damage. On the other hand, the improved lethality of future weapon systems will increase the vulnerability of our own soldiers and platforms (air, naval and land).

In recent years, significant progress has been made in material science and synthesis as they relate to energetic materials. New more powerful highly energetic crystals, energetic binders, nanoparticles, doped particles, polymorphic additives, thin coatings and metastable materials, as well as heterogeneous explosive charges, have the potential to significantly increase the amount of energy delivered by energetic materials, as well as our ability to manage the delivery of that energy, be it for explosives or propellants. Highly controlled energy release processes, new materials and focusing phenomena have the potential to significantly enhance weapon effectiveness (blast, shaped charge, explosively formed projectile, etc). Volumetric weapons (including thermobaric and fuel air explosives) pose severe blast and incendiary threats to soft targets and infrastructures and will need to be understood and exploited.

As a further R&D challenge, the launch velocities of missiles and projectiles must be increased to reduce their engagement time and increase their lethality. During the next 15-20 years, advanced, more powerful High Energy LOw Vulnerability Ammunition (HELOVA) gun propellants will provide high velocity propulsion, improved ignition systems and high operating pressure rocket propellants for missiles. The development of electro-magnetic guns and full electro-thermo-chemical propulsion will continue. Directed energy weapons, including dazzling/blinding lasers, are likely to become more prominent on the future battlefield. High power microwaves may be used with great efficiency against systems with vulnerable electronic components, such as communication and computer systems, radars, imagers and guidance and control systems. Computer-based M&S will be critical for designing, assessing and optimizing the effectiveness of future weapon systems.

Concealed explosive objects such as land mines and unexploded ordnance are a constant threat to the CF, which will only increase with time. In the future, the shift in scenarios toward asymmetric warfare will expand the nature of threats to include improvised explosive devices, individual small arms and combined explosive/CBR terrorist devices. (As an associated concern, the need to exercise ongoing environmental stewardship over test and training facilities that have undergone intensive use, by both the CF and its allies, must be investigated to ensure their long-term availability for the real-time training of the CF.)

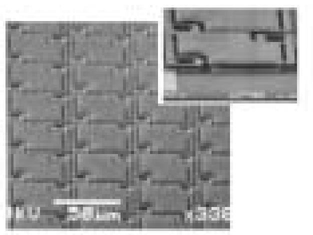
## Strategic Objectives



(A) **Novel materials and energy release processes to enhance the performance of weapons:** Develop a thorough understanding of explosives-materials interaction phenomena to permit timely threat assessments, and develop effective countermeasures for protecting both the warfighter and equipment. The exploitation of ongoing advances in material science and technology will provide higher energy density, higher and better-controlled combustion and detonation velocity, increased blast effect etc. while retaining insensitive munitions properties of energetic materials. Research will focus on producing new types of energetic ingredients through novel manufacturing processes. Extensive use of computer-based modelling of molecular dynamics will also be made.

(B) **Concepts for developing and deploying increased lethality and non-lethal weapons systems:** Develop a better understanding of the physics of the various classes of warheads with enhanced destructive energy and study their effectiveness against advanced armours (e.g. passive, reactive, active) and in the urban environment for minimal collateral damage. Three classes of weapons will be investigated: chemical energy release from an energetic material directly on a target (e.g. blast, explosively formed projectile, shaped charge); chemical energy release to launch preformed projectiles (e.g. kinetic energy penetrator, fragmentation/blast devices); and emerging non-conventional weapons (e.g. non-lethal weapons, high power microwaves, electromagnetic pulse, high energy lasers, etc.).

(C) **Countermeasures for improved survivability:** Develop much improved protection materials and systems for personnel and both mobile and fixed platforms. Detailed vulnerability and lethality (V/L) analysis needs to be performed prior to any design of new survivability systems. To carry out this task, new V/L assessment tools for novel and enhanced threats will be developed. Passive, active and reactive protection systems that have faster response time and are more effective in defeating future munitions will be pursued. Improved sensor systems (e.g. hyperspectral imaging, nuclear



*Autonomous microsystem for ground observation*

methods, nuclear quadrupole resonance) will be developed for the detection and identification of area defence weapons, unexploded ordnance and improvised explosive devices, with special emphasis on reliability and reduced false alarm rates.

(D) **Sustainable training and technologies to maintain availability of DND training facilities:** Advance the current state of knowledge on the nature and extent of the residual contamination of training sites and develop solutions to ensure the sound management of these facilities as sustainable resources. The R&D will address environmental matters related to unexploded ordnance on test and training ranges and contribute to sustaining range activities while ensuring environmental stewardship and regulatory compliance.

# Emerging Materials and Biotechnology

## Definition

This R&D Activity reflects the increasing importance of advanced or novel materials, both organic and inorganic, to military and civilian systems. Advances in materials technology and biotechnology have become technology drivers, rather than responses to requirements. R&D will concentrate on applied research in materials, biotechnology and advanced power sources, including some technology demonstration of applications in these areas.

## Trends, Threats and Opportunities

Commonly, materials are regarded as merely the fabric of structural systems, and have been all too often selected as an afterthought, or in response to a loading requirement.

“Functional materials” are those materials that have performance characteristics additional to their load-bearing capability, such as piezo-electric, magneto-strictive and semi-conducting materials. For some time, advances in functional materials have inspired design changes in acoustic transducers; recent advances in materials technology has encouraged investigation of materials-driven design in an expanded range of applications. New high-strain functional materials (such as di-electric polymers) will rival the performance of animal muscle tissue, revolutionizing the capability of transducers and actuators.

Successful laboratory-scale demonstrations of “smart materials” that adapt, or respond to their environments create an opportunity for large-scale development: smart sensors and actuators, adaptive control systems and smart structures.

Imagine an adaptive aircraft wing that alters its shape in response to flight conditions, replacing hinged flight control surfaces. Combat uniforms made of smart fabrics (with a biotechnology component) would satisfy traditional comfort and durability requirements, and also would have inherent resistance to chemical and biological threats with an adaptive camouflage capability.

Molecular manufacturing – the ability to design devices that are only tens to hundreds of atoms in dimension, and to manufacture them one atom at a time – promises rich rewards in electronics, sensors and tailored materials. Military applications include massive computing capacity, active/passive structural damping and signature control in military platforms, life cycle health monitoring, smart protective clothing, embedded warfare sensors, biological detectors and variable camouflage. This R&D Activity includes the application of bio-molecular self-assembly (how nature produces a substance with unusual properties) to the controlled synthesis of materials.

Biotechnology presents both threats and opportunities. Adversaries will be able to modify or mask threat agents with ease, making them more infectious, more damaging, harder to prevent, more difficult to detect and more difficult to treat. It will be possible to produce significant quantities of toxins and bio-regulators as non-lethal military weapons. To counter the new threats, biotechnology will allow production of new treatments and will accelerate production of improved vaccines and preventatives. Developments in biomedical engineering will combine advances in information processing, miniaturization and biotechnology to provide real-time monitoring of health status indicators, automated treatment delivery, field-tolerant diagnostic devices and triage aids.

Military operations are becoming increasingly dependent upon electrical propulsion, electronic systems and wireless communications, leading to a growing demand for electrical power. No technology can satisfy all the needs, but the number of power source variants must be minimized. The answer lies in developing electro-chemical, electro-mechanical and renewable power sources with an eye towards combining the best properties of each in hybrid power sources and improving power delivery components.

## Strategic Objectives

(A) **Functional materials for transducers, actuators and smart structures:** Develop controls and structures capable of optimal response to external loads to overcome the constraint of the performance of functional materials on the performance of transducers, actuators and control devices. The introduction of high-strain functional materials promises greater benefits than re-shaping existing designs.

(B) **Substitution of conventional materials for improved mechanical and chemical performance of materials:** Investigate tailored polymers as substitute materials by careful selection and formulation of materials and re-examination of design parameters for optimal exploitation of material capabilities. Develop advanced modelling techniques to predict mechanical and chemical performance, and to perform feasibility studies. Develop design capabilities, micro-structural characterization methods and qualification testing processes for environmentally compliant coatings systems.

(C) **Synthesis of materials by molecular manufacturing techniques for high performance military applications:** Develop and apply techniques for the synthesis of high-performance materials for tribological or combustion applications technology as traditional metallurgical techniques cannot yield the necessary combination of material toughness and hardness required for military systems. Molecular-level material assembly provides some promise, as R&D will initially focus on aeronautical applications, with spin-off to other applications and problems as experience develops.

(D) **Biotechnology for the environmental protection of CF personnel:** Develop coatings and materials with improved characteristics and performance to protect personnel in adverse environments using Biotechnology applied to material sciences.

(E) **Advanced power sources to meet the demands of future military platforms and personnel:** Improve electrical sources needed to meet the growing power demands in the platforms and equipment considered high priority by the CF. Work in this area will include R&D in:

1) novel materials and microfabrication techniques for electrochemical power sources;
2) storage and production of hydrogen and the reforming of logistic fuels for fuel cells; and
3) pulse power and platform integration technologies.

# Signature Management

## Definition

*Underwater radiated noise experiments.*

R&D in Signature Management addresses an ensemble of technologies related to the reduction of detectable emissions and fields (signatures) and the management of risk of detection, classification and targeting of assets by opposing forces. (This R&D Activity does not consider counter-detection and communication emission management, which are covered in other R&D Activities.) The technology is aimed at arranging the signatures of our military assets to be undetectable against the background, to the greatest degree possible. The object of Signature Management is to make operational commanders aware of signatures and the effects of their actions and decisions on vulnerability.

## Trends, Threats and Opportunities

Military forces already employ stealth to their advantage, but must continually upgrade their capability to counter the ever-increasing variety and sophistication of opposed sensor systems. Passive signatures (acoustic target strength, static electric and magnetic fields, radar cross section, optical retroreflectivity, etc.) can be reduced by applying novel materials, design, construction or shaping. Active signatures (radiated acoustic noise, low frequency electromagnetic, infrared plume, etc.) primarily require source level reductions and appropriate shielding and shaping. Both can be reduced by development of specific countermeasures.

CF assets are at risk from illumination by opposing forces, or from emissions from our own platform systems, including our active sensor equipment. Important signatures to be managed include acoustic, static and low frequency electric and magnetic fields, RF (radar, communication) and EO (in the visible, IR and UV bands). The threat comes from the increased sophistication of sensors, analysis afforded by computer processing and the potential for an adversary to exploit any possible emission. At present, the warfighter has an inadequate understanding of the risk to his operations, posed by his own signature, and the effects of his signature on his own sensors.

Signature reduction technologies increase survivability by reducing the enemy's ability to target our forces. They enhance our ability to engage adversaries anywhere in the battlespace, and they enhance CF sensor performance.

## Strategic Objectives

(A) **Underwater signature prediction and reduction for improved survivability and sensor effectiveness:** Investigate marine platform acoustics, electromagnetics and wake characteristics to assess potential solutions to current and future signature problems. The program will develop analysis, modelling and countermeasure capabilities, perform full-scale measurements, provide independent technical advice to DND, preserve the knowledge base required for major acquisitions and solve in-service problems.

(B) **Surface and air signature prediction and reduction for improved survivability and sensor effectiveness:** Investigate EO/IR, radar and RF signatures of vehicles and platforms to assess potential solutions to current and future signature problems. These include the development of adaptive materials and techniques for camouflage, the modelling of EO/IR camouflage, the investigation of monostatic and bistatic Radar Cross-Section (RCS) of Radar Absorbent Material (RAM)-covered platforms, the development of techniques for reducing RCS by shaping, the improvement of RCS measurement and modelling techniques (in particular for locating RCS "hot" spots), the investigation of multispectral and hyperspectral EO/IR signatures and the modelling of IR and UV signatures of platforms.

(C) **Methods to integrate and optimize total platform Signature Management:** Develop an integrated approach to Signature Management to ensure that improvements made to a signature, associated with one sub-system, do not have an adverse effect on another. The approach aims to optimize Signature Management across the whole platform and signature domain, and it applies to naval platforms, land vehicles and air assets. Develop Signature Management tools and methodologies to provide a commander and his combat control system with real-time information about the signatures being emitted by his platforms and their relative importance. Signature information will be integrated into a single user-friendly threat assessment and vulnerability evaluation tool for each platform and provide guidance for signature reduction.

(D) **Susceptibility assessment and mitigation for effective deployment of countermeasures:** Improve warfighter understanding of his susceptibility to being targeted and what platform and Signature Management can accomplish in minimizing this susceptibility. As well, the warfighter must understand the operational effectiveness of deception and affordable countermeasures. While the ideal situation might be to find technical solutions to make all platforms or other assets invisible, such a goal is not affordable or realistic. The objective addresses how to use countermeasures effectively, not their development, and how best to employ coordinated tactics and appropriate countermeasures with respect to all relevant signature dimensions during an engagement.

# Platform Performance and Life Cycle Management (LCM)

## Definition

This Activity involves the enhancement of performance, safety and LCM of military platforms. “Performance” has a broad scope: the ability to move and manoeuvre in operational environments, the requirements for powering and propulsion and efficiency. “Safety” is restricted to those basic platform attributes not otherwise linked to warfare-related R&D activities.

## Trends, Threats and Opportunities

Canadian military fleets are made of limited numbers of platform types or classes, with anticipated service lives of about 35 years. The modern pace of technology change in embarked systems is at odds with such long service lives. R&D is critical to mitigating the effects of operating obsolescent platforms for terms longer than would be acceptable in civil practice.

A corollary of LCM is that of safety. Canada operates some unique fleets and cannot always rely on other nations for management of

*CP-140 Aurora long range patrol aircraft.*

operational safety. In this area, on-demand consultation with operators and life cycle managers provides critical in-service support, and identifies R&D opportunities to extend the operational serviceability of platforms and equipment.

Fluid dynamic flows directly affect the powering, signatures and dynamics of air and marine platforms, and they form the principal environmental loads on their structures. Understanding of structural mechanics is necessary to ensure platform structural integrity, both to establish operational limits of new platforms, and to manage their safe and economic use throughout the life cycle. Materials science provides support to structural integrity, propulsive machinery and systems operations. Platform and systems life cycles demand insertion of new materials and innovative management of existing ones. Given the anticipated service lives of our platforms, opportunities to exploit whole-platform innovations are rare. In this environment, the CF must focus its efforts on integration of new technologies and systems (e.g., weapons systems) into existing platforms and on ensuring that the process of procuring new vehicles results in robust choices that have long-term flexibility and growth potential. Multi-disciplinary design optimization tools are essential to achieve this goal.

Simulation for training operators is well established, and it is becoming more common for training of maintenance personnel. When new equipment is introduced or LCM processes are changed, simulations are used to analyze LCM issues to meet current or anticipated CF resource availability, conduct "what if" studies, develop minimum cost/scheduled downtime approaches and examine personnel and training requirements. Although appropriate simulation technology already exists, work needs to be done to generate simulations with acceptable fidelity for LCM applications.

## Strategic Objectives

(A) **Reliable computational fluid dynamics for complex vehicle configurations and extreme flows:** Exploit current computational fluid dynamics methods to increase our understanding of extreme flows found in military applications. Investigate new methods to overcome the limitations of current methods. As computational technology improves, use it to provide solutions to the demanding requirements of complex geometric configurations. Explore the development of simpler methods that will provide fast, partial solutions to problem classes of interest.

(B) **Structural modelling for the insertion of advanced materials technology and LCM of military platforms:** Extend existing structural analysis models and numerical prediction capabilities to admit novel structural materials with their new or modified failure modes. Integrate discipline-related models into multi-disciplinary design and optimization processes that ensure appropriate weighting of performance and costs during the initial and modification/repair design phases. Additionally, extend structural analysis methods and in-service health monitoring methods to treat in-service structures efficiently and to enable future LCM based on validated simulation models. Develop analytical processes to fully understand degradation mechanisms caused by platform extension beyond design life and develop strategies and technologies, such as material substitution and coatings, to overcome them.

(C) **Advanced materials technology and modelling for improved LCM of military propulsion systems:** Develop cost-effective LCM techniques, new approaches to damage disposition and structural or high-temperature materials and coatings to address unique military requirements for propulsion system and propulsor performance. Integrate discipline-related propulsion performance, hardware design and advanced control systems into multi-disciplinary system design and optimization processes that ensure appropriate weighting of performance and cost during the initial and modification design phases to satisfy unique performance goals (efficiency and signature management) under LCM constraints.

(D) **Modelling of operational limits and safety for military platforms to enhance operational effectiveness and survivability:** Evaluate the integration of new systems into existing vehicles to enhance operational effectiveness and understand platform dynamics and stability as well as structural integrity, and also to provide the physical basis for simulation of platform systems and predictions of human performance.

# Multi-Environment Life Support Technologies (LST)

## Definition

LST sustains or enhances the effectiveness and individual protection of personnel operating from specialized combat platforms/systems, such as aircrew, submariners and divers, or soldiers operating in harsh environments. These operational environments preclude optimal exploitation of the platforms/systems capabilities, or endanger life, without the protection of LST.

## Trends, Threats and Opportunities

There is a revolution in materials sciences, which offers the potential for the development of materials and fabrics with novel and unique characteristics to improve protection and optimize individual performance and comfort. The challenge will be to capitalize on such advances and those in related technology areas such as sensors and computer processing power, and to integrate them into life support equipment/ system concepts.

The diverse battlespace and lethality of weapons inherent in the RMA concept of operations, the growing requirements for compatibility and interoperability with allies and current projections for CF roles and combat platforms for the next two decades, all indicate that the CF will require a broader range and greater sophistication of LST – both individual and collective – in aerospace, land and underwater operational environments.

*Arctic chamber replicates harsh winter environments.*

For example, the technological capabilities of current combat aircraft will continue to challenge human physiological tolerances of acceleration forces. If there is a decision to replace the current combat aircraft then the next generation of G-agile aircraft, some of which may operate at space equivalent altitudes, will demand novel LST. For divers, there is a continuing progressive evolution from SCUBA air to modern mixed-gas and oxygen re-breathers, surface supplied systems, remotely operated vehicles and submersibles. Planning related to the recent submarine acquisition includes escape and rescue contingencies, which will require supporting new LST.

The challenges extend beyond the realm of simply developing LST to cope with the limitations to human survival in such environments. These platforms, and those planned for the future land force, will incorporate sensor and information display technologies, which will provide enhanced situational awareness. This enhanced situational awareness can only be maintained if the LST are developed in a manner that preserves both physiological and cognitive capabilities.

Advances in other research domains will likely facilitate remote monitoring of vital physiological, cognitive and behavioural responses during LST-supported operations. Such monitoring will not only be useful in developing adaptive LST equipment, but it can also be exploited to enhance situational awareness for command and control purposes and for modelling and simulation.

## Strategic Objectives

(A) **Adaptive LST for improved protection against operational and environmental challenges:** Incorporate nanotechnology, sensor technology and biotechnology in integrated biological sensors and signal processors which could be applied to the development of "smart", reactive and "sacrificial" materials. This will lead to improved individual protective ensembles and engineering controls against environmental and operational threats. Such advances, when exploited together with knowledge of physiological and behavioural limitations and ergonomics, should also lead to markedly improved design and integration of LST.

(B) **Countermeasures to sustain and enhance human performance in adverse environments:** Characterise the impact of adverse environmental factors on individual physiological and cognitive performance. Develop related physiological and cognitive countermeasures and protective systems and techniques to maintain comfort and performance under adverse conditions.

(C) **Remotely monitor, register and transmit vital physiological, cognitive and behavioural signals for "anticipatory" life support control systems:** Develop systems to remotely monitor, register and transmit vital physiological, cognitive and behavioural signals for use in LST, C2 systems and for M&S. Integrate these systems with neural networks for "anticipatory" life support control systems and removal of the human from otherwise hazardous environments.

# Operational Medicine

## Definition

Operational Medicine R&D addresses knowledge, procedures and materiel needed to maintain physical and psychological health, to preserve operational capacity and to facilitate the early return to duty of affected military personnel. The R&D includes: adequate prophylactic measures to prevent injury and loss of operational effectiveness; materials, devices and procedures to rapidly and precisely identify, manage and treat trauma, and to treat infection and acute injury from operational hazards and weapons. The objective is to reduce or to eliminate injury or the operational impact of injury through the provision of early warning indicators, and diagnostic and triage aids to confirm injury status in the field, and to facilitate medical management in clinical settings behind the operational area.

## Trends, Threats and Opportunities

The requirements for preventing, diagnosing and treating combat casualties need to be in line with the emerging battlespace and future weapon effects, as well as the contingency operations that will occupy CF personnel. New asymmetric threats and the increasing emphasis on interoperability with the US and other highly capable allies in coalition actions and in contingency operations will require integrated medical countermeasures (such as approved devices, drugs and vaccines) and rapid diagnostic technologies. The requirement for regulatory

*A simulated casualty receives attention.*

approval of drugs and devices places additional procedural, cost and time burdens which begin in the research phases and extend through to development and deployment.

Military leaders are increasingly recognising the importance of CF health protection initiatives, not only for the battlefield, but also in humanitarian and peacekeeping missions. The availability of suitable medical countermeasures to endemic disease and to potential CB, occupational and environmental hazards has become a critical element in determining readiness, deployability and sustainment of operational capability. This is resulting in more requirements to provide protection and detection for a widening range of injury sources (e.g. accident, conventional weapons, CB hazards, non-lethal and newer weapons, combined injury and Toxic Industrial Materials (TIMs)) to reduce their operational impact.

The development of a non-invasive medical diagnostic aid system is of paramount importance in ensuring rapid and timely treatment of injuries, particularly those caused by blunt and blast trauma, and toxic hazards. Developments in biomedical engineering will provide advances in biosensors, imaging, information processing, miniaturization and biotechnology. This will result in new opportunities such as real-time monitoring of health status indicators, automated treatment delivery, field-tolerant diagnostic devices and triage aids for traumatic and other injuries.

Relevant technologies developed with private industry and academia are required to assure the development and application of products and capabilities required by the CF. In-house capabilities and expertise are essential to assure that solutions developed for clinical/civilian application are recognized, selected and developed to protect force health and to preserve operational capability. Medical management of injuries likely in operational environments will require knowledge of the mechanisms of CB agents and other toxic materials, psychological and physical injuries.

## Strategic Objectives

(A) **Devices, procedures and treatments for casualty management and diagnostics:** Develop devices, procedures and treatments to preserve life (physical and psychological), to stabilize injuries and to facilitate recovery. Diagnostics relate to robust, field-deployable methods and devices to identify indicators of trauma, disease or exposure to toxic threats, increasingly automated and linked to resource centres through telemedicine. Technologies include biomolecular engineering, M&S, embedded sensors, miniaturization, advanced materials and microelectronic components.

(B) **Produce new therapies, personal health monitoring systems and diagnostic aids:** Model specific therapies and exploit advances in biotechnology and computational chemistry/ CAD to produce new therapies. Recommend or develop personal health monitoring systems and diagnostic aids. Exploit advances in pharmacology to develop knowledge of the reactive components and actions of toxins and hazardous chemicals, detection and monitoring capabilities, as well as new specific treatments to prevent adverse actions of hazards and threats.

(C) **Prevention and treatment of both endemic and weaponized disease:** Develop procedures and barriers to prevent infection, vaccines (conventional, vectored and DNA-based vaccines) and non-vaccine methods such as antibodies or immune system modifiers. Develop treatments that include next generation antibiotics and antivirals. Develop improved devices to deliver therapies to sites of infection. Exploit advances in biotechnology to achieve required defensive / protective capabilities.

# Chemical / Biological / Radiological (CBR) Hazard Assessment, Identification and Protection

## Definition

Chemical, Biological and Radiological Defence (CBRD) involves the detection, identification, protection and consequence management of the CBRD threat agent spectrum. This spectrum ranges from "traditional" CBR weapons to

*Researchers pursue the latest technology to counter CB threats.*

novel, improvised or emerging threats including new nerve agents, radiological dispersion weapons and genetically engineered biological weapons agents and toxins.

## Trends, Threats and Opportunities

CBR hazards represent the original, most operationally significant and expanding asymmetric threats to the CF. The threat agent spectrum is increasing at a dramatic rate as a result of proliferation, new agent development, biotechnology and failures in appropriate infrastructure and control in states where contingency operations are required. To provide timely and accurate threat assessment and to develop effective countermeasures to protect the CF, an active and defensive research program in core scientific disciplines is required.

Asymmetric CBR threats provide an adversary with significant political and force multiplier advantages, such as disruption of operational tempo, interruption/denial of access to critical infrastructure and the promulgation of fear and uncertainty in military and civilian populations.

The trend towards increased development, deployment, applications and their proliferation will continue. The military use of toxic industrial materials is an increasing threat, which is readily available to any adversary. Genetically engineered or modified diseases and toxins have the potential for producing maximum casualties with minimal effort. Proliferation will continue to dramatically increase the threat from the use of CBR agents by states or terrorist organizations against unprotected civilian populations. Proliferation also poses an asymmetric threat against non-combatants outside the immediate theatre of conflict, including Canadians at home. As well, CBR agents will be developed against materials or weapons systems themselves. New threats of the future will be agents that attack rubber, advanced composites or electronic components.

Advances in biotechnology and biological sciences will result in much shorter development times for novel threat agents. As well, traditional threat indicators (research infrastructure, testing, production, weaponization and political will) may be hidden within legitimate research programs and not be visible to intelligence communities.

Development of effective countermeasures will have to be tied to realistic assessments of the threat. As the threat spectrum expands, it will not be possible to determine probable threat agents in advance. This will place an increased emphasis on rapid identification after first use. CBR detection will have to become more broad-based and accurate, and identification methods more rapid and disseminated. Networks of sensors and standoff detection capability will become increasingly available. Together, these capabilities will facilitate consequence management and reduce the operational and personnel impact of CBR hazards and asymmetric threats.

## Strategic Objectives

(A) **Hazard assessment and consequence management for enhanced decision-making:** Develop high fidelity model-based threat assessment to provide first responders, operational commanders and political leadership with increased situational awareness, accuracy and decision-aiding technologies. This includes modelling, simulation and field trial validation, fusing intelligence data, virtual reality and advanced computer techniques.

(B) **Detection, identification and diagnostics to overcome asymmetric threats:** Fuse nanotechnologies and biotechnologies to create new sensors to facilitate the development of remote, standoff detection systems and sensor platforms and packages. The integration of these with CBR hazard identification technologies will be a significant long-term challenge.

(C) **Individual and systems protection for advanced CBR countermeasures:** Develop systems level protection including, where possible, integrated commercial subsystems and technologies. Use biotechnology and advanced materials to develop or exploit integrated coatings and sensors. Electronics protection and the survival of other critical technological infrastructure must also be assured. Develop procedures and materials for safe and adequate decontamination of personnel, infrastructure and assets.

# Simulation and Modelling for Acquisition, Requirements, Rehearsal and Training (SMARRT)

*Soldiers hone skills on a simulated firing range.*

## Definition

SMARRT is concerned with M&S for examining future force concepts, for modern, affordable acquisition and for effective training and rehearsal of the future force. SMARRT R&D includes concept development and design, implementation, validation, verification and accreditation of models and simulations at all levels and for all classes (live, virtual and constructive) of simulation. Individual models or simulations can be linked together in virtual scenarios to provide a total analysis of the battlespace and provide for an analysis and choice of operational alternatives and the ability for operational crews to practice missions out of harm's way.

## Trends, Threats and Opportunities

M&S is an essential component behind Concept Development and Experimentation (CDE). Interactive synthetic environments are increasingly being used to examine future concepts and to identify future capabilities. They provide users with the opportunity to 'fight' a system in alternative (including future) scenarios and to develop doctrine for the future CF. This method can be used to assess technical feasibility and operational utility, the effectiveness of the human-machine interface, and procedures for exploiting technology. It will enable the evaluation of the effectiveness of proposed equipment or software in the environment in which they will be used and can provide an assessment of the effect of the specific equipment or capability on battle outcomes. Key tools behind this specific use of M&S in experimentation include, for example, High Level Architecture (HLA) and the Federation Development and Execution Process (FEDEP) model.

Cutting edge R&D will assist DND/CF in exploiting advanced acquisition concepts such as systems-of-systems methodologies, simulation based acquisition, integrated digital environments, life cycle planning and evolutionary acquisition. In this way, the time, resources and risks involved in the acquisition and LCM of new capabilities can be significantly reduced.

In training, simulations can enhance readiness by providing operators with the knowledge, skills, abilities and the confidence that they need to perform their military tasks. These are behavioural objectives requiring an appreciation of the psychological issues and human factors that govern the design and use of a simulator for effective transfer-of-training. Technology push from the education and entertainment industries affords opportunities for the exploitation of COTS products as a means of reducing the cost and improving M&S in synthetic environments. Future international operations will demand the ability to plan, train and rehearse in a virtual, interoperable environment. M&S provides the ability to prepare forces for specific operations by allowing practice and the selection of options in a life-like context.

## Strategic Objectives

(A) **M&S enablers for developing future force concepts and identifying future capabilities:** Develop the next generation of synthetic environments for use in CDE. These will identify and define the capabilities required by the future CF. R&D will include component reuse, conceptualization and symbology, and the representation of future technologies in synthetic environments. Current tools such as HLA, FEDEP and Synthetic Environment Data Representation & Interchange Specification (SEDRIS) will be applied and extended to identify and define future capabilities for specific CF initiatives.

(B) **Systems engineering and advanced acquisition concepts to modernize defence processes:** Develop and use advanced systems engineering methodologies, including systems-of-systems approaches, simulation-based acquisition, integrated digital environments, life cycle planning and evolutionary acquisition, to support the CF's defence modernization initiatives.

(C) **Human factors of SMARRT for human-in-the-loop and representation of human behaviour:** Exploit networking, virtual reality, human factors, visualisation and the latest advances in live, virtual and constructive simulations. The development, validation, verification and accreditation of models of human behaviour will be carried out to determine and enhance the usefulness and predictive validity of core models of individual and organization behaviours. This will involve drawing on human factors, M&S, HSI and software engineering to make better, early decisions. Artificial intelligence and advances in software engineering will be used to derive a greater understanding and better representation of human performance in simulations.

D) **Virtual models for optimization of platforms as integrated weapons systems:** Combine platform performance models with combat system models to produce virtual platforms capable of simulating all aspects of performance, especially in complex environments for which live exercises are difficult to arrange. This will facilitate the optimization of platforms as integrated weapon systems. This is expected to result in greater benefits than advances in individual technologies alone. The full benefit of collaboration with other nations and organizations will be facilitated by imposing compliance with HLA standards.

## Table 1: R&D Activity Linkages to Strategic Capabilities

Strategic Capabilities

| R&D Activities | Command | | | | Information & Intelligence | | | | Conduct Operations | | | | Mobility | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Strategic | Operational Domestic | Operational International | Tactical | Strategic | Operational Domestic | Operational International | Tactical | Strategic | Operational Domestic | Operational International | Tactical | Strategic | Operational Domestic | Operational International | Tactical |
| Command and Control Information Systems Performance and Experimentation | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● | | | |
| Information and Knowledge Management | ● | ● | ● | ● | ● | ● | ● | ● | | ● | ● | ● | | | | |
| Communications | | ● | ● | ● | ● | ● | ● | ● | | ● | ● | ● | | | | |
| Human Factors Engineering and Decision Support Systems | | ● | ● | ● | | | | | | ● | ● | ● | | | | |
| Command Effectiveness and Behaviour | ● | ● | ● | ● | | | | | | | | ● | | | | |
| Autonomous Intelligent Systems | | | | | ● | ● | ● | ● | | | | ● | | ● | ● | ● |
| Sensing (Air and Surface) | | | | | ● | ● | ● | ● | | ● | ● | ● | | | | |
| Underwater Sensing and Countermeasures | | | | | ● | ● | ● | ● | | ● | ● | ● | | | | |
| Space Systems | | | | | ● | ● | ● | ● | | ● | ● | ● | | | | |
| Electro-Optical Warfare | | | | | | | | ● | | | | ● | | | | |
| Radio Frequency Electronic Warfare | | | | | ● | ● | ● | ● | | | | ● | | | | |
| Network Information Operations | | | | | ● | ● | ● | ● | ● | ● | ● | ● | | | | |
| Precision Weapons | | | | | | | | | | ● | ● | ● | | | | |
| Weapons Performance and Countermeasures | | | | | | | | | | ● | ● | ● | | | | |
| Emerging Materials and Biotechnology | | | | | | | | | | | | ● | | | | ● |
| Signature Management | | | | | | | | | | ● | ● | ● | | | | |
| Platform Performance and Life Cycle Management | | | | | | | | | | ● | ● | ● | | ● | ● | ● |
| Multi-Environmental Life Support Technologies | | | | | | | | | | | | ● | | | | |
| Operational Medicine | | | | | | | | | | ● | ● | ● | | | | |
| Chemical / Biological / Radiological Hazard Assessment, Identification and Protection | | | | | | | | ● | | | | ● | | | | |
| Simulation and Modelling for Acquisition, Requirements, Rehearsal and Training | | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● | | ● | ● | ● |

| Protect Own Forces | | | | Sustain | | | | Generate Forces | | | | Coordinate with Other Government Initiatives | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| STRATEGIC | OPERATIONAL DOMESTIC | OPERATIONAL INTERNATIONAL | TACTICAL | STRATEGIC | OPERATIONAL DOMESTIC | OPERATIONAL INTERNATIONAL | TACTICAL | STRATEGIC | OPERATIONAL DOMESTIC | OPERATIONAL INTERNATIONAL | TACTICAL | STRATEGIC | OPERATIONAL DOMESTIC | OPERATIONAL INTERNATIONAL | TACTICAL |
| | | | | ● | | | | | | | | | ● | ● | |
| | | | | | | | | | | | | | ● | ● | |
| | | | | | | | | | | | | | ● | ● | |
| | | | | | | | | | | | | | | | |
| | | | ● | | | | | ● | ● | ● | | | | | |
| | | | ● | | | | | | | | | | | | |
| | ● | ● | ● | | | | | | | | | | ● | ● | |
| | ● | ● | ● | | | | | | | | | | ● | ● | |
| | ● | ● | | | | | | | | | | ● | ● | ● | |
| | | | ● | | | | | | ● | ● | | | | | |
| | ● | ● | ● | | | | | | ● | ● | | | | | |
| ● | ● | ● | ● | | | | | | | | | | ● | ● | ● |
| | ● | ● | ● | | | | | | | | | | | | |
| | ● | ● | ● | | | | | | ● | ● | | | | | |
| | ● | ● | ● | | ● | ● | ● | | | | | | ● | ● | |
| | ● | ● | ● | | | | | | | | | | | | |
| | | | | | ● | ● | ● | | | | | | ● | ● | |
| | ● | ● | ● | | ● | ● | ● | | | | | | ● | ● | |
| | ● | ● | ● | | ● | ● | ● | | | | | | | | |
| | ● | ● | ● | | ● | ● | | | | | | ● | ● | ● | ● |
| ● | ● | ● | ● | | | | | ● | | | | ● | ● | ● | ● |

**Table 2: List of Acronyms**

| | |
|---|---|
| **A** | |
| AIS | Autonomous Intelligent Systems |
| ASW | Anti-Submarine Warfare |
| ATR | Automatic Target Recognition |
| **B** | |
| BDA | Battle Damage Assessment |
| **C** | |
| C2 | Command and Control |
| C2IS | Command and Control Information Systems |
| C3I | Command, Control, Communications and Intelligence |
| C4I | Command, Control, Communications, Computers and Intelligence |
| CAD | Computer Assisted Design |
| CB | Chemical Biological |
| CBR | Chemical, Biological and Radiological |
| CBRD | Chemical, Biological and Radiological Defence |
| CDE | Concept Development and Experimentation |
| CF | Canadian Forces |
| COTS | Commercial Off The Shelf |
| **D** | |
| DIN | Defence Information Network |
| DNA | Deoxyribonucleic Acid |
| DND | Department of National Defence |
| DRDC | Defence Research and Development Canada |
| DSS | Decision Support Systems |
| **E** | |
| ECM | Electronic Countermeasures |
| EM | Electromagnetic |
| EO | Electro-Optical |
| EOCM | Electro-Optical Countermeasures |
| EOSM | Electro-Optical Support Measures |
| EPM | Electronic Protection Measures |
| ESM | Electronic Support Measures |
| EW | Electronic Warfare |
| **F** | |
| FEDEP | Federation Development and Execution Process |
| **G** | |
| GOTS | Government Off The Shelf |
| **H** | |
| HELOVA | High Energy LOw Vulnerability Ammunition |
| HFE | Human Factors Engineering |
| HLA | High Level Architecture |
| HSI | Human Systems Integration |
| **I** | |
| IED | Improvised Explosive Devices |
| IFF | Identification, Friend or Foe |
| IKM | Information and Knowledge Management |
| IO | Information Operations |
| IR | Infrared |
| ISR | Intelligence, Surveillance and Reconnaissance |
| ISTAR | Intelligence Surveillance Target Acquisition and Reconnaisance |
| IT | Information Technology |
| **L** | |
| LCM | Life Cycle Management |
| LST | Life Support Technology |
| **M** | |
| M&S | Modelling and Simulation |
| ManPAD | Man Portable Air Defence |
| MCM | Mine Countermeasures |
| MEMS | Micro Electromechanical Systems |
| **R** | |
| R&D | Research and Development |
| RAM | Radar Absorbent Material |
| RCS | Radar Cross-Section |
| RF | Radio Frequency |
| RMA | Revolution in Military Affairs |
| **S** | |
| S&T | Science and Technology |
| SEDRIS | Synthetic Environment Data Representation & Interchange Specification |
| SMARRT | Simulation and Modelling for Acquisition, Requirements, Rehearsal and Training |
| STA | Surveillance and Target Acquisition |
| **T** | |
| TD | Torpedo Defence |
| TIM | Toxic Industrial Material |
| TIS | Technology Investment Strategy |
| T/R | Transmit/Receive |
| **U** | |
| UAV | Unmanned Air Vehicle |
| UGV | Unmanned Ground Vehicle |
| UUV | Unmanned Underwater Vehicle |
| UV | Ultraviolet |
| UWW | Underwater Warfare |
| **V** | |
| V/L | Vulnerability and Lethality |

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