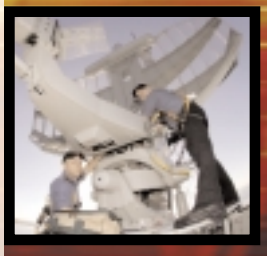
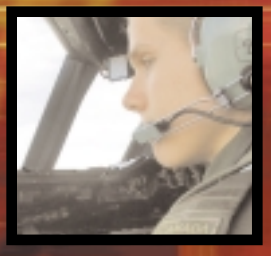
National Defence
Défense nationale

Defence S&T Strategy

Science and Technology for a Secure Canada

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Science and Technology for a Secure Canada

Nations and societies in the 21st century are undergoing rapid change. As a result, new defence and national security challenges have arisen. In response to those challenges, the Canadian Forces are undergoing transformation.

FOREWORD

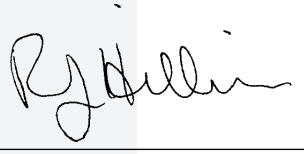
Due to a complex set of factors, nations and societies in the 21st century are undergoing rapid change. As a result, new defence and national security challenges have arisen. In response to these challenges, the Canadian Forces are undergoing transformation.

Science and Technology (S&T) can effectively support this transformation by contributing directly to the advancement of Canadian military capabilities. It enables superior situational awareness and decisive engagement across the increasingly complex spectrum of operations demanded of the Canadian Forces at home and abroad. The department's strong but selective defence S&T capability is essential to provide smart buyer and smart user advice, to share the burden of technology development with our allies, to avoid strategic surprise, to challenge existing doctrine and training, to envisage new concepts and doctrine, to develop and sustain essential military capabilities, weapon systems and supporting infrastructure, and to deliver these capabilities to the end-user — the Canadian Forces.

However, to fully realize this potential requires the ability to rapidly identify and adapt to new opportunities presented by S&T, to effectively coordinate the efforts of the many players across the defence institution, to build an enduring knowledge base covering key domains of S&T and to apply this knowledge across the full spectrum of defence activities.

The effective direction, delivery and exploitation of the departmental investment in S&T requires a team effort across the Department of National Defence and the Canadian Forces that is appropriately linked to other government departments, our allies, industry and academia. Equally important is that S&T providers and S&T consumers work together to harness the full potential of S&T to impact on Canada's defence and security priorities.

We are pleased to approve the **Defence S&T Strategy.** This first-ever pan-departmental initiative for science and technology highlights the importance of our departmental investment in S&T and will guide it over the course of the next five years by building strengthened interactions among the key stakeholders within an effective governance structure. We are confident that the implementation of this strategy will derive maximum benefit for our sailors, soldiers, and air men and women. We expect that all members of the Department of National Defence and the Canadian Forces will work together *to collectively harness Science and Technology for a secure Canada*.



R.J. Hillier
General
Chief of the Defence Staff

Ward P.D. Elcock
Deputy Minister

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EXECUTIVE SUMMARY

Science and Technology (S&T) plays a central role in military affairs and contributes to the advancement of military capabilities. It also affects the global geo-political and economic systems which shape Canada's interests and, indirectly, the roles assigned to its military.

The global advancement of S&T in this new era presents a significant opportunity for rapid and cost-effective improvements in the Canadian Forces' capabilities that provide decisive advantage. At the same time, this proliferation provides to Canada's adversaries the potential to use asymmetric means to counter our military capabilities or to target Canada's vital interests. Therefore, S&T presents both opportunities and threats that influence decisions regarding the departmental S&T investment.

Through the investment made in S&T, the Department of National Defence and the Canadian Forces recognize the important role that S&T plays in contributing to Canadian Forces transformation and operations, and to the alignment of the defence institution with both the transformation and wider government agendas.

The **Defence S&T Strategy** establishes the conditions to maximize the impact of the departmental S&T investment by ensuring that it is aligned with priorities, is properly harnessed to be a force multiplier and is duly supportive of the defence institution and its core business processes. The strategy is intended to guide the appropriate positioning of this investment so that S&T informs, enables and responds to Canada's defence and security priorities where the Canadian Forces and the department are expected to contribute. Specifically, the investment is expected to support decision making and to resolve important problems; to anticipate, assess and advise on the implications of emerging and potentially disruptive S&T; and to assess, mature, position and transition technologies for the benefit of the Canadian Forces and the department.

The departmental S&T investment will be managed through the **Defence S&T Enterprise**, a matrix organization that connects those within the Canadian Forces and the department that direct, deliver and exploit the outputs from the investment. It achieves maximum impact through coordination and harmonization of effort. Governance of the Enterprise resides within the larger departmental governance structure, wherein the Defence Management Committee provides strategic oversight. Functional authority for the Enterprise rests with the Assistant Deputy Minister (Science and Technology).

S&T informs, enables and responds to Canada's defence and security priorities.

The Enterprise provides a window on the global S&T knowledge base. As such, it maintains purpose-built linkages with a number of external stakeholders, including other government departments and central agencies, the defence and security S&T community of Canada's allies, and Canadian industry and academia.

The Enterprise manages the departmental S&T investment taking into consideration four interdependent perspectives: contribute to **mission-critical outcomes**; exploit S&T outputs; produce S&T outputs; and build S&T capabilities.

Success in implementation of the **Defence S&T Strategy** is measured through its ability to position the departmental S&T investment to demonstrate eight key attributes. The primary measure of success is that the investment will derive maximum **impact**, or value-for-money. Six **enabling attributes** assist the Defence S&T Enterprise in focusing its approach: linkage, innovation, excellence, leverage, agility and balance. Finally, underpinning the effectiveness of the Defence S&T Enterprise is appropriate **governance**.

Implementation of the strategy is incremental, to align effectively with the broader ongoing Canadian Forces transformation and departmental alignment agendas. Implementation objectives will be reviewed and adjusted annually as part of the Enterprise's governance.

The plan for implementation, called "Moving Forward Together", comprises four interdependent **action areas**. Each area addresses specific **deliverables**, developed and refined iteratively over multiple years, as outlined below.

Over the years, the departmental S&T investment has achieved an excellent record of delivering critical scientific and technological support to the Canadian Forces and the Department of National Defence. The **Defence S&T Strategy** will ensure that S&T is judiciously utilized into the future to contribute to an effective Canadian Forces and to a secure Canada.

Action One:

Establish an integrated governance mechanism

Deliverables: Defence S&T Enterprise Charter; communications plan; process model for the S&T Enterprise Annual Business Cycle; aligned Research, Technology and Analysis Program management.

Action Two:

Develop a "full-service" defence S&T capability

Deliverables: S&T capability assessment of the S&T Enterprise; human resources plan for the S&T Enterprise; infrastructure plan for the S&T Enterprise.

Action three:

Build strategic partnerships

Deliverables: process model for managing partnerships; partnering arrangements among S&T Enterprise members; international partnering framework and supporting agreements; partnering framework for industrial, academic and other government departments.

Action four:

Establish Enablers

Deliverables: information management/ information technology capability to support the S&T Enterprise; intellectual property management principles; harmonized procurement practices across research, development and acquisition; departmental approach to technology insertion.

Science and technology for increased sensing capabilities

The Aurora Incremental Modernization Project has exploited the departmental S&T investment to deliver a modern sensor suite that converts the CP140 Aurora into a multi-mission platform for surveillance over land and sea.

Science & Technolgy...



... is a driver for change in the 21st century. It contributes directly to the advancement of military capabilities.

INTRODUCTION

In response to the defence and security challenges facing Canada today, the Canadian Forces are undergoing transformation, guided by the principles of command-centric leadership, Canadian Forces culture, operational focus, clear authorities and responsibilities, and integration of military, both regular force and reserve, and civilian personnel. In parallel, the Department of National Defence is working to maintain effective and efficient alignment between the department and the transformed Canadian Forces, while responding to broader government direction.

Science and Technology (S&T) is a driver for change in the 21st century. It contributes directly to the advancement of military capabilities. It affects the global geo-political and economic systems which shape Canada's interests and, indirectly, the roles assigned to its military. S&T must be harnessed in the 21st century to contribute to Canada's defence and security priorities.

Through the investment made in S&T, the Department of National Defence and the Canadian Forces acknowledge the important role that S&T plays in contributing to the Canadian Forces and departmental agendas.

The **Defence S&T Strategy** establishes the conditions to maximize the impact of the departmental S&T investment as a force multiplier to provide the Canadian Forces with a decisive advantage. It is the means to realize the full potential of the investment by ensuring it is both aligned with the nation's defence and security priorities, and is duly supportive of the defence institution and its core business processes. The strategy is shaped by the goals of both Canadian Forces transformation and defence institutional alignment and positions the S&T investment to serve the needs of the Canadian Forces and the department, now and into the future.

This strategy outlines the strategic context within which the Canadian Forces and the department operate and the role that S&T plays in this context. It articulates the expectations placed on the departmental S&T investment, specifically as viewed through the lens of the core processes by which the department and the Canadian Forces function. The concept of the Defence S&T Enterprise (including a governance and management framework) serves a central role to the strategy's approach of ensuring maximum impact from the investment. Finally, the strategy identifies measures of success and the actions to guide its implementation. The actions are introduced in side boxes within the related S&T strategy issues and then all actions are addressed in detail in "Actions for Implementation" on page 20.

The shelf-life of the strategy is expected to be in the order of five years, whereupon it will be refreshed in the context evident at that time.

The Defence S&T Strategy establishes the conditions to maximize the impact of the departmental S&T investment as a force multiplier to provide the Canadian Forces with a decisive advantage.

SETTING THE CONTEXT

Science and technology for underwater warfare

The Remote Mine Hunting System (RMS), used by the Navy, was sponsored by Defence Research & Development Canada and developed by an integrated project team of government and industry. The semi-submersible, compact, portable and remotely-controlled system can detect and classify sea-bottom mines in water depths of 200m at survey speeds of up to five metres/second (10 knots).

The Defence and Security Environment

The world is changing at an accelerating pace. The globalization of world markets, transportation, communications and financial systems is having a major influence on both developed and developing nations from an economic, cultural and political perspective. These trends represent important opportunities for Canada as a G8 nation and leading partner in the global community. To capitalize on these opportunities, Canada must address emerging and enduring trends. Significant among these trends are growing global energy demand, cross-cultural interactions, changing migration patterns, rapid worldwide disease propagation, environmental degradation and natural disasters, new political alliances and political instability. National security threats that result from these trends include failed and failing states, global terrorism and proliferation of weapons of mass destruction. They now determine defence and security priorities around the world. Collectively, these pressures now shape global insecurity and future conflict and must be considered in defence and security planning and operations.

National security threats include failed and failing states, global terrorism and proliferation of weapons of mass destruction.

SCIENCE AND TECHNOLOGY FOR IMPROVED INTEROPERABILITY

A CF-18 HORNET AND A USAF F-16 TRAIN TOGETHER DURING THE TIGER MEET OF THE AMERICAS. THE AIM IS TO PROMOTE SOLIDARITY AND OPERATIONAL UNDERSTANDING BETWEEN NATO MEMBERS INCLUDING OPERATION OF ELECTRONIC WARFARE, RADAR AND DATALINK SYSTEMS.

The defence and security context facing Canada today, and against which this S&T strategy is positioned, is influenced by four interrelated factors:

1 — Emergence of the Asymmetric Threat

The threats to Canada's national security are changing with the emergence of international terrorism and the radicalization of elements within the societies of developed nations.

Unlike the Cold War threat, where inter-state stand-offs defined a static threat, the terrorist threat is asymmetric and more volatile. While the adversary does not possess comparable military means, it possesses incredible agility, readily available technology and the ability to rapidly identify and exploit societal, military and technological vulnerabilities. This threat also demonstrates a great will, often rooted in dedicated but irrational behaviour by western standards, thereby challenging traditional military solutions.

2 — Globalization of Science and Technology

The accelerating pace of S&T advances presents a significant opportunity for rapid and cost-effective improvements in the Canadian Forces' capabilities. However, S&T proliferation enables our adversaries to use asymmetric means to challenge our military capabilities and to target Canada's vital interests.

Driven largely by advances in information technology, our military has benefited from the introduction of

precision targeting, stealth, information operations and autonomous systems. However, the timeframe in which a leading-edge military technology provides operational advantage continues to decrease.

Unlike the previous century, military institutions no longer drive most scientific and technological advancements. Advancements with the greatest potential to disrupt military capabilities are increasingly expected to be the consequence of civil sector investments. In the past ten years alone, the world has witnessed the birth and widespread accessibility of the World Wide Web, personal communications, novel materials and genomics – each with defence consequences. On-going civil sector advances in machine intelligence, miniaturization, biotechnology and the convergence of these technologies are expected to shape our future defence capabilities as well as those of our adversaries. Moreover, the origin of many of these innovations is now in Asia and emerging economies, which further erodes the West's military advantage.

In the past ten years alone, the world has witnessed the birth and widespread accessibility of the World Wide Web, personal communications, novel materials and genomics — each with defence consequences.

The future will likely see further volatility and technological surprise such as demonstrated over the past decade by the emergence of network-spread computer viruses and the proliferation of nuclear, biological and chemical (NBC) capabilities.

3 — Growing Complexity of the Conflict Spectrum

The Canadian Forces are expected to operate in an increasingly complex conflict spectrum. The priority of peacekeeping has largely been replaced by a much more complex peacemaking role. The achievement of mission success is evaluated against a tightly coordinated set of effects from a defence, development, diplomatic and trade perspective. Today, the Canadian Forces must fight and win the "three-block war" — the simultaneous conduct, in close proximity, of high-intensity warfare, stability operations and humanitarian operations, typically in a complex environment such as a large urban area.

No longer are Canadian Forces operations focused predominantly on those outside North America. Rather, the national security environment is changing radically. Emerging risks to Canada and Canadians include new health concerns, climate change, bio- and cyber-terrorism and the vulnerability of the nation's critical infrastructure. Indeed, the Canadian Forces contribution to the security of the nation and North America has become the first priority.

Science and Technology for Improved Soldier Systems

The "Clothe the Soldier Program", an initiative of ADM (Materiel) partnered with Canadian Industry, addressed the deficiencies in CF member's uniforms and equipment. After careful analysis of the Canadian environment, a digital camouflage pattern, CADPAT (Canadian Disruptive Pattern), was developed to offer better protection from detection. The Clothe the Soldier Program went beyond addressing visual spectrum concerns to include countermeasures against enhanced vision technologies, such as infrared scanners, by developing a coating that could be applied to the soldiers' equipment and uniforms.

4 — The Canadian Defence and Security Agenda

During the Cold War, national security challenges were largely separate from public security issues. Today, they represent more of a single agenda. The Government of Canada, the Department of National Defence and the Canadian Forces are taking actions to shape defence and public security capabilities together. Among these actions is the priority being assigned to the transformation of the Canadian Forces to assure operational success in the new defence and security context, including the most radical transformation of the Canadian military command and control structure in several decades. In parallel, the department is aligning institutional processes for maximum benefit. Key initiatives in the context of this strategy include the adoption of capability-based planning, reform of the materiel procurement process to improve the timeliness and cost-effectiveness of equipment acquisitions, and the rationalization of the department's Information Technology/Information Management assets and capabilities.

Finally, the departmental S&T investment must be managed in conformance with an increasingly complex set of legislative and policy constraints, including the government's fiscal framework and in compliance with the law. In particular, Canada has an obligation in the study, development, acquisition or adoption of a new weapon, or means or method of warfare to conform with the requirements of national and international law.

This new context calls for a repositioning of the expectations and management of S&T in defence. The remainder of this strategy describes how this will be achieved.

The Canadian Forces contribution to the security of the nation and North America has become the first priority.

The Defence Science and Technology Investment

The Value of Defence Science and Technology

In an era of rapid transformational advances, S&T enables strategically relevant and tactically decisive Canadian Forces by applying state-of-the-art knowledge and methodologies to deliver timely and cost-effective solutions.

S&T, appropriately positioned, is a key enabler for success in Canadian Forces transformation and operations and, indeed, for national security. Judicious use of S&T has a major impact on decisions and costs associated with conception, development, acquisition and sustainment of military capabilities. Effective application of S&T saves money, reduces risk, develops more effective solutions in the Canadian context and helps build a better Canadian Forces. In delivering solutions to these needs, the departmental S&T investment is also a major contributor to national innovation and productivity.

Defence Science and Technology

The selective and rigorous generation, communication and application of state-of-the-art, validated knowledge for practical defence purposes.

The departmental S&T community spans the Department of National Defence and Canadian Forces. This workforce includes those trained in the social sciences, physical sciences and engineering. They are producing S&T results or are making use of them for decision making. They are both military and civilian and they work in almost every organization within the department and the Canadian Forces, providing scientific, technical or analytic support or making decisions that affect all the core processes — from policy and strategy through force development, to force generation and force employment.

The departmental S&T community does not work in isolation of the larger national and international S&T

Departmental Core Processes

Strategy and policy: A process for developing a roadmap by which the Department of National Defence and the Canadian Forces, as an instrument of government, will meet the defence and security objectives of the Government of Canada.

Force development: Longer-term planning associated with the creation and maintenance of military and departmental capabilities tailored to and aligned with the security environment and available resources.

Capability production: The process of developing capability implementation options; acquiring equipment, personnel and infrastructure; developing training, doctrine, capability support and supply systems; and integrating them into specific Canadian Forces capabilities. Outputs are Canadian Forces operational capabilities.

Force generation: The process by which forces are trained, equipped and assembled for potential operations. The process is completed once the forces are declared operationally ready and their command is transferred to the field.

Force employment: The exercise of authority over assigned forces in the field. It includes planning, directing, coordinating and controlling these forces in the conduct of operations.

community. Indeed, the huge investments outside the department in industry and academia, domestically and internationally, produce vast amounts of knowledge that can be accessed and applied to departmental and Canadian Forces needs.

The Defence S&T Strategy introduces two complementary programs of work for managing the departmental S&T investment: the Research, Technology and Analysis (RTA) Program and the Development, Engineering and Evaluation (DEE) Program.

First is the work conducted under the department's **Research, Technology and Analysis** (RTA) Program. The Program provides focused research activities addressing knowledge generation needs across all departmental core processes, explores and advances emerging technologies at the early to mid Technology Readiness Levels[1], including technology demonstration, and conducts targeted operational research and analysis to provide support to decision makers across the Canadian Forces and department.

The Defence S&T Strategy introduces two complementary programs of work for managing the departmental S&T investment: the Research, Technology and Analysis (RTA) Program and the Development, Engineering and Evaluation (DEE) Program.

The RTA Program is managed strategically through an annual planning cycle that commits effort to a balance of both multi-year and short-term projects. The bulk of Program funding is provided through departmental business planning, supplemented with project-specific funds provided from various departmental accounts. Many Canadian Forces and departmental organizations are engaged in the formulation and execution of the RTA Program. Program funds support the internal capabilities resident in Defence Research and Development Canada, a special operating agency of the department, and other departmental RTA performers such as the Royal Military College. They also enable the engagement of external S&T performers such as other government departments, allied governments, industry and academia. The departmental lead for the RTA Program resides with the Assistant Deputy Minister (Science and Technology).

Second is the work conducted under the department's **Development, Engineering and Evaluation** (DEE) Program. The Program enables the evaluation, maturation and transition of technologies with the potential to deliver identified capability needs, supports the science-based and engineering-based investigation of service life issues and on occasion supports the targeted development of technological or system solutions to meet specific defence acquisition needs.

The selection of DEE Program activities and related investment decisions is driven primarily by individual

1 Technology Readiness Levels (TRL) are a measure of the state of maturity of technology that range from the observation of basic principles through the various stages of concept evaluation, development and testing to prototype evaluations and full implementation into operational systems.

Science and technology for force protection

The Ferret Acoustic System, installed on Coyote-type vehicles deployed by Canadian Forces in Afghanistan, is a passive acoustic system for the detection and localization of small-arms fire. The system offers better protection to Coyotes operating alone or in convoys and to civilian populations exposed to gunfire.

business cases or by the needs of materiel acquisition and support functions as they arise. As such, the Program is managed primarily on a case-by-case or project basis, without an overarching annual program formulation cycle. Where appropriate, it is linked to other departmental strategies like those that have been developed for materiel and information management. The Program also provides multi-year funding to support key internal capabilities such as those of the Test and Evaluation centres resident within the Materiel and Information Management (IM) Groups. Activities are delivered through a blend of internal and external capabilities, most typically under the management of staff within the Materiel or IM Groups, or within the Canadian Forces force generation staff. DEE activities regularly reach back into the knowledge and expertise generated within the RTA Program. The departmental lead for the DEE Program is shared between the Assistant Deputy Ministers (Materiel) and (Information Management).

The departmental S&T investment capitalizes on the capabilities of the members of the national and international innovation systems including industry, academia, allied governments and governmental agencies.

Through these two programs, the departmental S&T investment supports all core processes of the department (see Departmental Core Processes – page 6) with the efforts of all stakeholders coordinated and harmonized to achieve synergy. Furthermore, the departmental S&T investment capitalizes on the capabilities of the members of the national and international innovation systems including industry, academia, allied governments and governmental agencies.

The remainder of this document describes the conditions by which the full potential of the departmental S&T investment will be realized.

Expectations for Science and Technology in Defence

The **Defence S&T Strategy** is intended to ensure that the departmental S&T investment is appropriately positioned so that S&T informs, enables and responds to Canada's defence and security priorities through the support it provides to the Canadian Forces and the Department of National Defence.

Specifically, this investment is expected to:

- Bring S&T to bear on supporting decision making and resolving important problems across the defence institution;
- Anticipate, assess and advise on the implications of emerging and potentially disruptive S&T; and
- Assess, mature, position and transition technologies with the potential to meet identified capability goals for the Canadian Forces and the department.

These expectations are managed and S&T services are provided through elements of many organizations within the department and the Canadian Forces and under the direction of various line and functional authorities.

When viewed through the lens of the core departmental processes, the expectations for S&T in defence define the "full-service" capability enabled by the departmental S&T investment, as summarized below.

Moving Forward Together

Action:

Develop a "Full-Service" Defence Science and Technology Capability

DELIVERABLES:

— Capability Assessment of S&T Enterprise
(First assessment April 07)

— Human Resources Plan for S&T Enterprise
(First version Sept 07)

— Infrastructure Plan for S&T Enterprise
(First version Sept 07)

Strategy and Policy *and* Force Development

S&T contributes to the Canadian Forces' and the department's understanding of the emerging strategic environment to which defence and security capabilities will likely need to respond. Outlooks for emerging and potentially disruptive S&T, and the assessment of their defence and security implications, are integrated with broader analysis of the social, political, security and economic factors that shape this environment.

The departmental S&T investment is expected to support decision making, anticipate emerging S&T and address technology transition.

S&T supports the formulation and validation of the Canadian Forces strategic operating concept through its contribution to the exploration of emerging approaches such as effects-based and network-enabled operations, and the juxtaposition of joint, interagency, multinational and public perspectives, and to the validation of the benefits of such approaches through robust, credible experimentation. S&T provides the underpinning methodologies and tools by which the department and the Canadian Forces identify and select the appropriate mix of defence capabilities that best support the vision for the Canadian Forces within available resources. At the same time, it provides informed choices for new or improved, yet affordable, solutions to capability objectives that take advantage of new S&T opportunities.

Capability Production

S&T contributes to the reduction of risk in the production and fielding of new or improved defence capabilities. It helps in improving the understanding of the interplay among the multiple perspectives that contribute to a capability. This includes both the relation among a capability's operational systems and technical viewpoints and the interdependence of a capability's materiel, personnel and infrastructure requirements.

For reasons of interoperability, economy of scale and affordability, Canada emphasizes non-developmental procurement. Through the provision of smart buyer and smart user advice, S&T can directly support this approach. The department's strong but selective defence S&T capability to support acquisition helps in: shaping performance specifications, informing decision makers on acquisition options, sharing the burden of technology development with our allies in order to gain access to their knowledge base and pursuing investments in technology development that will position affordable acquisition options, where non-developmental options are not available. Where development is pursued, the defence S&T capability approach to engaging industry and managing its intellectual property will be carefully positioned so as to enable future exploitation of successful developments.

When viewed through the lens of the core departmental processes, the expectations for S&T in defence define the "full-service" capability enabled by the departmental S&T investment.

With the rapid pace of technological advancement, and by consequence technological obsolescence, the Canadian Forces and the Department of National Defence are adopting the concept of incremental technology refresh for its equipment and information assets. This is intended to maintain higher levels of operational effectiveness and mission relevance over a platform's or system's lifetime at no more cost than the current approach based on major, but less frequent, upgrades. This technology insertion approach provides considerable opportunities for S&T to contribute solutions to the challenges of performance upgrades. However, it also requires well coordinated exploitation strategies that are enabled by government procurement practices.

Force Generation *and* Force Employment

S&T supports the Canadian Forces' ability to generate mission-tailored forces, and to build and sustain readiness across the suite of military capabilities. It supports the diverse challenges of managing the life-cycle of complex military equipment, of recruiting and training Canadian Forces personnel and of sustaining and regenerating its human capacity in face of high operational tempo.

S&T helps in identifying and assessing technologies held by adversaries and in understanding their vulnerabilities. It contributes to the development of mitigating tactics and countermeasures. It provides tools and knowledge to red-teaming exercises and proposes practical, rapidly-fielded improvements in Canadian Forces capabilities.

Finally, S&T provides time-sensitive and practical advice and solutions to support the resolution of issues that occur during operations, whether derived from adversary action, from unpredicted operational requirements or from the fielding of new capabilities.

DELIVERING SCIENCE AND TECHNOLOGY **FOR IMPACT**

Science and technology from concept to application

1000 kg net explosives quantity (NEQ) is detonated for an ammunition storage trial to validate the proposed storage structure and determine field safety distances.

The **Defence S&T Strategy** positions the departmental S&T investment for impact through the implementation of the concept of the **Defence S&T Enterprise**. Furthermore, the Enterprise manages the investment through a purpose-built **management framework** within the department's **governance** structure. The key principles are summarized below.

The Defence Science and Technology Enterprise

The departmental S&T investment is managed through the Defence S&T Enterprise, a matrix organization that connects those that direct, deliver and exploit the outputs from the investment. It is this Enterprise that generates knowledge where required, accesses knowledge from external sources in the national and international innovation systems and applies this knowledge in order to achieve desired outcomes.

The departmental S&T investment is managed through the Defence S&T Enterprise, a matrix organization which connects those that direct, deliver and exploit the outputs from the investment.

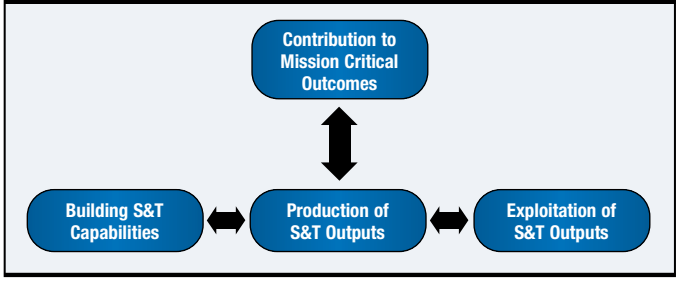
The Enterprise spans virtually all departmental and Canadian Forces organizations. It achieves maximum impact through harmonized effort by which S&T contributes to all core business processes of the department and the Canadian Forces.

A charter defines the Defence S&T Enterprise objectives, organizational architecture, relationships among its members and their roles, as well as its governance, (including the establishment of the annual planning and review processes).

Management Framework

The Defence S&T Enterprise operates within a management framework that ensures that all activities enabled by the departmental S&T investment are focused and coordinated to contribute to the achievement of the Canadian Forces and departmental mission-critical outcomes. This contribution is only realized through the exploitation of carefully selected S&T outputs be they advice to decision makers or the introduction of battlespace-ready applications of S&T. The production of these outputs depends upon the availability of S&T capabilities within the department or within external performers, which are maintained through appropriate investments and strategic partnerships. Figure 1 summarizes the main interdependent perspectives of the framework, which are further described below.

Figure 1 – Management Framework for the Defence S&T Enterprise



Contribution to Mission-Critical Outcomes

The Defence S&T Enterprise works towards clearly defined objectives that are shared by all members. These objectives are consistent with directions articulated in strategic documents defining Government of Canada and departmental policy. They address existing capability requirements of the Canadian Forces, while challenging S&T to seek out solutions that provide decisive military advantage into the future.

Eight strategic mission-critical outcomes[2] have been identified to target Canadian Forces and departmental capability objectives where S&T can contribute. These outcomes are derived from departmental objectives enunciated in policy and strategic guidance albeit refined appropriately to more explicitly express the contributions expected from S&T. These outcomes are expected to be enduring for the shelf-life of this strategy though they must clearly remain consistent with the evolution of defence strategy documents.

2 Outcomes are further clarified in Annex A to this document.

The outcomes are:

1. Trusted situational awareness, intent prediction and decision making for achieving operational superiority;
2. Robust operational command and control in Canada and abroad;
3. Seamless interoperability with other government departments, other Canadian partners and allied forces in a complex environment;
4. Agile, tailored force for deployment and operations in complex environments;
5. Full-spectrum protection including from weapons of mass destruction;
6. Sustainability, affordability, supportability of operations, assets and people;
7. Asymmetric advantage for defeating terrorist groups and tactics; and
8. Defence policy and force development informed and enabled by S&T developments.

SCIENCE AND TECHNOLOGY FOR COMMUNICATION AND INFORMATION MANAGEMENT

PETTY OFFICER 2ND CLASS BRUCE CAMPBELL (LEFT), CORPORAL JASMINE MAITLAND AND DAVID MONSOUR, MEMBERS OF THE INFORMATION TECHNOLOGY SUPPORT NAD SUPPLY PERSONNEL, WORK TOGETHER IN A SERVER ROOM.

Exploitation of Science and Technology Outputs

The return on S&T investment can only be achieved through exploitation of the outputs of S&T activity. In order for exploitation to be accomplished, three principles guide the management of the S&T Enterprise:

- S&T activities are formulated and managed taking into consideration the ultimate use of their output in terms of the core processes they support.
- Providers and ultimate users of the in-service application of S&T output participate from the early stages of S&T activity to ensure that formulation and execution consider exploitation needs. Exploitation is not only desirable it must also be achievable by those mandated to bridge S&T outputs with in-service deployment;
- The management of the S&T investment mitigates potential barriers to exploitation, including facilitating the management of intellectual property and the development of external partnerships.

The return on the departmental S&T investment can only be achieved through exploitation of the outputs of S&T activity.

S&T integration plays an important role in exploitation. Through multi-disciplinary teams of S&T providers and consumers, the Enterprise ensures that outputs can be effectively introduced into both future plans and current operations with minimal risk and interruption. These teams combine the knowledge resident in the S&T areas of expertise, the knowledge of requirements and the knowledge of the departmental core processes.

Management of the S&T Enterprise prioritizes and coordinates S&T activities to produce outputs that are balanced across the many expectations of S&T.

The management of the S&T Enterprise always ensures that exploitation of S&T outputs is a principal consideration throughout the planning and execution of S&T activities.

Production of Science and Technology Outputs

The S&T Enterprise produces S&T outputs to:

- Provide specific products or advice for exploitation within the core processes;
- Develop the expertise and capabilities for present and future S&T contributions.

The **Defence S&T Enterprise Activities** (see Box this page) are formulated in an integrated manner as described below.

S&T integration optimizes the effort towards achieving mission-critical outcomes.

The S&T Enterprise plans for ultimate exploitation of the output from each activity to contribute to the achievement of mission-critical outcomes. Therefore, ***knowledge application*** is a major consideration in the selection of S&T activities.

To promote ***knowledge generation***, S&T activities use internal capability together with that of partners in the Canadian and global innovation systems. For S&T to respond across the spectrum of expectations it is essential to have a balance of internal and external S&T capabilities that work synergistically in an approach that favours co-discovery and co-development of solutions. Knowledge can be generated through research and development, operational analysis, concept development and experimentation, engineering and test and evaluation.

The Defence S&T Enterprise only has the capacity, even with partners, to generate but a fraction of the scientific and technological knowledge that is needed by the department and the Canadian Forces. Therefore, mechanisms and methodologies are required for ***knowledge access*** – to monitor, access and assess the implications of global S&T advancements thereby capturing and exploiting knowledge from other national and international sources.

Management of the S&T Enterprise prioritizes and coordinates S&T activities to produce outputs that are balanced across the many expectations of S&T within the department.

Defence S & T Enterprise Activities

Knowledge Generation: The systematic and rigorous creation of new, validated knowledge that represents the consensus of the scientific community. It is accomplished through analysis, research and development.

Knowledge Access: The gathering, assessment and incorporation of defence-relevant scientific knowledge from external sources and partners.

Knowledge Application: The selective, systematic exploitation of knowledge derived from science to achieve defence outcomes.

S&T Integration: The synthesis of new knowledge pertaining to scientific, technological, conceptual, doctrinal and organizational perspectives to support decision making and capability development.

Building Science and Technology Capabilities

The Defence S&T Enterprise requires a foundation of S&T capabilities that is either resident within the enterprise or is reliably accessible through partnerships with external S&T performers. Capabilities in ***knowledge generation*** and ***knowledge access*** are integrally linked and need to be coordinated to maximize the benefits of both while making the best use of available resources. The S&T knowledge base, whether generated internally or accessed externally, needs to be harmonized to avoid duplication and to ensure that S&T capabilities exist to meet the "full-service" expectations placed on the departmental S&T investment.

The decision to create or retain S&T capability within the department versus relying on outside sources is based on the following criteria:

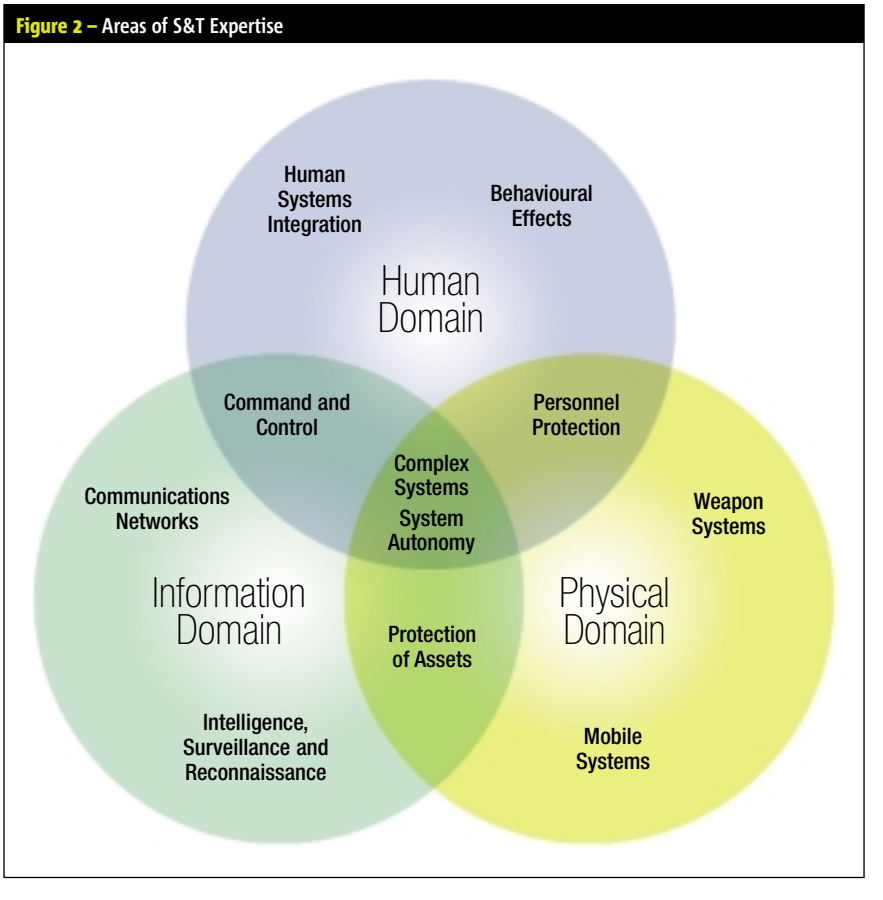
- Certain knowledge is of a sensitive nature and is inaccessible or is too specific to be of interest to others;
- Niche capabilities are of value to trade when cooperating with partners or allies to generate or access knowledge that is of common interest; and
- Fundamental understanding of certain subject areas is critical to be able to interpret information that is available from other sources.

Figure 2 identifies eleven primary areas of S&T expertise[3] in which critical mass must be maintained in order for the departmental S&T investment to affect the mission-critical outcomes. These S&T areas are grouped in three domains: physical, information and human.

A number of these areas, such as system autonomy and complex systems, include aspects of more than one domain. Multi-disciplinary teams will be established to understand and advance such areas.
The national and international innovation systems are major sources of S&T capability that can be used to complement internal capabilities. Internally-retained skills for ***knowledge access*** and ***knowledge application*** are needed to interpret available information. This requires not only domain-specific expertise but also knowledge of techniques for accessing and analyzing information from diverse sources and for identifying what is relevant to the Canadian Forces and the department. The S&T Enterprise should also maintain an internal capability for S&T integration.

Finally, management of the S&T Enterprise addresses all factors related to the development and retention of key S&T capabilities, including human resource planning, management development and S&T infrastructure investment.

Figure 2 – Areas of S&T Expertise



3 Areas of S&T expertise, and the challenges that they address, are described in Annex B to this document.

Governance

Consistent with the management framework described previously, the Defence S&T Enterprise needs appropriate governance to ensure that its goals are defined and met through a coordinated effort of all the members. Effective governance includes mechanisms by which priorities are established, resources are fairly distributed, capabilities are reviewed, perspectives from enterprise members and external stakeholders are considered and performance is measured. This is accomplished through an S&T Enterprise annual business cycle that is harmonized with the departmental annual business cycle. In addition, the governance mechanism responds to emergencies requiring resources from across the Defence S&T Enterprise. Finally, specific partnership agreements between elements of the Defence S&T Enterprise manage enduring relationships among the members.

The Defence S&T Enterprise needs appropriate governance to ensure that its goals are defined and met through a coordinated effort of all the members.

Coordination is complex, given the matrix nature of the Enterprise, whereby members report internally through many channels. As such, the assignment of functional authority for the direction and effectiveness of the Defence S&T Enterprise is appropriate. The functional authority works with departmental and Canadian Forces leadership to ensure that the efforts of the Defence S&T Enterprise meet the expectations identified in this strategy. Governance of the enterprise resides within the departmental governance structure, wherein the Defence Management Committee[4] provides strategic oversight and the Defence Management Oversight Committee is the working-level body charged with ensuring that the guidance provided by the Defence Management Committee is applied. The Assistant Deputy Minister (Science and Technology) exercises this functional authority and is accountable to the Deputy Minister and Chief of the Defence Staff. It is recognized that activities and initiatives must be carefully coordinated with other functional authorities within the department to avoid overlap and conflict.

Specifically, as functional authority for the Defence S&T Enterprise, the Assistant Deputy Minister (Science and Technology):

- Leads the development and maintenance of the Defence S&T Enterprise Charter and related policies, including its governance and the definition of roles, responsibilities and partnerships for the member organizations of the Enterprise;
- Provides oversight of the Enterprise, ensures expectations are established, and reports to Defence Management Committee on its performance in maximizing the impact of the departmental S&T investment, including recommendations for improvements; and
- Coordinates and facilitates the external S&T partnerships that enable and support the Enterprise.

Moving Forward Together

Action:

Establish an Integrated Governance Mechanism

Deliverables:

— Defence S&T Enterprise Charter
(First version March 07)

— S&T Strategy communications plan
(January 07)

— Process model for S&T Enterprise Annual Business Cycle – includes objectives for first cycle
(April 07)

— Aligned Research, Technology and Analysis Program management
(Spiral 1 - March 07; Spiral 2 - March 08)

4 As the departmental governance structure evolves, governance of the Enterprise will be adjusted accordingly.

Linkages to External Partners

The Defence S&T Enterprise depends upon access to the international S&T base and to S&T providers outside of the department and the Canadian Forces. This access provides the window onto global S&T advancements critical to defence and security and to future acquisitions. Although key S&T capabilities are developed and reside within the Defence S&T Enterprise, access to outside S&T providers augments the internal capabilities in areas where other sources are more economical, offers alternative solutions, avoids duplication of effort and unnecessary infrastructure investments and provides surge capacity when needed.

Moving Forward Together

Action:

Build Strategic Partnerships

DELIVERABLES:

— Process model for managing partnerships
(Spiral 1 – September 07; Spiral 2 - September 08)

— Partnering arrangements among S&T Enterprise members
(March 07)

— International partnering framework and supporting agreements (first version March 08)

— Partnering framework for industrial, academic and other government departments
(March 08)

Measurable benefits include: increased S&T capacity to support departmental core processes, shortened fielding times for technology solutions and improved access to global leading-edge S&T advancements. These external linkages also support the innovation agenda of the Government of Canada. In short, linkages to external partners are critical to the success of the Defence S&T Enterprise.

These linkages are purpose-built to ensure compatible objectives with each external partner community. They are grouped according to four communities. However, most S&T activities will likely have linkages to more than one of these communities.

Other Government Departments

The Defence S&T Enterprise links to other Government of Canada departments and central agencies. Capabilities and infrastructure that exist in other federal and provincial government departments can be applied to defence and security priorities, and strategic partnerships must be nurtured accordingly. On the other hand, the Defence S&T Enterprise contributes to the development and advancement of federal policies and, where appropriate, provides an S&T perspective and advice to senior policy makers and contributes to or leads government initiatives.

Access to outside S&T providers augments the internal capabilities in areas where other sources are more economical, offers alternative solutions, avoids duplication of effort and provides surge capacity when needed.

In particular, the common needs and interests of the defence and security agenda benefit from a shared approach to providing S&T solutions. The Defence S&T Enterprise plays a proactive role in contributing to the public security S&T agenda, just as the Canadian Forces contribute to the public security agenda.

Allied Defence and Security S&T Organizations

Canada and its allies share common challenges and are often required to work together in defence and security operations. It is mutually beneficial to develop common solutions so as to: lower the cost of defence and security technology development to each participant through cooperative effort and burden sharing, promote interoperability through shared technology developments and processes, and increase global security through a mutual understanding of the state of the art in defence and security technologies.

The Defence S&T Enterprise nurtures and maintains a portfolio of trusted bilateral and multilateral partnerships with the S&T organizations of Canada's defence and security partner nations and military alliances

such as NATO. Canada must be a credible and valued partner within these relationships, one that respects the sensitivity of information provided by her partners, and that brings world calibre capabilities and knowledge to the table in niche areas.

Industry

Industry forms a key component of the Canadian innovation system. The Canadian Forces and the Department of National Defence depend upon Canadian and international industrial suppliers to provide equipment and system solutions to important problems. Industry is a major source of innovative ideas and has the capability to translate concepts into reality. It is critical that the Defence S&T Enterprise develops strategic relationships with domestic and multi-national industry so that all parties are appropriately able to contribute their best ideas across all core processes and co-develop solutions to identified challenges through a sharing of ideas and provision of unique expertise.

These partnerships also provide the basis by which co-developed technological solutions can be positioned for Canadian Forces acquisition and for commercialization within appropriate international markets, thereby supporting national economic objectives.

Academia

By encouraging the engagement of Canadian universities, and the academic system more generally, in defence and security S&T activities, innovative ideas can be identified and explored at the early stages of development at minimal cost. By building strategic partnerships with granting councils, the Enterprise strengthens the defence and security community of interest within academia, while leveraging the government investments in academia. These partnerships can also lead to shared investments in critical S&T infrastructure and to the interchange of government and academic researchers.

Science and technology for problem solving and improved safety

Captain Amy Tsai-Lamoureux of the Quality Engineering Test Establishment finds causes of problems with aircraft and identifies solutions to prevent future problems.

Universities are the source of future defence S&T workers. Participation in defence and security S&T activities, in partnership with the Defence S&T Enterprise, promotes the development of effective education programs and graduates that meet the specific needs of the defence and security S&T community.

The Canadian Forces' university, the Royal Military College, is an important asset in this respect as it has the ability to engage the broader academic system in Canada, to exercise agile and flexible relationships with industry and other S&T performers, and to provide the department with an in-house academic research capability.

MOVING FORWARD **TOGETHER**

The success of the Defence S&T Strategy depends on an effective implementation plan that addresses the requirements and principles of operation of the S&T Enterprise. In order for the S&T Enterprise to move forward three factors are needed. Measures of success assist with the evaluation of progress. A clear definition of resources that are dedicated to S&T ensures effective implementation. Finally, a set of action areas with clearly defined deliverables provide the steps for implementation including planning, tracking and phasing.

Measures of Success

Success in implementation of the Defence S&T Strategy will be measured through its ability to position all departmental S&T investments to demonstrate eight key attributes (Figure 3).

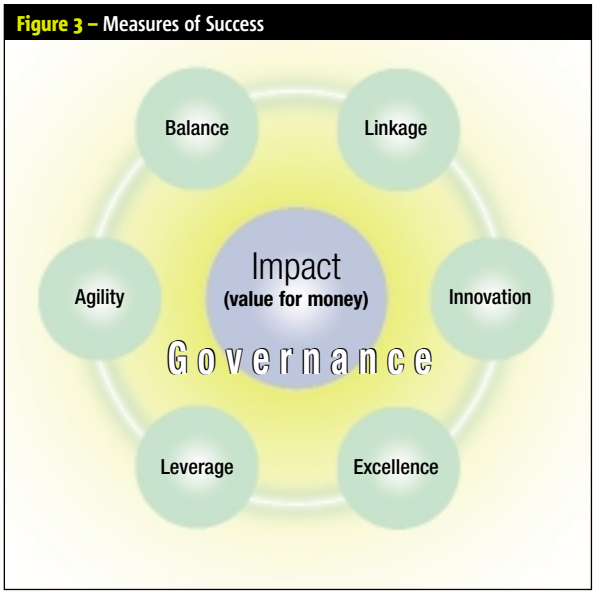
The primary measure of success is that the investment, as managed through the activities of the Defence S&T Enterprise, will derive maximum ***impact***, or more explicitly, maximum ***value-for-money***.

Success in implementation of the Defence S&T Strategy will be measured through its ability to position all departmental S&T investments to demonstrate eight key attributes: impact, linkage, innovation, leverage, agility, balance, excellence and governance.

Six enabling attributes assist the Defence S&T Enterprise in achieving the desired impact: ***linkage, innovation, leverage, agility, balance and excellence***.

- ***Linkage*** – through the Enterprise, departmental and Canadian Forces organizations are effectively positioned and synchronized to contribute to the direction, delivery and exploitation of S&T outputs.

Figure 3 – Measures of Success



- ***Innovation*** – the Enterprise, with its external partners, produces innovative, cost-effective solutions or novel alternatives to the highest priority defence and security needs that are appropriate to the Canadian context.
- ***Leverage*** – the Enterprise attracts top-tier national and international S&T partners so as to leverage their resources, knowledge, experience and technology.
- ***Agility*** – the Enterprise is appropriately agile so as to identify and respond effectively to new threats and opportunities that derive from the global advancement of S&T or from the rapidly evolving defence and security environment.
- ***Balance*** – the S&T outputs produced by the Enterprise are suitably balanced from multiple perspectives. These outputs address the prioritized needs from the perspectives of core departmental processes, Canadian Forces and environment-specific capability requirements. They address the needs across multiple time horizons, from responding to the challenges of today's operations to shaping the Canadian Forces of the future. Finally, they sustain core internal S&T capabilities across as broad a spectrum as resources allow while ensuring the critical mass necessary in each area to produce world calibre results.
- ***Excellence*** – the Enterprise consistently produces results of the highest possible quality and credibility built on niche world-calibre internal S&T capabilities and strong, effective external partnerships.

Science and technology for improved combat systems

Operators utilize Canadian developed enhancements to the combat system of the Victoria Class Submarine.

Finally, underpinning the effectiveness of the Defence S&T Enterprise is ***governance***. Governance ensures that commitments are respected and achieved. It ensures that S&T requirements are prioritized and that outputs are consistently exploited to impact on mission-critical outcomes.

Resource Guidance

Through the Defence S&T Enterprise governance structure, the full dimension of the departmental S&T investment is both visible and subject to improved coordination, harmonization and coherence. The overall scope of this investment is examined periodically by the Defence Management Committee so as to determine the adequacy of the investment for the expectations placed on it. The process is supported by the analysis and recommendations of the Assistant Deputy Minister (Science and Technology) which is consistent with the functional authority assigned to his/her position.

For that portion of the departmental S&T investment directed to the delivery of the departmental Research, Technology and Analysis (RTA) Program, the following guidance is provided:

- The distribution of Program effort across the departmental core processes is established through strategic direction that is reviewed annually;
- Approximately 50% of Program funds support in-house delivery of S&T, with the other 50% used to engage external S&T performers;
- The Program seeks to leverage participation and investment by partners in both the defence and security sectors at a rate of at least $0.75 for each dollar of departmental investment; and
- The contribution to the Program from the department represents a multi-year average of about 2.0% of the total defence budget.

For that portion of the departmental S&T investment provided for the delivery of the departmental Development, Engineering and Evaluation (DEE) Program, the following guidance is provided:

- Departmental investment in targeted technological or system development is based on the merits of the individual business case validated through a horizontal consultation and approval process;
- The DEE Program resources sustain an appropriate balance of in-house engineering and evaluation capabilities and external strategic and project-specific capabilities;
- The appropriate level of departmental investment in the Program is identified through the S&T Enterprise annual business cycle.

The contribution to the RTA Program from the department represents a multi-year average of 2.0% of the total defence budget. The level of departmental investment in the DEE Program is identified through the S&T Enterprise annual business cycle.

Actions for Implementation

Four strategic action areas are described below that create the conditions necessary for the achievement of the strategy's fundamental objective – *to maximize the impact of the departmental S&T investment*. These action areas are: to establish an integrated governance mechanism, to develop a full-service defence S&T capability, to build strategic partnerships, and to establish enablers.

For each action area, a series of specific deliverables are identified. Deliverables are typically expected to be refined over the course of multiple passes of the **annual business cycle** for the S&T Enterprise. Implementation objectives will be reviewed and adjusted annually as part of Enterprise governance to ensure an incremental approach that is consistent with available resources.

1 — Establish an Integrated Governance Mechanism

An effective governance mechanism will be established to ensure that the Defence S&T Enterprise

Science and technology for new military capabilities

An Altair CU-163301, a medium-altitude, long-endurance Uninhabited Aerial Vehicle (UAV). The aircraft conducted Intelligence, Surveillance and Reconnaissance (ISR) activities over Baffin Island and Atlantic Canada during the Atlantic Littoral Intelligence Surveillance Reconnaissance ISR Experiment (ALIX), conducted by the Canadian Forces Experimentation Center (CFEC).

works as an integrated and cohesive organization to collectively set priorities, allocate resources and track progress towards common objectives.

Desired Outcome: A remodelled governance mechanism is established for S&T activities conducted across the Department of National Defence and the Canadian Forces that replaces and improves existing mechanisms. Initial Operational Capability for the S&T Enterprise is targeted for 1 April 2007, with Full Operational Capability set for 1 April 2009.

Deliverables:

- Defence S&T Enterprise Charter (March 07)
- S&T Strategy communications plan (January 07)
- Process model for the S&T Enterprise Annual Business Cycle – includes objectives for first cycle (April 07)
- Aligned Research, Technology and Analysis (RTA) Program management (Spiral #1 – March 07; Spiral #2 – March 08)

2 — Develop a "Full-Service" Defence Science and Technology Capability

A full-service defence S&T capability will be developed to ensure that expectations for S&T in support of all departmental processes will be met either internally or through secure relationships with external S&T providers. The capability to effectively deliver S&T is based on the appropriate combination of the processes for delivering S&T (inputs, outputs, training, quality standards, process rules and process infrastructure), human resources and infrastructure. Issues to be resolved in the course of implementation include choices of internal versus external sourcing (make or buy) and addressing cultural differences across the S&T Enterprise.

Desired Outcome: S&T capabilities are in place to meet the requirements of all core processes.

Deliverables:

- S&T capability assessment of the S&T Enterprise – first assessment: establish baseline for current internal capabilities and survey external capabilities (April 07)

- Human resources plan for the S&T Enterprise (first version September 07)
- Infrastructure plan for the S&T Enterprise (first version September 07)

Science and technology for facilitating decision making and collaboration

At an Advanced Collaborative Capability Engineering Support System (ACCESS) facility, users have at their disposal sophisticated software and classified networks. The ACCESS concept design includes a knowledge portal, specific capability engineering applications, databases and associated infrastructure to facilitate collaborative work, decision-making capabilities, brainstorming, data management, document sharing and management, workflow management, and analysis.

3 — Build Strategic Partnerships

Strong and vibrant strategic partnerships will be built among key stakeholders within the Defence S&T Enterprise and with external S&T performers to ensure that the collective of partnerships is coordinated, that the right skill sets are available in the right circumstances, and that an integrated approach is taken to addressing critical issues. Effective partnerships must have shared commitment and objectives and must provide value to all partners. Each partnership is unique and must be approached in a manner that is tailored to the specific context.

Desired Outcome: A vibrant network of partners, both internal and external to the Canadian Forces and the department of National Defence, that work together for mutual benefit to address defence and security S&T priorities and to represent defence and security S&T interests in government decision making.

Deliverables:

- Process model for managing partnerships (Spiral #1 - September 07; Spiral #2 - September 08)
- Partnering arrangements among S&T Enterprise members – outline in S&T Enterprise Charter (March 07)
- International partnering framework and supporting agreements (first version March 08)
- Partnering framework for industrial, academic and other government departments (March 08)

4 — Establish Enablers

Successful implementation of the strategy depends upon the establishment of a number of enabling practices and capabilities.

Desired Outcome: A supportive environment that facilitates the establishment of effective internal and external partnerships and the timely exploitation of S&T outputs.

Deliverables:

- Information management / information technology capability to support S&T Enterprise operations (first version Sep 07)
- Intellectual property management principles that facilitate external partnerships and the timely exploitation of S&T outputs (first version June 07)
- Harmonized procurement practices across research, development and acquisition (first version April 08)
- Departmental approach to technology insertion across defence system life cycles (first version Dec 07)

SUMMARY

Over the years, the departmental S&T investment has achieved an excellent record of delivering the scientific and technological support that has been critical to maintaining the capability of the Canadian Forces and the department to contribute to Canada's defence and security priorities. The operational effectiveness of the Canadian Forces today has been built on the legacy of S&T investments of the past. Similarly, the Canadian Forces of the future can benefit from today's departmental S&T investment. The **Defence S&T Strategy** and its ensuing implementation will ensure that S&T is judiciously utilized in the 21st century to contribute to an effective Canadian Forces and to a secure Canada.

The Defence S&T Strategy and its ensuing implementation will ensure that S&T is judiciously utilized in the 21st century to contribute to an effective Canadian Forces and to a secure Canada.

SCIENCE AND TECHNOLOGY FOR URBAN OPERATIONS

DURING AN URBAN OPERATIONS TRAINING MISSION, A SOLDIER KEEPS WATCH DOWN THE HALLWAY FOR ANY SIGNS OF ENEMY MOVEMENT. THE CANADIAN DEFENCE S&T COMMUNITY HAS CONTRIBUTED TO URBAN OPERATIONS TECHNOLOGIES, INCLUDING SOLDIER PROTECTION, ROBOTIC VEHICLES, COUNTER MEASURES AGAINST IMPROVISED EXPLOSIVE DEVICES (IED) AND SNIPER DETECTION.

ANNEX A — MISSION-CRITICAL OUTCOMES [5]

The **Defence S&T Strategy** identifies eight strategic mission-critical outcomes that target Canadian Forces and departmental capability objectives where S&T can contribute. These outcomes are derived from departmental objectives enunciated in policy and strategic guidance, albeit refined appropriately to explicitly express the expectations for S&T. These outcomes are expected to be enduring for the shelf-life of this strategy, but must be reviewed periodically to ensure that they remain consistent with defence strategy documents, as they evolve.

1. Trusted situational awareness, intent prediction and decision making for achieving operational superiority

The key to operational superiority is to have complete awareness of all aspects of the environment within the theatre of operation. This includes the understanding of the positioning, capabilities, actions and intent of both adversaries and allies as well as other influences including weather, political and sociological factors that could affect the ability of the Canadian team to accomplish its mission.

2. Robust operational command and control in Canada and abroad

As the Canadian Forces adapt to new Canadian requirements for military intervention and support, a new command and control structure that is capable of operating within Canada and in theatres of operation abroad needs to reflect the requirement for self-contained, adaptable, autonomous Canadian capability within domestic and international environments.

3. Seamless interoperability with other government departments, other Canadian partners and allied forces in a complex environment

The deployment of the Canadian Forces will be both within Canada and abroad including failing and failed states. They must operate effectively in situations from high intensity battles to stabilization and restoration operations. Invariably, the Canadian Forces will need to work with other organizations, both Canadian and international and both military and non-military. This will require a flexible and agile organization that is capable of handling a large variety of new situations involving new environments and diverse personal and cultural interactions.

4. Agile, tailored force for deployment and operations in complex environments

The Canadian Forces must have the ability to apply a level of force that is appropriate to the situation. Force application, whether it is through the use of conventional weapons or psychological techniques, must be precise and tailored in order to minimize cost and eliminate collateral damage. This requires that commanders have understanding of and full and immediate access to both lethal and non-lethal weapons as well as the ability to coordinate actions with partners from the efficient initial deployment of forces to stabilization of post crisis situations.

5. Full-spectrum protection including from weapons of mass destruction

The Canadian Forces must be able to protect their own assets as well as the assets and territory it is tasked with defending. With increased emphasis on addressing asymmetric threats and protection of Canadian territory, the need goes beyond the traditional requirements for protection of Canadian Forces personnel and equipment to protection of civilian populations in complex environments that include chemical, biological, radiological and nuclear weapons, suicide bombers and attacks on cyber-structure.

6. Sustainability, affordability, supportability of operations, assets and people

Effective operations require reliable equipment and supply techniques to ensure that the right supplies and personnel are delivered to the right place at the right time. The equipment must be robust and the personnel must be prepared for the diverse situations they will encounter. Cost effectiveness is essential to the sustainability of operations and must include cost of ownership optimization through acquisition, deployment and operations. Similarly, personnel must be supported through training, deployment and post-deployment.

5 This list of Mission-Critical Outcomes was generated with consultation within the department during 2005 but they are subject to periodic review when new requirements are defined or strategic guidance is issued.

7. Asymmetric advantage for defeating terrorist groups and tactics

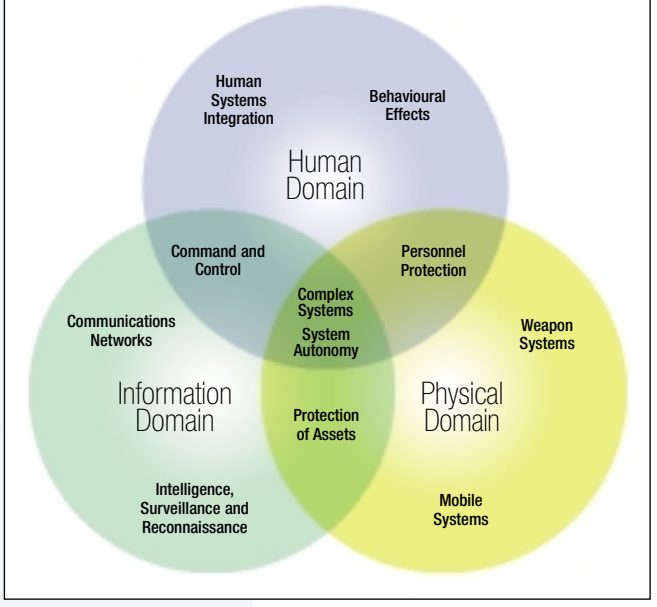
One of the greatest threats to Canadian security comes from failed and failing states as well as non-state actors. This asymmetric threat has forced nations to react to conditions that are set by these adversaries. By developing new techniques of "warfare", the Canadian Forces can force asymmetric adversaries to react and return the strategic advantage to organized states. Techniques will include cooperation with non-military partners to remove access to certain weapons such as CBRN and elements of public infrastructure. Techniques to identify terrorist networks and sources of funding can lead to effective countermeasures. Deployment techniques in foreign territories may reduce target opportunities. By understanding psychological and sociological aspects of asymmetric warfare, techniques can be developed to change or eliminate conditions in the environment that give the advantage to terrorists or to influence the environment to work against the adversaries.

8. Defence policy and force development informed and enabled by S&T developments

Science and technology is being developed and applied at an accelerating pace in the changing global security environment. Policies, doctrine and force development must reflect this trend in order to effectively exploit new technology and defend against new threats. Therefore, mechanisms must be in place to ensure that at the early stages of development, S&T issues are understood and taken into consideration.

ANNEX B — AREAS OF S&T EXPERTISE[6]

Areas of S&T Expertise



The **Defence S&T Strategy** identifies eleven primary areas of S&T expertise in which critical mass must be maintained in order for the departmental S&T investment to be able to reliably affect the mission-critical outcomes identified in Annex A. As shown in the Figure at left (reproduced from the strategy's main text), these S&T areas group into three domains: physical, information and human. A number of these areas include aspects of more than one domain. In this annex, each of these primary areas of S&T expertise is described further. For each area, a set of S&T challenges is defined that represents what are considered the most important scientific and technical obstacles that must be overcome. These challenges help to further clarify and focus the effort to establish the S&T expertise. These areas of expertise are expected to be enduring for the shelf-life of this strategy, but must be reviewed periodically to ensure that they remain consistent with defence strategy documents, as they evolve.

6 This list of Areas of S&T Expertise and the corresponding S&T Challenges were generated with consultation within the department during 2005 but they are subject to periodic review when new requirements are defined or strategic guidance is issued.

Table B-1 – List of Areas of S&T Expertise and S&T Challenges

S&T EXPERTISE	S&T CHALLENGE
1. Command and Control	1.1 Enhanced decision making in C2 environments
	1.2 Flexible and adaptable C2 concepts and structures for achieving common intent
	1.3 Effects-based visualization and awareness for the decision maker
	1.4 Information Fusion and Knowledge Management and Representation
	1.5 Software Protection and Counter Measures
2. Communications Networks	2.1 Robust, reliable networks
	2.2 Computer Network Operations (CNO)
	2.3 Robust wireless communications
	2.4 Communications Electronic Warfare (CEW)
	2.5 Navigation Warfare
3. Intelligence, Surveillance and Reconnaissance	3.1 Collaborative adaptive sensing
	3.2 Sensing systems to exploit diversity (in phenomena, space, time and spectrum)
	3.3 New sensing technologies
	3.4 Exploitation of target and environment characteristics
	3.5 Exploitation of adversaries' emissive systems
4. Complex Systems	4.1 Smart acquisitions and enhanced materiel support
	4.2 Capability Based Planning
	4.3 Capability Engineering
	4.4 Analysis of Integrating Concepts
	4.5 Analysis of complex systems and concepts
	4.6 Improvements in multi-purpose capability of new and existing systems
5. System Autonomy	5.1 Intelligent Autonomous Systems for operation in complex environments
	5.2 Emergent behaviour of simple autonomous systems
6. Mobile Systems	6.1 Condition-based monitoring and prognostic and health management methodologies
	6.2 Integrated platform models and their application
	6.3 Characterization of effects of environment and expanded operating envelope on vehicles
	6.4 Development of efficient energy storage and power sources

Table B-1 – List of Areas of S&T Expertise and S&T Challenges (continued)

7. Weapons Systems	7.1 Non-lethal weapons
	7.2 Assessment of the effects of weapons and weapon systems
	7.3 Tailored precision weapons
	7.4 Enhanced weapons systems for complex environments, including urban ops
8. Personnel Protection	8.1 Evaluation and mitigation of hazards from toxic materials, infectious threats and weapons
	8.2 Diagnostic and Adaptive Systems for Environmental Stresses
	8.3 Personnel Protection Systems and Signature Reduction
	8.4 Casualty Prevention and Management
9. Protection of Assets	9.1 Structures and materials for protection against weapons attacks
	9.2 Reduced observability through active and passive signature management
	9.3 Active countermeasures for platform protection
	9.4 Minimization of impact of military operations, including training, on the environment
	9.5 Decontamination of equipment and structures exposed to toxic and corrosive materials
10. Human Systems Integration	10.1 Human performance models for military simulations
	10.2 Human Systems Integration (HSI)
	10.3 Monitoring, predicting and enhancing psycho-physiological readiness
	10.4 Increased effectiveness and efficiency of the CF HR system
	10.5 Distributed, adaptable, and on-demand learning, training and rehearsal
11. Behavioural Effects	11.1 Understanding, prediction and influence of adversaries' intent
	11.2 Strategies for promoting collaborative behaviour among teams, agencies, organizations, and societies
	11.3 Selection and development of leaders and members consistent with the ethos of the CF
	11.4 Strategic Outlook - Tools and models to analyze and assess implications of changes in national and international policy, socio-economic trends and political climate

Table B-2 – Description of Areas of S&T Expertise and S&T Challenges

S&T EXPERTISE	S&T CHALLENGE
1. Command and Control Command and control involves the conveyance of intent in complex environments that involves humans and systems. S&T expertise that supports this requirement addresses information and knowledge management, visualization technologies, decision making tools, and concept development methodologies.	**1.1 Enhanced decision making in C2 environments** Command and control (C2) involves multiple, diverse, networked teams that can involve national and coalition partners and non-military agencies, challenging the commander to deal with options along various dimensions. The C2 environment and the human decision making process must be understood in order to accurately model decision-making for individuals and teams. With this knowledge, the challenge is to apply concepts of decision analysis, artificial intelligence, multi-criteria analysis and cognitive methodologies to develop decision support systems for that can be modelled and used for training as well as for operations. The decision support system needs to include the ability to present the expected effects and risks of a particular course of action to allow the decision maker to quickly evaluate the advantages and trade-offs of one decision over another.,
	1.2 Flexible and adaptable C2 concepts and structures for achieving common intent The CF face increasingly challenging operating environments, both in North America and abroad, where Canadian commanders work with other military and non-military organizations for achieving common effects. Concepts such as Effects-Based Operations and Network Enabled Operations promise improvements in force effectiveness but they challenge the traditional C2 concepts, structures and decision centralization. The speed at which events occur and the complexity of developing situations requires timely decisions and the ability to disseminate commands aligned with the common intent. The challenge is to develop flexible and adaptable C2 concepts and structures to address flattened hierarchies, wider spans of control, and ambiguous authority-responsibility relationships while anticipating spontaneous group behaviour. This requires new strategies to share information and knowledge for collaborative planning activities and to establish common understanding among teams of Command intent.
	1.3 Effects-based visualization and awareness for the decision maker The key to making effective and accurate decisions is to have clear and accurate information about the situation, including activities and intent of allies and adversaries. The decision maker also needs to understand the possible consequences of any decision. The challenge is to assemble and present information from many sources (e.g., sensors and human intelligence) and to present it in a form to facilitate the development of a clear awareness of the situation, including inference of intent of allies and adversaries. This includes systems to align, correlate, combine, distil, interpret, and control the inflow of a mix of dissimilar data and information (often inherently uncertain) to assemble a high-quality representation of aspects of interest in the environment. This objective demands intelligent "effect-aware" display methods, depicting differences between desired and actual effects and associated uncertainty.

Table B-2 – Description of Areas of S&T Expertise and S&T Challenges (continued)

1. Command and Control (Continued)	**1.4 Information Fusion and Knowledge Management and Representation** It is recognised that the effectiveness of any military or para-military intervention depends heavily on the comprehension of the situation at hand. Knowledge and awareness of local culture, customs, languages and geo-political reality enable the CF to interact efficiently. The challenge lies in implementing effective toolsets for creating, analyzing and managing relevant data, information, and knowledge. Efficient exploitation requires organisational practices through which information and know-how, in their broadest senses, are shared to facilitate operational effectiveness.
	1.5 Software Protection and Counter Measures Modern C2 systems rely on complex software systems running on networked computers and communications systems. The reliability of the systems can be compromised by subtle alterations of the application or by imbedding (intentionally or unintentionally) functionality that present vulnerabilities to attack or failure. The challenge is to develop techniques to rapidly assess software products for reliability, integrity and vulnerability. Understanding techniques to camouflage functionality of software is imperative for detecting hidden malice and thereby ensuring trustworthy software quality assessment. These techniques may also be applied to develop and inbed in trap doors or Trojans in software used by adversaries.
2. Communications Networks Communications networks form the basis for linkages among all elements of an organization. S&T expertise must exist in the areas of wireless and networked systems and computers, including architecture, protection, and countermeasures to ensure robust, adaptable and reliable networks.	**2.1 Robust, reliable networks** Future CF operations will employ integrated forces working with a wide range of domestic security partners and international allies, networked with different platforms, including soldiers, sensors and weapons. The challenge will be to ensure that robust, reliable communications networks, including appropriate security layers, are developed to provide seamless and timely information sharing across all levels, from strategic to tactical, over static wired and mobile wireless domains, to enable full spectrum, effective operations. This requires new strategies and techniques allowing dynamically reconfigurable networks to meet varying demands and react to network failures, while providing interoperability and end-to-end security over complex multiple-bearer architectures and across coalition systems. The development of these systems will require methodologies to apply security tags to all information and to track and control users and data throughout the system while taking into account respect for national and coalition security policies.

Table B-2 – Description of Areas of S&T Expertise and S&T Challenges (continued)

S&T EXPERTISE	S&T CHALLENGE
2. Communications Networks (Continued)	**2.2 Computer Network Operations (CNO)** Computer networks have become a battle space in their own right in which one conducts cyber-warfare. Information, information processing, and both wired and wireless communications networks are now at the core of every military activity, and as such they must be protected from adversarial activities. Adversaries are equally threatened by network countermeasures. CNO challenges include: defensive measures to protect and defend information, computers, and networks; operations to gather information from target adversary computers and networks; and operations to disrupt, deny, degrade, or destroy information resident in computers and networks, or the computers and networks themselves.
	2.3 Robust wireless communications As the CF transforms to network enabled operations, the future battle space will require connectivity and information flow at all levels. In particular combat platforms, sensors, weapons and warfighters will all need to be connected. The challenge is to provide robust wireless links with adequate communications capacity to these systems operating in highly mobile, difficult environments and complex terrain. As terrestrial wireless and satellite communications technologies continue to advance, opportunities arise to evolve and adapt these technologies to military applications providing mobile, interoperable, high-capacity wireless communications that make full use of the available radio spectrum.
	2.4 Communications Electronic Warfare (CEW) Operating environments such as urban operations, battlefields with dense tactical communications and "three-block war" zones pose new challenges to old and new communications systems. Net-centric concepts are leading to complex communications systems that make more use of wireless systems for flexible and pervasive information exchange. Moreover, wireless communications are being used for diverse applications (e.g., remotely triggered explosive devices). Not only do these conditions create new types of vulnerabilities in friendly systems, but they open new opportunities to deceive adversaries or to penetrate their systems. The challenge is to develop CEW technology, systems, and techniques, tactics & procedures (TTPs) to exploit adversaries' use of radio and wireless networks while neutralizing the adversaries' ability to monitor and use them against friendly forces.
	2.5 Navigation Warfare The use of Global Positioning Systems (GPS) and other electronic navigation techniques has led to tremendous improvements in accuracy of navigation. The use of GPS as a source of accurate time and, thus, its use for various military applications (including communications) is increasing. Techniques are needed to electronically protect the systems from attack or interference and to deny their use to adversaries. In addition, other methodologies are needed for navigation in situations where GPS is not available (e.g., indoor/underground or urban environments).

Table B-2 – Description of Areas of S&T Expertise and S&T Challenges (continued)

3. Intelligence, Surveillance and Reconnaissance Situational awareness and decision making depend on information collected and organized to describe the environment and activity. S&T expertise in development, deployment and fusing of sensing systems is required for effective information gathering.	**3.1 Collaborative adaptive sensing** In an effort to increase situational awareness, sensing systems of varying types are being deployed. Technology continues to offer the ability to connect via networks the outputs from diverse and powerful sensor types and autonomous systems that can be widely distributed and used for multiple purposes. New challenges include the necessity to address the complexities of tasking, communication with and co-ordination and management of these systems in a collaborative networked environment. Specific mission objectives include persistent surveillance and fleeting target detection.
	3.2 Sensing systems to exploit diversity (in phenomena, space, time and spectrum) Individual sensing systems provide differing pictures of a situation, either through different physical phenomena, spectral sensors, spatially dispersed sensors and observations over time. The challenge is to combine, integrate and fuse the information from the individual sensors to discern an understanding of the environment or situation to increase target detectability or reduce false alarms. Concepts and designs for integrated systems need to be developed to improve area surveillance in littoral, air or urban environments.
	3.3 New sensing technologies The need to improve situational awareness and threat detection cannot be met solely through the use of existing sensor systems. Particular needs include covert systems and improved detection, identification and tracking of elusive targets in challenging environments. Science and technology continues to offer opportunities for new types of sensors that are smaller (nano-scale), low power, less expensive and have increased or new sensitivities to the electro-magnetic, acoustic spectrum or other signals of interest. The challenge is to exploit and develop new sensor materials and systems for specific military tasks.
	3.4 Exploitation of target and environment characteristics Military operations seldom occur under ideal circumstances of clearly identifiable targets and friendly environments. Adversaries intentionally minimize their profiles so as to escape detection. The natural environment creates additional difficulties in detection and tracking by attenuating or distorting. For example, underwater characteristics can be extremely variable in both space and time and lead to distortion of acoustic signals. The urban environment with many surfaces and barriers can suppress and distort acoustic and electro-magnetic signals. The challenge is to develop methodologies and techniques to characterize the effects of the environmental media through which signals pass. Methods are also needed to identify the unique multi-spectral characteristics of difficult targets so that their signatures can be detected through background noise. Characteristics of the environment and targets then need to be translated into algorithms that can be used to subtract out the environmental effects and to increase the ability to detect, recognize and track targets.

Table B-2 – Description of Areas of S&T Expertise and S&T Challenges (continued)

S&T EXPERTISE	S&T CHALLENGE
3. Intelligence, Surveillance and Reconnaissance (Continued)	**3.5 Exploitation of adversaries' emissive systems** Electromagnetic and acoustic signals that are emitted by adversaries and neutral parties permeate all theatres of operation. These emissions provide an opportunity to passively detect, locate, classify, and track the source for intelligence, surveillance and threat alert. Methods are needed for specific identification (fingerprinting), detection of low probability of intercept (LPI) sources, detection of emitters in rugged terrain, timely cueing of counter-measures, navigation through the use of adversaries' and neutral transmissions, and using these emissions for hiding covert friendly signals for sensing and communication.
4. Complex Systems Many requirements in the defence and security environment go beyond traditional training and understanding to a convergence of disciplines that need to address the fundamental principles of complexity. S&T expertise in this area includes analysis of complexity, methodologies for capability based planning and capability engineering as well as methodologies to analyze integrating concept and other complex systems and concepts.	**4.1 Smart acquisitions and enhanced materiel support** Some of the most resource intensive and difficult challenges facing the CF are related to acquisition and support of equipment. Multi-billion dollar decisions to maintain, replace or upgrade equipment carry great risk. Overarching analysis techniques are needed to assist in making decisions about procurement (repair-replace-modular upgrade strategies), life-cycle management and repair. These techniques need to include improved models for risk assessment, financial modelling, and cost of ownership and analysis of support concepts and strategies. They must be capable of handling various sources of uncertainty and a wide variability of solutions and evolving capability requirements. Methods are needed to properly account for uncertainties in assumptions and to account for technology developments in the future that may radically affect the solutions.
	4.2 Capability Based Planning The CF has moved towards capability-based planning whereby high-level government policy and objectives are translated into military capability requirements. This requires the systematic assessment of the "value" of equipment, personnel, organizational and doctrinal change options to meet these capability goals appropriately assessed and prioritized according to utility in scenarios, missions and tasks. The value must be derived and expressed in new and transparent ways. It must be coupled with cost to support strategic decisions, and it must include risk, consequence and trade-offs in its formulation. New mathematical and soft system techniques are needed that can provide a systematic, repeatable and transparent analysis. Specific challenges include the development of models for: assessment of weapons, sensors and C2 system performance; joint combat simulation including group behaviours and command decision making; and comparing and valuing joint force structure options in a holistic manner across different scenarios.
	4.3 Capability Engineering As Capability Based Planning is implemented by the CF as the corporate methodology for force development a major challenge will be to determine the mix of equipment, personnel, information and doctrines required to meet the capability goals and how to transition in a timely manner while being constrained by budgets, overall force structure and other limitations.

Table B-2 – Description of Areas of S&T Expertise and S&T Challenges (continued)

4. Complex Systems (Continued)	Capability Engineering is the collection of methodologies and techniques required for this task. Tools are needed to assist in clarifying the requirement, to define the capability function; to assess the quantity of each option required, to assess cost factors, to determine requirements for personnel and their competencies. Existing methods, processes and tools for rigorous definition, analysis, and development of complex military capabilities will have to be adapted and new tools will need to be developed to support the transformation of the CF.
	4.4 Analysis of Integrating Concepts A number of integrating concepts of various types, including Network Enabled Operations (NEOps) and Effects Based Operations (EBO) are being used to guide development and concepts of operations for the CF. The early assessment of the impact of such integrating concepts on the employment of the CF must necessarily be done without detailed information about the processes and technologies that might support them. By their nature, these integrating concepts bring together not only a range of different capabilities, including the human dimension, but also organizational issues, processes, doctrine, and tactics. Thus an interdisciplinary approach must be used in their analysis. General methodologies for assessing these concepts at a high level and at various stages of their development are needed, in particular, methodologies for assessing capability interdependence and synergies.
	4.5 Analysis of complex systems and concepts The requirement to operate in increasingly complex environments, with large numbers of coalition members, in hostile surroundings, with diverse combatants, using different C2 systems and a large variety of equipment dictates a need to develop new tactics, doctrine and concepts. Technologies to simulate systems with humans embedded in a virtual environment continue to mature and offer unique capabilities to develop, test and evaluate complex systems and concepts and their interactions with variations in operational tactics and doctrines. Future development needs to concentrate on timely simulations and representations with flexibility in reconfiguration so that many concepts can be quickly evaluated for their effects. Emphasis needs to be placed on exploratory modelling techniques to model complex systems and ideas in ways that allow a balance of fidelity and adaptability. Effort must be placed on the development of capability to model goal directed behaviour and performance, individually and collectively, and represent it in synthetic environments.

Table B-2 – Description of Areas of S&T Expertise and S&T Challenges (continued)

S&T EXPERTISE	S&T CHALLENGE
4. Complex Systems (Continued)	**4.6 Improvements in multi-purpose capability of new and existing systems** Demands for new military capabilities drive the need for new and upgraded equipment and systems. It is often more cost effective to enhance capabilities of existing equipment rather than to purchase new platforms. The challenge is to modify existing systems and equipment or develop or acquire new equipment to meet new operating requirements. This requires an intimate understanding of present equipment combined with knowledge of new developments. Methodologies, including systems engineering, are needed to characterize existing and new capabilities and to predict performance improvements through physical modification or changes in the method of operation of existing systems or through the acquisition of new equipment.
5. System Autonomy Technological developments combined with a need for cost reduction and minimization of casualties has led to an increased reliance upon automatic and autonomous systems. S&T expertise includes robotics, artificial intelligence and understanding of emergent behaviours of systems of autonomous agents.	**5.1 Intelligent Autonomous Systems for operation in complex environments** Uninhabited systems are becoming more and more prevalent in all theatres of operation (land, sea, air and urban). Current systems require support and operator input. Force multiplication and operational dominance will be aided when these systems are more autonomous, executing missions and tasks based on their own capabilities and intelligence. Systems will become more autonomous when they can identify and address obstructions and challenges in their environment, identify threats, adversaries and allies, and provide greater support to the operation than is typical of the robotic sensor packages of today. Ultimately, the systems will be able to determine and take correct courses of action, with no intervention from human commanders or controllers. The challenge is to develop environment recognition and course of action algorithms for flexibility, creating mobile integrated systems that can operate autonomously and in support of units and commands.
	5.2 Emergent behaviour of simple autonomous systems Autonomous systems, systems that can run unattended and make limited choices in response to stimuli and instructions, can vary from the very simple to the very complex. Simple systems often have an advantage of lower cost and smaller size although the individual functionality is reduced. However, the cooperative interaction of many simple systems can lead to complex task performance or behaviour (e.g., biological systems such as ant colonies). System concepts that depend on many simple autonomous systems operating together through simple direct or indirect communication among the individuals can accomplish difficult and complex logistical, sensor or tactical tasks. Theories and tools are needed to develop and analyze concepts of synergistic systems and to predict and design emergent behaviours in order to exploit simple autonomous systems in operational theatres.

Table B-2 – Description of Areas of S&T Expertise and S&T Challenges (continued)

6. Mobile Systems An important element of effective engagement is the ability to move troops and place equipment in key locations quickly and efficiently. S&T expertise in this area focuses on the development, adaptation and maintenance of the mobile platforms that are needed for this task, including design, performance analysis and their integration into systems.	**6.1 Condition-based monitoring and prognostic and health management methodologies** Mobile platforms like ships, aircraft and armoured vehicles provide the basis for transportation of personnel and equipment as well as sensing platforms. One of the major challenges of ownership is maintaining availability and reliability within the constraints of limited operating budgets. Repair and maintenance of new and aging equipment is a significant cause of down time, particularly with conservative maintenance schedules and unpredicted repairs. The challenge is to understand and predict factors that can lead to failures and to develop methodologies that recommend maintenance and repairs only when needed but before catastrophic failure occurs. Condition-based monitoring systems that make use of embedded sensors and distributed sensor arrays can provide near-real-time information to physics-based prognostic and health management systems. Methods need to be developed to properly interpret incoming data and to incorporate models of the health of platforms into efficient maintenance programs. **6.2 Integrated platform models and their application** Platforms and their components are increasingly being developed to meet multiple functional requirements. Over the life of a platform, individual component functional capabilities deteriorate with time and usage, and at different rates. Advances in materials and platform analysis capabilities over that same time frame should be exploited to better optimize platforms for the requirements of vulnerability, survivability, maintainability, cost-effectiveness and mobility. This opportunity presents itself both in existing platforms, especially where extra measures beyond routine maintenance are needed to extend platform life, and in new construction. The challenge is to integrate the multiple models that describe platform functionality and to make the integrated products usable. One key enabler will be single product-models for whole platforms. The challenge also encompasses advances in materials modelling at a broad range of scales which will enable the exploitation of concurrent design of materials and structures including application to the development of advanced repair technologies. Success will be the demonstrated in the reduction of the cost of platform ownership. **6.3 Characterization of effects of environment and expanded operating envelope on vehicles** Mobile platforms and vehicles are exposed to a wide variety of conditions some of them that have not been anticipated during the design. These can be from extreme environments, from direct attack or from unexpected or new applications of vehicles. The result can be decreased handling performance, long-term deterioration or short-term damage. To improve performance under extreme conditions, the challenge is to characterize the effects of the environment and effects of expansion of the operating envelope. This knowledge then needs to be used to develop methods to control handling qualities, to develop and improve auxiliary systems in the vehicles, to modify the structures and to develop long-term maintenance and repair strategies.

Table B-2 – Description of Areas of S&T Expertise and S&T Challenges (continued)

S&T EXPERTISE	S&T CHALLENGE
6. Mobile Systems (Continued)	**6.4 Development of efficient energy storage and power sources** The provision of fuel and energy to forces in operations is a major component affecting cost and mobility of operations. New electronic systems that provide more capability also create a greater demand for power. The challenge is to develop and exploit new lightweight high-capacity long-life energy sources for applications such as systems on vehicles, soldier-carried systems and sensing systems.
7. Weapons Systems Modern weapons must be effective against a variety of targets in challenging environments such as urban terrain. S&T expertise includes identification and characterization of lethal and non-lethal weapons as well as the application of new weapon concepts to meet CF requirements.	**7.1 Non-lethal weapons** The CF is operating in many theatres that include dangerous mixes of military and civilian belligerents along with friendly personnel. It is often necessary to disable personnel or equipment without causing permanent damage or death. This leads to a new requirement for weapons that can ensure effective performance while minimizing collateral damage. The challenge is to identify potential non-lethal weapons and methods to characterize them, including evaluation of effectiveness, and to develop innovative concepts for these new weapons systems.
	7.2 Assessment of the effects of weapons and weapon systems The CF use and are exposed to weapons that are intended to kill and destroy. There is a need to continually identify and assess new weapons systems and to ensure that their effects are clearly understood both for lethality and protection. The challenge is to anticipate, develop and maintain the capacity and expertise to characterize the effects of weapons that employ traditional means such as explosives and electronics, but also the effects of non-traditional weapons systems of the present and future, such as kinetic energy, chemical, biological and radiological weapons.
	7.3 Tailored precision weapons More precision is required for the destruction of targets than previously because of more complex environments and a greater aversion to collateral damage. Precision also increases efficiency so that fewer resources are needed to accomplish a task. The challenge is to increase the precision of delivery in space, time and effect of weapons as well as to identify new systems and techniques to achieve improved effects.
	7.4 Enhanced weapons systems for complex environments, including urban ops New operating environments, including urban operations, present new challenges to the CF's mobility and ability to produce desired effects. New or enhanced weapons systems are needed to add further capability, including Special Forces. The challenge is to define the unique problems associated with urban and complex operations, to explore technical options for addressing these problems and to develop systems that are practical and effective.

Table B-2 – Description of Areas of S&T Expertise and S&T Challenges (continued)

8. Personnel Protection Personnel of the CF and their allies and the people they are tasked to protect need to be protected from various threats including weapons, environmental toxins and disease. People also need to be monitored to ensure that they are capable of performing the required tasks when needed. S&T expertise includes threat evaluation, diagnostic methods, physical protection and treatment.	**8.1 Evaluation and mitigation of hazards from toxic materials, infectious threats and weapons** Toxic materials (e.g., CBRN and toxic industrial materials), infections and weapons present major threats to CF and other Canadian personnel in theatres of operation. Effective force protection requires a multi-disciplinary capability to provide proper assessment of the threats, prediction of their effects and the development of strategies and methods to avoid or mitigate them. The challenge is to develop capabilities and techniques that can evaluate the threats, anticipate the threat environments, identify risks and vulnerabilities, predict the probability and extent of exposure, and identify and prove the most effective protective and recovery actions. The best outcome would be to prevent the effects of the weapon or threat, removing the risk and eliminating the advantage the weapon might provide. **8.2 Diagnostic and Adaptive Systems for Environmental Stresses** Operational effectiveness is reduced by the effects of attacks, the environment, disease or the rigours of operations and battle. Prediction and diagnosis are important elements in the treatment of infections, injuries and other operations-related ailments. The challenge is to produce diagnostics and predictive models that anticipate and identify early indicators of infection, injury and operational readiness. **8.3 Personnel Protection Systems and Signature Reduction** Personnel entering areas of known threats need to be physically protected from detection and injury. Known methods include protective systems like body armour, CBR protective suits or camouflage to prevent detection. Personnel may also use shelters (including vehicles and military shelters with collective protection systems) to protect themselves from certain agents. There is a need for greater protection and reduced detection that does not inhibit mobility. The challenge is to produce low-burden protection that adapts to the conditions and systems that reduce vulnerability across the entire spectrum and to develop the capability to assess and improve personnel protection using shelters. **8.4 Casualty Prevention and Management** Prevention and treatment of injury of personnel is critically important to save lives and to maximize operational readiness and tempo. There is a need to ensure that personnel in all operational theatres can be treated using new and proven interventions, treatments and preventative measures to reduce the consequences and course of injury and infection. The challenge is to develop procedures and capabilities that are effective in the field and in support to the field and that require a minimum of equipment and medical support. These will include casualty care provided by an integrated ensemble (e.g., embedded biochips) comprising intelligent diagnostic and treatment systems thus providing autonomous care and self-sustainment.

Table B-2 – Description of Areas of S&T Expertise and S&T Challenges (continued)

S&T EXPERTISE	S&T CHALLENGE
9. Protection of Assets Physical structures and infrastructure need to be protected from attack and the environmental damage needs to be minimized during military operations. S&T expertise includes methodologies for structural survivability, reduced observability and signature management, countermeasures against weapons and equipment decontamination techniques.	**9.1 Structures and materials for protection against weapons attacks** Platforms, equipment and critical infrastructure need to be protected from weapons attacks during operations. Structures and materials need to be able to withstand fire, impact, shocks, blasts and radiation. The challenge is to identify techniques, materials and structural concepts that can be added to existing equipment or incorporated in new acquisitions to minimize impact on weight and functionality while maximizing protection.
	9.2 Reduced observability through active and passive signature management The first layer of protection for platforms and equipment consists in minimizing the risk of detection in all the spectral domains available to adversaries. The challenge is to design platforms and other equipment to reduce detectable emissions, fields, and reflections and manage the risk of detection, classification and targeting by adversaries. The objective is to be undetectable and unrecognizable against the background and make operational commanders aware of signatures and the effects of their actions on vulnerability. Applying novel materials, modeling, design, construction and shaping can reduce passive signatures. Source level reductions, shielding and shaping can reduce active signatures.
	9.3 Active countermeasures for platform protection Active counter-measures blind and confuse adversary reconnaissance, surveillance and targeting systems; and seduce or deceive adversary weapons, such as missiles, torpedoes and mines. They reduce the adversary's probability of detecting, engaging and hitting CF and friendly platforms. Systems are needed that can adjust to changing engagement priorities, undertake threat assessment, and apply synchronized, multi-platform, cross-spectrum, on-board and off-board, attack and response mechanisms. The effectiveness of our counter-measures depends on our understanding of the vulnerabilities of our adversary's weapon systems.
	9.4 Minimization of impact of military operations, including training, on the environment Long-term sustainability of operations implies a minimal impact on the environment, both during training and deployments. For instance, unexploded ordnances and live fire training generate adverse impact on the battlefield and training ranges. The challenge is to identify technologies that can help to protect the environment while minimizing detrimental effects on operational effectiveness.
	9.5 Decontamination of equipment and structures exposed to toxic and corrosive materials Equipment or facilities that have been exposed to a hazardous environment or attacks from adversaries may be intact but contaminated and unusable. Methodologies and techniques are needed to return the equipment or building

Table B-2 – Description of Areas of S&T Expertise and S&T Challenges (continued)

9. Protection of Assets (Continued)	to full usability. The challenge is to develop and implement preventative and decontaminating strategies for structures and equipment that have been exposed to toxic or corrosive attacks.
10. Human Systems Integration Humans are required to interact with more and more complex systems to communicate, obtain information and effect actions. S&T expertise includes modeling of humans for simulation and system performance evaluation, human-systems integration, monitoring and predicting of psycho-physiological readiness and the design of systems that effectively train and prepare humans for operations.	**10.1 Human performance models for military simulations** Readiness for military operations demands training under realistic conditions. Almost all functions of military operation include humans interacting with other humans or with military systems, and increasingly so in complex terrains. The challenge is to develop human behaviour models that can be incorporated into simulation and training systems to accurately represent plausible behaviours of commanders, allies, adversaries and non-combatants. Such models can also improve realism of combat situations for operational analyses (e.g., war-gaming) and concept development. **10.2 Human Systems Integration (HSI)** Technology and automation have become critical elements of every element of military activity. However, the role of the human remains paramount and the interaction of humans and technological aids is critical to mission accomplishment. Net-enabled, effects-based operations will place ever-increasing emphasis on the design of agile, socio-technical systems that allow acquisition and concept development to be both more timely and more effectively goal directed. The challenge of Human Systems Integration is to create innovative tools, techniques and methods that seamlessly work with the systems engineering and concept development processes to truly integrate knowledge of human capabilities and limitations. Ultimately, advances in neuro-physiological monitoring will be harnessed to develop smart interfaces that monitor an operator's cognitive performance and brain status via a suite of neuro-physiological measures and allow direct control of operational systems. **10.3 Monitoring, predicting and enhancing psycho-physiological readiness** The spectrum of military operations represents a complex interaction of acute stressors (environmental stress, fatigue, uncertainty) that impact immediate physical and cognitive functioning (work performance, situational awareness, decision making), as well as chronic stressors (chronic deployment stress & OPTEMPO, moral and ethical dilemmas) that impact the long-term operational effectiveness of personnel (health, deployment rates, retention). Methods are needed to predict and improve performance under acutely and chronically stressful conditions. The challenge is to identify biological and psychological processes that affect short and long-term operational effectiveness and to identify and design new intervention strategies (selection and training, holistic/pharmaceutical interventions) that will optimize the level of physical, psychological and mental readiness, capability, and resilience of CF personnel.

Table B-2 – Description of Areas of S&T Expertise and S&T Challenges (continued)

S&T EXPERTISE	S&T CHALLENGE
10. Human Systems Integration (Continued)	**10.4 Increased effectiveness and efficiency of the CF HR system** Effective recruitment, training and personnel assessment is crucial to support of CF operations. As the CF undergoes transformation, the HR system also needs to transform to support the changes and to provide timely recruitment and training. The challenge is to develop operational concepts, techniques and tools that will lead to a more efficient way of providing HR services to the CF and other DND personnel.
	10.5 Distributed, adaptable, and on-demand learning, training and rehearsal Tactical and operational success demands CF capability of timely, affordable, and effective learning. In particular, full operational control of a transformed and integrated CF charged with an expanded variety of missions will require distributed and adaptable training capabilities. The challenge is to advance technologies and psychological techniques for deployable training and rehearsal that facilitates rapid deployment into a Joint Interoperable Multinational Public environment including interoperability with allies and cultural awareness.
11. Behavioural Effects The prediction and influence of human behaviour is important for understanding and defeating adversaries but also for developing more effective operations that may include members from diverse backgrounds and different organizations working cooperatively. S&T expertise includes understanding of motivation, communication, cultural effects, leadership and cooperation.	**11.1 Understanding, prediction and influence of adversaries' intent** The focus of Effects Based Operations is to influence adversaries in the world theatre by understanding their position and intent. Terrorism involves non-state groups and organizations, often represented at the point of attack by a small group of individuals or even one individual, using a wide variety of tactics and weapons, some sophisticated and some not. The challenge is to understand the many contributing factors influencing adversary motivation, including politics, religion, economics, and personal freedoms. This understanding will help achieve countermeasure and deterrent strategies to pre-empt hostile activity (i.e., effect-based outcomes).
	11.2 Strategies for promoting collaborative behaviour among teams, agencies, organizations, and societies Future crises will require the CF to work effectively with various government and non-government organizations and agencies. International conflicts will involve joint operations and multinational coalition forces embedded in diverse social and cultural settings. Accordingly, planning and decision-making in future CF operations will involve collaborative work, often in distributed Network Enabled Operations and ad-hoc teams. The challenge is to understand key psycho-social aspects of collaborative work (e.g., effective leadership and teamwork behaviours, establishing and maintaining shared intent and situation awareness, and fostering a climate of trust) and to develop methods and models to foster collaborative behaviour. One of the key elements is the establishment and maintenance of trust within teams, across organizations such as the CF and among organizations such as allies.

Table B-2 – Description of Areas of S&T Expertise and S&T Challenges (continued)

11. Behavioural Effects (Continued)	**11.3 Selection and development of leaders and members consistent with the ethos of the CF** The CF is operating in more complex, ambiguous international operations (including the three-block war context). CF members and leaders must be fundamentally integrated in terms of attitudes, motivation, responsibility and commitment and their decisions must reflect the values espoused in *Duty with Honour*. The challenge is to develop policies and methods, for selecting, socializing and educating members from an increasingly diverse Canadian society to ensure alignment with the military ethos of the CF while keeping the appropriate balance between cohesion and diversity.
	11.4 Strategic Outlook – Tools and models to analyze and assess implications of changes in national and international policy, socio-economic trends and political climate. Future scenarios and operations of the CF will be influenced by changes in national and international policy, socio-economic trends or forces and political climate. Better assessments are needed of the effects of these changes on world conditions and on future scenarios that the CF are likely to face. The challenge is to develop better strategic analysis tools to identify and monitor key indicators and to anticipate futures to support operating concepts such as Effects Based Operations.