CF Guidance to the Technology Demonstration Program

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Abstract

This report outlines options for a process that provides guidance from the Canadian Forces (CF) to Defence Research and Development Canada's (DRDC) Technology Demonstration (TD) Program. First, a survey is presented of the current processes by which operational and capability requirements are used to guide research and development performed by DRDC. After reviewing the current processes, options for an additional, complementary process are investigated. We recommend a simple process by which the new operational Commands and the Chief of Force Development (CFD) contribute to a list of capability and operational priorities. Since CFD is already tasked with producing a Strategic Capability Roadmap (SCR) that includes input from the Commands, we advocate adopting the SCR to guide the TD Program. The SCR can then be translated into priority Science and Technology Options for the SCR (STO-SCR). Both the SCR and the STO-SCR should provide concise, top-down, guidance to the TD Program. The creation and adoption of this type of guidance will not be without challenges; these challenges are elaborated in the main report.

Résumé

Le présent document décrit un processus par lequel les Forces canadiennes (FC) pourraient orienter le Programme de démonstration de technologies (DT) de RDDC. Tout d'abord, le document présente un survol des processus actuels au moyen desquels les besoins opérationnels et les besoins en capacités servent à orienter les activités de R-D menées par RDDC. Après ce survol des processus actuels, le document traite d'un processus complémentaire possible. Nous recommandons un processus simple par lequel les nouveaux commandements opérationnels et le Chef - Développement des Forces (CDF) contribueraient à l'élaboration d'une liste des priorités opérationnelles et des priorités en matière de capacités. Comme le CDF est déjà chargé de l'élaboration d'une Feuille de route sur les capacités stratégiques (FRCS), qui tient compte de l'avis des commandements, nous préconisons l'adoption de cette FRCS pour guider le Programme de DT. Les options prioritaires en sciences et technologies pourront ensuite être dégagées de la FRCS pour créer la FRCS-OST. La FRCS et la FRCS-OST devraient donner au Programme de DT une orientation concise, déterminée par la hiérarchie. La création et l'adoption de ce type de processus ne seront pas sans difficultés. Ces difficultés sont décrites dans le rapport principal.

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Executive summary

CF Guidance for the Technology Demonstration Program

D. Waller, S. Babcock; DRDC CORA TM 2008-051; Defence R&D Canada – CORA; July 2009.

Background: The Technology Demonstration (TD) Program of Defence Research and Development Canada (DRDC) facilitates the demonstration of relatively advanced technologies and concepts in a military context. The TD Program helps DRDC to achieve its objectives of making the Canadian Forces (CF) technologically prepared and operationally relevant. TD projects must address the priorities of the CF to maximize their relevance. Currently there is no centralized, top-down mechanism for determining and communicating CF priorities to the TD Program. This report proposes a new process that should provide the desired guidance.

Review of current processes: The current processes for determining and communicating the capability and operational requirements of the CF are reviewed. How these priorities are communicated to DRDC is of particular interest and is examined in some detail. Although many lines of communication exist between the CF and DRDC, each tends to be limited to small communities in the CF and DRDC.

Programs in allied countries that are similar to the TD program are also reviewed. The Joint Capability Technology Demonstration and Advanced Concept Technology Demonstration Programs in the United States and the Capability and Technology Demonstrator Program in Australia are strongly influenced by the operational and capability priorities of their respective militaries. The methods used for determining and communicating these priorities are examined in terms of their applicability to the TD Program.

Recommendations: A new process is proposed that will provide guidance to the TD Program based on the priorities of the CF and the science and technology (S&T) capabilities of DRDC. The first half of the process is simply to use the forthcoming Strategic Capability Roadmap (SCR) from Chief of Force Development (CFD) for top-down guidance. The SCR will be a ranked list of the CF's capability priorities. This list will be heavily influenced by input from the Environmental Chiefs of Staff and the Commands. The input from the Commands provides operational input to the priorities.

In the second half of the process, we recommend that DRDC produce a ranked list of S&T options that address specific items of the SCR. The S&T Options for the SCR (STO-SCR) will be created by DRDC's Directorates of Science and Technology and will reflect the

SCR priorities, DRDC's S&T capabilities, and the appropriateness and technology readiness level of each S&T option.

The STO-SCR can be used to guide what TD projects are proposed each year. The SCR can be used to rank the TD proposals based on military utility and impact. The guidance provided by these two lists will increase the responsiveness of DRDC to the requirements of the CF, and will eliminate a perceived source of bias in the ranking of TD proposals. Even though the production of a complete SCR might take two years, it is recommended that the interim SCR (planned to be completed in Summer 2008) be used for the 2009 TD Program cycle. An interim STO-SCR could be created from this SCR. Both of these documents would have immediate impacts on the TD Program and consequently the S&T output of DRDC.

Challenges: The purpose of the proposed process is to provide guidance; the STO-SCR and SCR are not intended to restrict the submission and selection of TD proposals unduly. Proposals not associated with the SCR or STO-SCR should continue to receive full consideration and, in exceptional circumstances, may rank ahead of proposals that do address the SCR. This ensures that the STO-SCR does not act as a filter, and consequently suppress innovation. Despite this caveat, there may be cultural challenges to implementing this type of centralized guidance. First, the military sponsors (from the three different environments) of TD proposals should feel that the SCR reflects the priorities of their environments. Second, for this guidance to be successful, it is important that all DRDC scientific and corporate personnel involved in the TD Program support the roles of the SCR and the STO-SCR. It is especially important that DRDC personnel feel a sense of ownership of the STO-SCR.

The extent to which the SCR and STO-SCR are successful at providing guidance to the TD Program will depend on the resources and time that are available to create and interpret these lists. Since the final version of the SCR has not been produced yet, there is some uncertainty about the type of details it will contain. The level of detail will depend on the resources and time that CFD has available. Similarly, the quality of guidance the STO-SCR provides will depend on the availability of already busy DRDC personnel. Despite these challenges, it is hoped that the perceived benefits of the SCR and STO-SCR will result in their receiving adequate support to achieve their goals.

Sommaire

CF Guidance for the Technology Demonstration Program

D. Waller, S. Babcock ; DRDC CORA TM 2008-051 ; R & D pour la défense Canada – CARO ; juillet 2009.

Contexte : Le Programme de démonstration de technologies (DT) de Recherche et développement pour la défense Canada (RDDC) facilite la démonstration de technologies et de concepts relativement avancés dans un contexte militaire. Le Programme de DT aide RDDC à veiller à ce que les Forces canadiennes (FC) soient préparées sur le plan technologique et à ce qu'elles soient aptes à mener des opérations. Pour être utiles, les projets de DT doivent correspondre aux priorités des FC. À l'heure actuelle, il n'existe pas de mécanisme centralisé vertical pour déterminer et communiquer les priorités des FC pour le Programme de DT. Le présent rapport propose un nouveau processus qui devrait permettre d'imprimer au programme l'orientation voulue.

Survol des processus actuels : Le document passe en revue les processus actuels pour déterminer et communiquer les besoins opérationnels et les besoins en capacités des FC. Le mode de communication de ces priorités à RDDC est particulièrement intéressant et est décrit en détail. Bien qu'il existe maintes voies de communication entre les FC et RDDC, chacune tend à ne joindre que de petits groupes dans les FC et à RDDC.

Le document passe également en revue les programmes des pays alliés semblables au programme de DT. Les Joint Capability Technology Demonstration and Advanced Concept Technology Demonstration Programs aux États-Unis et le Capability and Technology Demonstrator Program en Australie sont fortement influencés par les priorités opérationnelles et les priorités en matière de capacités de leurs armés respectives. La possibilité d'appliquer au programme de DT les méthodes utilisées pour déterminer et communiquer ces priorités est examinée.

Recommandations : Un nouveau processus pour orienter le Programme de DT en fonction des priorités des FC et des capacités en sciences et technologies (S et T) de RDDC est proposé. La première moitié du processus consiste simplement à utiliser comme guide la Feuille de route sur les capacités stratégiques (FRCS) du Chef - Développement des Forces (CDF), qui sortira prochainement. La FRCS consistera en une liste des priorités des FC en matière de capacités, classées par ordre d'importance. La liste sera fortement influencée par les idées fournies par les chefs d'état-major d'armée et les commandements. La contribution des commandements permet de tenir compte de l'aspect opérationnel au moment de déterminer les priorités.

Dans la seconde moitié du processus, nous recommandons que RDDC produise une liste hiérarchisée des options possibles de S et T pour chaque élément de la FRCS. Les options de S et T pour la FRCS (FRCS-OST) seront créées par les Directions - Sciences et Technologie et refléteront les priorités de la FRCS, les capacités en S et T de RDDC ainsi que le caractère pertinent et le niveau de développement technologique de chaque option de S et T.

La FRCS-OST pourra servir à déterminer quels projets de DT seront proposés chaque année. La FRCS pourra être utilisée pour classer les propositions de DT en fonction de leur utilité militaire et de leur portée. Les indications fournies par ces deux listes permettront à RDDC de mieux répondre aux besoins des FC et mettront fin à ce qui est perçu comme des préférences dans la priorisation des propositions de DT. Même si la production d'une FRCS complète peut prendre deux ans, il est recommandé d'utiliser la FRCS provisoire (qui devrait tre au point à l'été 2008) pour le cycle du Programme 2009 de DT. Une FRCS-OST provisoire pourrait être créée à partir de cette FRCS. Ces deux documents auraient un impact immédiat sur le Programme de DT et, de lè, sur le travail accompli par RDDC en S et T.

Difficultés : Le but du processus proposé est de donner des indications, étant entendu que la FRCS-OST et la FRCS ne visent pas à limiter indûment la soumission et la sélection de propositions de DT. Les propositions non associées à la FRCS ou à la FRCS-OST devraient continuer d'être prises en considération et, dans des circonstances exceptionnelles, il n'est pas exclu qu'elles puissent avoir préséance sur des propositions découlant de la FRCS et ce, afin d'éviter que la FRCS-OST serve de filtre, ce qui empêcherait l'innovation. En dépit de cette mise en garde, il pourrait y avoir des obstacles à la mise en place de ce type d'orientation centralisée. D'abord, les militaires (venant des trois environnements) à l'origine des propositions de DT devraient avoir le sentiment que la FRCS tient compte des priorités de leur environnement. Ensuite, pour que ce document porte fruit, il est important que tout le personnel scientifique et le personnel ministériel de RDDC participant au Programme de DT se servent de la FRCS et de la FRCS-OST comme il se doit. Il est particulièrement important que le personnel de RDDC sente que la FRCS-OST est un document à lui.

La capacité des FRCS et FRCS-OST de fournir une orientation pour le Programme de DT dépendra des ressources et du temps disponibles pour créer et interpréter ces listes. Comme la version définitive de la FRCS n'a pas encore été produite, le type de renseignements qu'elle contiendra n'est pas encore déterminé avec certitude. Le niveau de détail dépendra des ressources et du temps dont le CDF disposera. Pareillement, la qualité des indications fournies par la FRCS-OST dépendra de la disponibilité du personnel de RDDC, qui est déjè passablement occupé. En dépit de ces obstacles, on espère que les avantages perçus de la FRCS et de la FRCS-OST leur vaudront un soutien qui permettra d'atteindre les objectifs qu'elles visent à atteindre.

Table of contents

List of figures

List of tables

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1 Introduction

One of the key components of the mission of Defence Research and Development Canada (DRDC) is to ensure "that the Canadian Forces are technologically prepared and operationally relevant by... conducting research, development and analysis to contribute to new and improved defence capabilities"[1]. In order for the Canadian Forces (CF) to be operationally relevant, the science and technology (S&T) outputs of DRDC programs should address current operational and future capability requirements [1]. At present, there does not exist a complete, top-down assessment of the operational and capability priorities of the CF. As a result, there is no formal mechanism for using CF priorities to guide defence S&T in Canada. This report addresses the requirement for a formalized means of assessing CF priorities and the development of a means of communicating these priorities to the defence S&T community.

In the absence of guidance from specific priorities, high-level documents such as the defence section of Canada's International Policy Statement [3] and the 1994 Defence White Paper [4] have been used to guide defence S&T effort; however, these documents tend to be quite general, and therefore do not contain detailed priorities [2]. Another problem with relying on high-level documents is that they are not updated very frequently. These documents tend to be produced every few years at best, while priorities can evolve much more rapidly than this. Having a mechanism to capture and promptly communicate the priorities of the CF at least once a year would help to improve the responsiveness of defence S&T. Ultimately, the impact of defence S&T will be maximized if, in addition to carrying out forward looking research and development, it also addresses the most pressing requirements.

This study focusses on the responsiveness of DRDC's Technology Demonstration (TD) Program to CF priorities. The TD Program facilitates the demonstration of relatively advanced technologies and concepts in a military context. More details of the TD Program are given in Section 2.1. Not surprisingly, since there is no centralized mechanism for determining and communicating CF priorities to the S&T community, there is also no formal mechanism for using priorities as criteria for the selection and definition of TD projects.

Improving this feature of the TD Program has been identified as a priority by the management of the Director General Science and Technology Operations (DGSTO) [3]. A report

1. An operational requirement is defined as "an established need justifying the timely allocation of resources to achieve a capability to accomplish approved military or civil objectives, operations, missions, or actions"[2]. A capability requirement is defined as a "capability required by the CF to meet Defence policy, Defence objectives, and Defence commitments"[2]. The key difference between the two is that an operational requirement addresses a more immediate need than a capability requirement. Also, operational and capability requirements are determined by different parts of the CF.

2. The newly released Defence S&T Strategy (December 2006) will help to guide Canada's defence S&T effort, but it does not provide guidance that is explicitly based on operational or capability requirements. See Section 3.2.1 for more details.

3. DGSTO has existed since July 2007. Previously, most of the responsibilities of DGSTO, including

conducted by the Public Works and Government Services Canada Consulting Services for Department of National Defence (DND) Chief Review Services (CRS) has also identified this as an area for future improvement in the TD Program [5]. In their review of the TD Program, the CRS reports that the TD Program should "seek clear top-down direction on capability development"[5]. It also reports that the TD Program should "give priority to TD projects that are good fits for addressing [the] most urgent CDS [4] requirements". The review concludes that achieving these two objectives will "improve on program responsiveness to CF vision".

Allied countries such as the United States and Australia have S&T programs similar to the TD Program. These programs are guided by operational and capability priorities in a variety of ways. Section 2.2 will review how this guidance is provided. This section will also review how defence S&T priorities are determined in the United Kingdom.

A key assumption that motivates this study is that all research areas would benefit from a well structured, centralized process for determining CF priorities. This process would result in a list of priorities where S&T can contribute either by helping to improve a current capability, fill a capability gap, or create a new capability. This should lead to defence S&T that is more focussed and responsive. Additionally, a centrally-produced and widely distributed list of CF priorities might enhance the ability of different DRDC centres to improve CF capabilities to which they do not traditionally contribute. [5]

There are a number of decentralized processes that allow CF priorities to influence (to varying degrees) the S&T outputs of DRDC. In some areas of research and development (R&D) very rigorous processes are used for guidance of their programs. Other R&D areas employ less structured processes. All processes that are currently employed will be reviewed in Section 3.

After an overview of the TD Program and practices in allied countries (Section 2), the current processes for communicating CF priorities to DRDC will be summarized (Section 3). Section 4 investigates options for a new process that will incorporate CF priorities into the TD Program. It is intended that the adoption of the recommended process will make the TD Program more focussed on the most important requirements of the CF.

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the TD Program, fell under the Director General Research and Development Programs (DGRDP). In this document, DGRDP and DGSTO are used interchangeably.

4. Here, CDS, Chief of Defence Staff, is synonymous with the CF.

5. The various R&D groups often have close relationships with a limited number of CF partners, but if their area of expertise might be useful to a non-traditional partner, they might not know it, since there is currently no centralized list of priorities.

2 Background

This section briefly summarizes the Technology Demonstration Program (TDP) and similar S&T programs in three allied nations.

2.1 Technology Demonstration Program

The TDP is one of DRDC's main programs for providing funding to S&T projects. The goal of the TDP is quoted below [6]:

> The objective of the TDP is to demonstrate technologies fostered by Defence R&D Canada (DRDC) and Canadian industry in the context of real and potential future Canadian Forces capabilities, concepts, doctrine, operations, and equipment. The TDP is aimed at concept development and evaluation for force design purposes and is therefore typically not focused on hardware development.

A brief review of the program is given here. For more details, see the official TDP web page [6] or the aforementioned CRS review [5]. Ideally, technologies and concepts investigated in TD projects are at or near the last stage in the research, development and demonstration process before they are ready to be fielded by the CF. Funding is awarded on a competitive basis with typically eight to twelve projects vying for approximately $37 million. Normally, four to six projects are funded each year.

The projects are assessed on five criteria:
– military fit,
– military impact,
– S&T merit,
– quality of demonstrations, and
– project execution.

Various stakeholders from the CF, DND and DRDC rank the project proposals for the different criteria. The rankings of the stakeholders are combined so that an overall ranking is produced for the proposals. The top proposals are funded at their requested levels until the available funding is exhausted.

The military fit criterion is in principle very similar to the criterion that is the subject of this study: "operational and capability priorities". In fact, in the 2006 TD Program Instructions to Evaluators, military fit is defined as assessing "how the project proposal:
– aligns with DND/CF's vision and mission (e.g., Defence Policy Statement and the new CF Vision); and
– responds to a military capability priority (e.g., Capability Outlook 2002-12 and the Strategic Capital Investment Plan."[7]

Despite the link between "military fit" and "military capability priority", both DGSTO management and the CRS report on the TD Program indicate that this program requires improved guidance so that TD projects address CF priorities. Moreover, as stated earlier, such documents as the Defence Policy Statement and the CF Vision tend to be at too high a level to provide constructive guidance to individual S&T programs. Accordingly, there is currently no way of reliably comparing the relative "military fit" for all TD project proposals. These problems can be addressed by assessing the criterion of "military fit" against a recent, centralized list of CF priorities.

In addition to being useful as a means to evaluate TD project proposals, a list of CF priorities could be used in a number of other ways. For instance, it could:
– guide which TD projects are proposed;
– guide S&T in DRDC beyond the TD Program, including the Applied Research Program and the Technology Investment Fund; and
– provide an additional means of communicating CF requirements to companies involved in defence R&D.

2.2 S&T programs and priorities in allied countries

The TD Program is similar to other technology demonstration programs in allied countries. A brief overview of the similar US and Australian programs is given in Sections 2.2.1 and 2.2.2. An overview of the S&T priorities in the UK is given in Section 2.2.3.

2.2.1 United States - A/JCTD Programs

The Joint Capability Technology Demonstration (JCTD) and Advanced Concept Technology Demonstration (ACTD) Programs are the United States' Department of Defense (DoD) equivalents to DRDC's TD Program. The US DoD also has an Advanced Technology Demonstration (ATD) program. The focus of the A/JCTD programs is on the evaluation of the military utility of a technology, while the goal of the ATD program is to evaluate the technical performance of an advanced technology. While there is overlap of the TD Program with both the ATD and the J/ACTD programs, we will focus on the J/ACTD programs as their goals are closer to the goal of the TD Program.

The ACTD program will be phased out in the next three to five years, with the JCTD program covering all future projects in this domain. The JCTD program is designed to have shorter projects, so that the deliverables are provided to the clients faster. The clients for the JCTD program are the Combatant Commanders (CoComs). Since the CoComs are the clients, they influence what JCTD projects are proposed, selected and funded. In fact, each JCTD project must be sponsored by a CoCom plus one of the services. The sponsors provide 75% of the funds for a JCTD project.

The CoComs provide top-down guidance to the JCTD program by producing Integrated Priority Lists (IPLs). Each CoCom's IPL is a "succint statement of key capability gaps that could hinder performance of assigned missions"[8]. The IPLs support the Joint Programming Guidance, which is a document produced by the United States Secretary of Defense to delineate fiscally-constrained goals for the programs of the DoD.

Priorities listed in an IPL might range from "Force Protection" to "Joint ISR" [6] to "Joint Blue Force Situational Awareness". The IPLs are analyzed by the Directorate for Force Structure, Resources, and Assessments (J-8) of the Joint Staff to identify common priorities and themes [9]. Priorities that are ranked high by individual CoComs or are ranked by multiple CoComs are given the highest overall rankings. This assessment also allows for a "balance of service" criterion to be considered, so that the requirements of individual services are considered. Table 1 contains the highest rated items of the IPLs for 2004 [8].

CoComs provide not only their current operational priorities and capability gaps, but also the requirements they expect to have in 12 or more years [10]. Naturally, it is the current operational requirements and capability gaps that influence the A/JCTD programs.

2.2.2 Australia - CTD Program

Australia's Defence Science and Technology Organization (DSTO) runs the Capability and Technology Demonstrator (CTD) Program; this program is similar to the US DoD's A/JCTD programs. The CTD Program "aims to show the ADF (Australian Defence Force) users how leading edge technology can be integrated quickly into existing, new, enhanced or replacement high-priority capabilities"[11]. As a result, the focus of this program is near term (Horizon 0) capabilities. The program allows industry to demonstrate their technologies that might lead to improvements in the ADF's capability. One of the five criteria used to select CTD projects is the "potential to contribute to Defence Capability Development"[12]. The CTD proposals are guided by defence requirements in three ways.

First, the call for CTD proposals gives an unranked list of current areas of interest. For 2006/2007, this list has ten items [13]:
– battlespace energy generation and storage;
– non-lethal weapons;
– force protection systems;
– counter-measures for Improvised Explosive Devices;
– innovative gun technology;
– improving human factors in the field;
– management and security of battlespace networks;
– common standard information systems and exchange services (including tactical, logistics and health platforms);

6. ISR stands for Intelligence, Surveillance and Reconnaissance.

CoCom	Priority 1	Priority 2	Priority 3	Priority 4	Priority 5
CENTCOM	Force Protection	Persistent Tracking of High Value TST	Counter-Insurgency Operations	Force Projection/ Theater Logistics	Multinational Information Sharing
EUCOM	Global ISR	Persistent Tracking of High Value TST	Theater Logistics	Force Projection	Multinational Information Sharing
JFCOM	Coalition Information Sharing	Joint Blue Force Situational Awareness	Force Projection and Support Ops	Joint ISR	Information Superiority
NORTHCOM	Missile Defense Full Spectrum	Wide Area Surveillance	Maritime Interdiction Ops	Low Altitude Air Threat Defense	Interagency Coordination
PACOM	Missile Defense	Interagency Coordination	Multinational Information Sharing	Force Projection	Combating WMD
SOCOM	Force Protection	Persistent Tracking of High Value TST	Counter-Insurgency Operations	Force Projection/ Theater Logistics	Multinational Information Sharing
SOUTHCOM	Interagency Coordination	Counter-Insurgency Operations	Joint Theater Logistics	Persistent Tracking of High Value TST	Multinational Ops & Information Sharing
STRATCOM	Global Strike	Blue Force Tracking Combat ID	Persistent ISR		IO and Space Control JOCs
TRANSCOM	Theater Logistics	Force Projection	Operational Access	Interagency Operations	Multinational Operations

Table 1: *Prioritized Integrated Task Lists (IPLs) for 2004 from US Combatant Commanders (CoComs). More recent IPLs are currently classified. The IPLs are used to give top-down guidance to the DoD's A/JCTD programs.*

– intrusion detection and analysis systems for fixed assets, operational environments and border security;
– intelligence, surveillance and reconnaissance in complex terrains (including portable low-signature marking and tracking devices).

Proposals are not limited to these areas, but this list clearly communicates the priorities. This list is produced by the Capability Development Executive (CDE) [14]. The CDE also acts as the sponsor for the CTD projects.

The second means of guidance is provided by direct communication amongst the companies making proposals and the Capability Development Group of Defence and the relevant research division of DSTO. This guidance complements the CDE list as it can provide more details to the interested companies.

Companies intending to submit CTD proposals are also encouraged to consult a high-level policy document, Defence 2000: Our Future Defence Force [15]. It is suggested that companies can determine ADF priorities from this document. This document gives a broad overview of defence plans for the future; however, the low level of detail makes the inference of capability requirements more speculative. This is the third way by which guidance is provided for the CTD.

2.2.3 United Kingdom - Defence S&T Priorities

In October 2006, the United Kingdom's Ministry of Defence (MoD) released its Defence Technology Strategy (DTS) [16]. The DTS is a detailed plan that identifies the UK's defence S&T priorities. It highlights the importance of specific, current S&T areas and details where future S&T investments should be made. The DTS follows the UK's Defence Strategic Guidance (DSG) and Defence Industrial Strategy (DIS). The DIS was derived from the DSG, and in turn, the DTS is derived from the DIS.

A number of workshops were held to formulate the DTS. A broad range of experts from industry, defence science advisors and the MoD analyzed the DIS and DSG to identify key S&T areas in which significant R&D capabilities are required to meet national security objectives. One of the main outputs of the DTS is an unranked list of S&T priorities. This list will help to guide what defence R&D is performed in the UK. The priorities are summarized in a seven page annex of the DTS (Annex A); see reference [16]. An example of the level of detail provided by the DTS is given by the list of "cross-cutting technologies" that are identified as being "important": sensors and countermeasures; information exploitation; the human as part of the system; platforms and structures; the physical environment; technologies to establish "through life capability management". Taking as an example"sensors and countermeasures", the DTS goes into further detail about specific sensors (e.g. radar) and the particular S&T advances that are needed to improve them (e.g. instantaneous wideband e-scan steering for radar).

The summary of priority technologies in the DTS is not meant to be exclusive; if a researcher has a novel idea with military utility the research can still receive funding. However, it is expected that the majority of UK defence R&D will address priorities identified in the DTS.

2.2.4 Summary of S&T programs and priorities in allied countries

It is clear that the US A/JCTD programs are very similar to the Australian CTD program. Both aim to improve the capability of their armed forces by demonstrating mature technologies. Also, both are given top-down guidance based on operational and capability priorities. The only difference of significance to this study is how the priorities are presented and who determines the priorities. The CoComs' priorities are ranked while the CDE's priorities are not. The pros and cons of ranked and unranked lists will be discussed later in Section 4.2.

For the A/JCTD programs the priorities are determined by the CoComs, who are mostly operational commanders, with consideration given to balance of service. For the CTD program the priorities are determined by a centralized body: the CDE. In both cases, the choice of group to determine the priorities is reasonable. Both the CDE and CoComs are well-placed to assess and prioritize the capability and operational requirements for their armed forces. For the TD Program, capability and operational guidance could be provided by the DND/CF equivalents of either or both of these groups. The DND/CF equivalent to the CDE would be the Chief of Force Development (see Section 3.1.1 for details). The DND/CF equivalents to the CoComs are the Commanders of the operational Commands (see Section 3.1.2 for details).

The guidance provided by the UK's DTS is clearly quite different from the guidance provided to the A/JCTD and CTD programs. The DTS focuses on specific technologies while the priorities for the A/JCTD and CTD programs address operational and capability requirements, without specifying any particular technologies. Since the goal of this study is to investigate ways by which top-down CF requirements guidance can be provided to the TD Program, the A/JCTD and CTD programs are appropriate examples to follow.

3 Review of current CF/DND/DRDC processes

In this section, the current processes related to the determination of CF priorities and their communication to DRDC will be reviewed. Section 3.1 will review the various processes by which priorities are determined by various organizations in the CF/DND. Section 3.2 will review how CF priorities are communicated to DRDC in order to guide what R&D is performed.

3.1 Operational and Capability Priorities of the CF

Due to its large size and complexity, the CF and DND have a number of smaller organizations that determine their own operational and capability priorities. In principle this leads to a large number of different lists of priorities. CF transformation should simplify the current situation as strategic force development, which addresses capability priorities, is now coordinated by the Chief of Force Development (CFD). CF transformation is not complete yet though, so there are many other organizations that carry out their own determination of capability priorities. Sections 3.1.1 to 3.1.4 outline how various bodies in the CF/DND determine their priorities.

3.1.1 Capability Priorities: Chief of Force Development

In the re-structured CF, CFD is a natural choice for a body to help influence defence R&D. CFD is responsible for determining what future defence capabilities are required. Although the CFD is not an operational command, the capability requirements it identifies (with input from the operational Commands) reflect the expected operational priorities of the future.

CFD determines the CF capability requirements by employing a capability-based planing methodology [7]. This methodology involves mission analysis of the Force Planning Scenarios; these scenarios represent the breadth of activities that the CF is expected to be involved in from the present to at least ten years in the future. After the scenarios are drafted, military experts analyze them to determine what effects are required to accomplish the missions successfully. In order to realize the desired effects, various tasks must be accomplished. These tasks are rigourously analyzed in terms of generic capabilities to determine what capabilities are required to carry out the tasks. The tasks and capabilities are then further analyzed to determine their importance by considering (a) the consequence to the missions if the tasks and capabilities are not achieved, and (b) the frequency that the tasks and capabilities are required. Tasks/capabilities that have severe consequences if they

7. The various stages of capability-based planning are carried out by a number of different directorates in CFD. However, this paper does not detail the responsibilities of individual directorates due the ongoing evolution of the detailed structure of CFD.

are not completed/available and are required in multiple scenarios are ranked at the highest priority. This process ultimately results in a prioritized list of capability requirements that reflects expected operational requirements.

Once this process is complete, the prioritized list of requirements will provide an excellent guide for capability generation (including through defence R&D). Unfortunately, the analysis of the Force Planning Scenarios is labour intensive and time consuming. At the time of writing of this document, less than half of the scenarios had been fully analyzed and approved by the Capability Development Board. As a result, it has been decided that only the eight scenarios that have been approved will be used for the first iteration of the list of capability requirements. This list of capability requirements is called the Strategic Capability Roadmap (SCR) and is expected to be completed by Summer 2008.

After this first iteration is finished, the work to determine the CF's capability priorities is not complete. First, the analysis of the remaining ten scenarios needs to be done. Second, as the political and security environment evolves over time, the types of operations that the CF is likely to be involved in will change. This will require periodic updates to the scenarios that are analyzed. As a result, CFD will continue creating and analyzing new scenarios.

There remains, however, a limitation with the Force Planning Scenarios: they are hypothetical. Real world CF operations will undoubtedly be different. Consequently, additional capabilities might be required or priorities might change. This leads to the conclusion that while the analysis of the Force Planning Scenarios is a vital component of determining the priorities of the CF, it must be complemented with input from additional organizations. Organizations with operational responsibilities on behalf of the CF are an obvious source of this input.

3.1.2 Operational Priorities: The Operational Commands

As part of the transformation of the CF, four new operational Commands have been established: Canada Command (Canada COM), Canadian Expeditionary Force Command (CEFCOM), Canadian Special Operations Forces Command (CANSOFCOM), and Canadian Operational Support Command (CANOSCOM). Canada COM is responsible for the defence of Canada. CEFCOM is responsible for conducting international operations. CANSOFCOM is responsible for conducting special operations (including anti-terrorism operations) both inside and outside Canada. CANOSCOM is responsible for supporting domestic and expeditionary (i.e., international) operations by providing services such as logistics, medical care, military police, land equipment maintenance, and military engineering.

As these Commands are responsible for the ongoing operations of the CF, they are best positioned to determine the current operational requirements. All of the Commands identify high priority operational requirements in one way or another. However, since the Commands were established very recently (April 2006), none of the Commands currently has a

formal process by which operational priorities are determined. Instead, the priorities tend to be determined informally through consultation between the Command Commanders and their staffs.

Not surprisingly, the Commands' priorities tend to focus on their most pressing, immediate needs. For this reason, it is not obvious that their operational priorities can be met by defence R&D within the desired time-lines. For example, TD projects usually take three to five years to complete. In general this would be too long for the Commands to wait. However, it is possible that there is no existing solution to a Command's operational requirement. In these cases, R&D might be required, so TD projects could be relevant for meeting the requirements of the Commands.

A recent example of an approved TD project that was driven by the requirements of an operational command is the Counter Improvised Explosive Device TD. Recent CF casualties in Afghanistan resulting from improvised explosive devices (IEDs) have made countering IEDs an operational requirement of paramount importance for CEFCOM. The TD Program was identified as an appropriate means of providing solutions to the IED threat. The Counter IED TD was approved for funding in Fall 2006; preliminary results are expected in the near future.

3.1.3 CF Priorities: Strategic Joint Staff

The Strategic Joint Staff (SJS) provide military analysis and decision support to the Chief of Defence Staff (CDS). The Director of Staff of SJS produces a priority list in consultation with the CDS. The process to produce this list is informal and the content is generally of a higher-level or strategic nature so it is not directly applicable to determining capability or operational priorities; however, CF priorities could be derived from this list through a process similar to the one used by CFD in its analysis of the Force Planning Scenarios.

The J7 Lessons Learned unit of SJS also periodically produces a Critical Task List which highlights current issues that require resolution. These issues are sometimes operational in nature. However, operational issues are usually passed on to the operational Commands (e.g. CEFCOM for an issue directly related to operations in Afghanistan). Also, the Critical Task List identifies issues that require investigation, but does not include the outcomes of the investigations. For example, if the result of an investigation is the decision that a new capability is required, this is not captured in the list. It would be useful to have a process to capture the outcomes of the investigations so that new requirements that are identified can be communicated to the appropriate bodies (DRDC, materiel acquisitions, etc.).

3.1.4 CF Priorities: DRDC Partner Groups and Directorates of Science and Technology

DRDC's R&D program is delivered to seven Partner Groups (PGs): Integrated Canadian Forces, Maritime, Land, Air, Personnel, C4ISR [8], and Human Effectiveness and Protection [9]. Each PG is associated with a Directorate of Science and Technology (DST) that is responsible for overseeing the research programs for each of the PGs and acting as a liaison between DRDC and the CF. Although the DSTs do not determine CF priorities, each DST consults with its partners in the CF to determine what requirements can and should be addressed by defence R&D.

The DSTs determine the operational and capability priorities of their partners by a wide variety of means. Two of the DSTs take advantage of formal processes to prioritize R&D objectives that are based on CF priorities; however, these priorities tend to reflect the priorities of the individual PG, not the whole CF. The other three established DSTs rely on informal means for their prioritization. The formal processes include annual workshops with participation from a large number of representatives (50 to 100) from the operational and research communities. A key outcome of these workshops is the determination of the operational and capability requirements of the corresponding PGs.

The Air Force held its first Aerospace Capabilities Initiatives Forum in February 2006. At this workshop, members of the Air Force met with members of the S&T community to determine what capabilities were most desired by the Air Force. At the workshop, the Air Force produced a prioritized list of 34 capabilities, the Aerospace Capabilities Initiatives List (ACIL), which are individually ranked from first to last. The ACIL is intended to provide guidance for the Air Force portion of the S&T program of DRDC.

The ACIL is very heavily focussed on Horizon 1 requirements. Although TD projects are intended to focus on Horizon 1 and 2 requirements, the S&T community sought guidance for longer term goals also. Dedicated interviews of select members of the Air Force were conducted after the forum to determine longer term requirements.

The overwhelming focus on Horizon 1 capabilities in the 2006 ACIL capability list should be improved for 2007 by communicating more clearly to the Air Force participants the desire to determine long term capability requirements, in addition to immediate requirements. The military's understandable focus on the present is frequently noted as a challenge by other DSTs when efforts are made to guide S&T.

The inaugural Maritime Capability Development Workshop took place in November 2006.

8. Command, Control, Communications, Computers, Intelligence, Surveillance, and Reconnaissance

9. The Integrated Canadian Forces and Personnel PGs were created in July 2007. Since they are very new and have not been involved with the TD Program yet, they were not included in this study. In July 2007 the term "Partner Group" replaced "Client Group"; the terms Client Group and Partner Group are used interchangeably in this document.

The participants were divided roughly equally between members of the maritime S&T community and personnel from the Navy. During the workshop, small working groups were formed to determine S&T priorities based on operational and capability requirements. The priorities were divided into three time-related categories: sustain, modernize and transform. Sustain corresponds to the present, modernize to the near future and transform to further in the future. The information gathered at the workshop is currently being analyzed to produce a long term Maritime S&T strategy.

The three other DSTs surveyed for this study do not employ formal processes to determine the priorities of their CF partners. Instead they rely on the thrust advisory groups (TAGs) and less formal consultation between the research and operational communities. [10] Each DST's area of research is divided into four or five thrusts that focus on specific R&D topics. The TAGs provide guidance to the R&D programs carried out in each thrust. The TAGs, which are composed of CF and DRDC personnel, provide a vehicle for communicating the military's needs to the research centres. While this is valuable for guiding defence R&D work, it does not result in an overall prioritization of CF requirements across all the thrusts or even within an individual PG.

3.2 Communication of CF Priorities to DRDC

Currently, CF priorities are communicated to DRDC through a number of official channels. Details of these avenues of communication are listed in Sections 3.2.2 to 3.2.4. It is important to note that in addition to "official" channels, more informal communication is also of great value. For some of the PGs, informal communication is cited as the most important and effective means of communication.

3.2.1 Assistant Deputy Minister (S&T) and the Scientific Advisors

The Assistant Deputy Minister of Science and Technology (ADM(S&T)) and the Scientific Advisors are the highest ranking members of DRDC. As a result, they are members of many committees and boards at the highest levels in DND and the CF. The ADM(S&T) is a member of "Level 1" committees and boards with other ADMs and the corresponding CF personnel (generally the Environmental Chiefs of Staff). The ADM(S&T)'s participation at this high level provides insight into the priorities of the CF at the highest levels of decision making. This insight can be communicated to DRDC through a "trickle-down" effect.

The Scientific Advisors are members of "Level 2" committees and boards with other Directors General and the corresponding CF personnel (typically General Officers, i.e. Brigadier-General (in the Army and Air Force) or Commodore (in the Navy) and higher ranks). The

10. The Air and Maritime DSTs also use these means to determine priorities, in addition to their formal processes.

Scientific Advisors (SAs) are also Directors General (DGs) for the different DRDC centres. The SAs' interactions with the CF at these high levels also provides insight into the priorities of the CF. Their knowledge of CF priorities can also be communicated to the rest of DRDC via "trickle-down".

In addition to the trickle-down communication of CF priorities, the ADM(S&T) communicates priorities for future S&T work through the Defence S&T Strategy [17]. This document provides strategic guidance for the next five years and beyond. The Strategy identifies eight "mission-critical outcomes" that identify key CF capabilities where defence S&T can contribute. While this guidance for the S&T community is extremely valuable, it is not strictly operational or capability guidance. The strategy has been endorsed by the Deputy Minister and the Chief of the Defence Staff, but it was produced mainly within the S&T community and the mission critical outcomes are at such a high level that they cannot be used to guide or select individual TD projects. Moreover, since the Defence S&T Strategy will not be produced annually, it cannot be expected to provide definitive guidance or prioritization on evolving CF requirements.

3.2.2 DG Science and Technology Operations and the Directorates of S&T

As mentioned in Section 3.1.4, the research programs of DRDC are coordinated by seven DSTs: Integrated Canadian Forces, Maritime, Land, Air, Personnel, C4ISR, and Human Effectiveness and Protection. [11] The DSTs, in turn, are coordinated by and fall under the Director General Science and Technology Operations (DGSTO). The coordination of the R&D programs is done in association with the Scientific Advisors (DRDC DGs). The DSTs also have a responsibility for maintaining liaisons with the operational community so that they can ensure that the defence R&D programs meet military needs; the DSTs are the primary points of contact for the military partners.

Section 3.1.4 described how two of the DSTs (Air and Maritime) have started formal, annual processes for determining capability and operational priorities. Closely linked to this processes is the communication of the priorities, once they are determined. For DST Air, this resulted in the production of the ACIL capability list. For DST Maritime, the first iteration of the process is not yet complete so no priority list exists yet; however, one should be produced upon completion of the process. These lists clearly communicate priorities to the respective R&D communities.

11. The Integrated Canadian Forces and Personnel PGs were created in July 2007. Since they are very new and have not been involved with the TD Program yet, they were not included in this study.

3.2.3 Thrust Advisory Groups

As mentioned in Section 3.1.4, the Thrust Advisory Groups (TAGs) deal with subsets of the R&D covered by each PG. Each PG has four or five thrusts, each of which is overseen by a TAG. Since the TAGs are made up of defence scientists (usually at the section head level) and military personnel, they provide fora for communications for people who are close to (but still usually above) the working scientist and operational personnel levels. The members of the TAGs are very well informed about their areas of specialty, but each TAG is focussed on a relatively narrow range of CF priorities and S&T solutions.

3.2.4 S&T Liaison Officers

The Science and Technology Liaison Officers (S&T LOs) positions have only recently been created by the Associate DGSTO. There are S&T LOs for each of the four operational Commands and the SJS. [12] The S&T LOs were created specifically to improve communication between the operational community and the S&T community. The S&T LOs divide their time between the Commands/SJS and the DRDC centres. Their presence at the Commands/SJS make them well-placed to know the priorities of these organizations. Their presence at the DRDC centres means they are well-informed about the defence S&T capabilities within DRDC. Consequently, the S&T LOs can inform the operational community about areas where R&D can help solve CF requirements. Additionally, the S&T LOs play a key role in helping to provide guidance to defence R&D.

Although none of the Commands yet has a formal process for determining operational priorities, the S&T LOs assess the operational priorities of the Commands based on their first-hand knowledge. For this study the S&T LOs were able to provide lists of priorities for all but one of the Commands. These lists were originally compiled at the request of the Associate DGSTO. Annex A contains the priority lists of the Commands. It is clear that these lists are focussed on short term objectives; it is not obvious how many of the objectives can be addressed by R&D projects, which usually have longer timescales. Many of the items on the lists are also very general, so it may be difficult to translate some items into the type of specific language that is required to provide clear guidance.

3.3 Summary of current processes

There are a number of processes already in place to help determine the operational and capability priorities of the CF, and a number of avenues for communicating these priorities to the defence R&D community. This should not be a reason for complacency, however. With the exception of the ongoing analysis of the Force Planning Scenarios under the auspices of CFD (see Section 3.1.1), all of the processes suffer from varying degrees of "stove-piping":

12. Currently, there are three S&T LOs so two of the LOs maintain liaisons with two of these organizations each.

priorities are set for subsets of the CF as opposed to a holistic approach. This leads to difficulties when trying to prioritize R&D projects from the perspective of CF requirements. Prioritization is necessary as funding for defence R&D is limited and the demand for funding is greater than the available resources.

In the absence of clear guidance from the operational community, a new process or mechanism is required to fill this gap. The following section outlines several options for a new process that should improve the current situation.

4 Options for a new process

This section outlines possible options for a process to identify and communicate CF priorities for defence R&D purposes. The objective of this process is to produce a list of priorities, which we call the Canadian Forces Priority List (CFPL), that will be used to influence, but not fully determine, TD projects in the future. Before the process options are discussed, it must be stated that this paper recommends a process that is very similar to the existing process employed by CFD for determining CF priorities. The CFD process will produce the Strategic Capability Roadmap (SCR). As a result, we recommend adopting CFD's SCR to guide the TD Program instead of creating a new (and redundant) CFPL. However, since this study approached the problem of identifying CF priorities in a manner that did not presuppose the recommended process would be similar to the CFD process, we will first describe how our recommended process was determined without reference to the SCR.

Section 4.1 discusses the potential contributors to the list. The characteristics of this list are examined in Section 4.2. Section 4.3 discusses how priorities from different CF organizations can be integrated into a single list. Section 4.4 outlines the approval process for the list. The translation of a military priority list into an S&T priority list is discussed in Section 4.5 and finally, Section 4.6 discusses how the list of CF priorities may be used in the TD Program and more broadly by DRDC, industry, and academia.

4.1 Contributors to CF priorities list

There are many organizations in the DND and CF that could contribute to the CFPL. They include
– the Chief of Force Development,
– the four operational Commands,
– the Strategic Joint Staff (SJS), and
– the various requirements directorates under the Environmental Chiefs of Staff.

The processes employed by CFD, SJS and the operational Commands to identify priorities were described in detail in Section 3.1. To summarize, CFD analyzes the Force Planning Scenarios to determine the prioritization of capability goals for the CF. The Commands do not yet have formal processes, but the S&T liaison officers have assessed their priorities and provided lists for this study (see Annex A for the lists). SJS does not currently have a formal process for identifying CF priorities, but, in consultation with the Chief of the Defence Staff, produces a list of high-level, strategic priorities.

Under each Environmental Chief of Staff (ECS) is a directorate responsible for determining requirements: Director Air Requirements (DAR); Director Land Requirements (DLR); Director Maritime Requirements Sea (DMRS). Although each of these directorates determines the requirements for its environment, it would be difficult to integrate these re-

quirements directly into a single list for the CF. Ranking Army, Navy, and Air Force requirements against each other is a politically sensitive area that is best left to the new CF organizations resulting from transformation (e.g., CFD).

As mentioned in Section 3.1.4, some of the Directorates of Science and Technology (DSTs) have worked with their CF counterparts to determine the prioritization of CF requirements in their areas of S&T. These lists will not be incorporated into this process for the same reason the ECSs will not be directly incorporated: under transformation, comparison of the requirements of the environments is best left to central bodies like CFD. In addition, not having the DSTs involved in determining CF priorities to guide the TD Program removes a potential conflict of interest; instead, the DSTs can focus on the delivery of S&T to support CF priorities.

The arguments in favour of having CFD and the operational Commands contribute to the integrated priorities list are given in detail in Section 3.1. To summarize, the results of the analysis of the Force Planning Scenarios are critical to determining the capability priorities for the CF across a wide spectrum of operations (mainly Horizons 2 and 3). The Commands are ideal for determining the present operational priorities as they are responsible for current operations (Horizon 1). The TD Program, with its responsibility to bridge Horizons 1 and 2, requires a means of reconciling and consolidating these diffuse and, at times, competing requirements.

Due to its strategic (and longer term) focus, the SJS is not ideally positioned to contribute to a list of priorities that will be used for selecting TD projects; TD projects are intended to produce near term results. For this reason, we recommend that CFD and the operational Commands should be the contributors to the list of CF priorities. Figure 1 is a notional view of the process to produce a Canadian Forces Priorities List (CFPL).

4.2 Characteristics of CF priorities list

The ultimate goal of this process is to produce a list of priorities that will clearly guide investments in defence R&D (in particular the TD Program). To achieve this goal, the list must identify specific CF requirements that can be addressed by R&D. The items on the list must be generic enough to allow flexibility on the R&D side, but specific enough so that clear priorities can be discerned. The list should not specify technologies that need to be developed, but rather should specify capabilities that are required; scientists and engineers at DRDC or in industry should not be unnecessarily constrained in the range of solutions they might consider.

The CFPL can categorize the priorities in three different ways: ranked, unranked, and "grouped". The advantages of a ranked list are
– no ambiguity about relative priority;
– no personal bias when using the list to compare R&D projects;

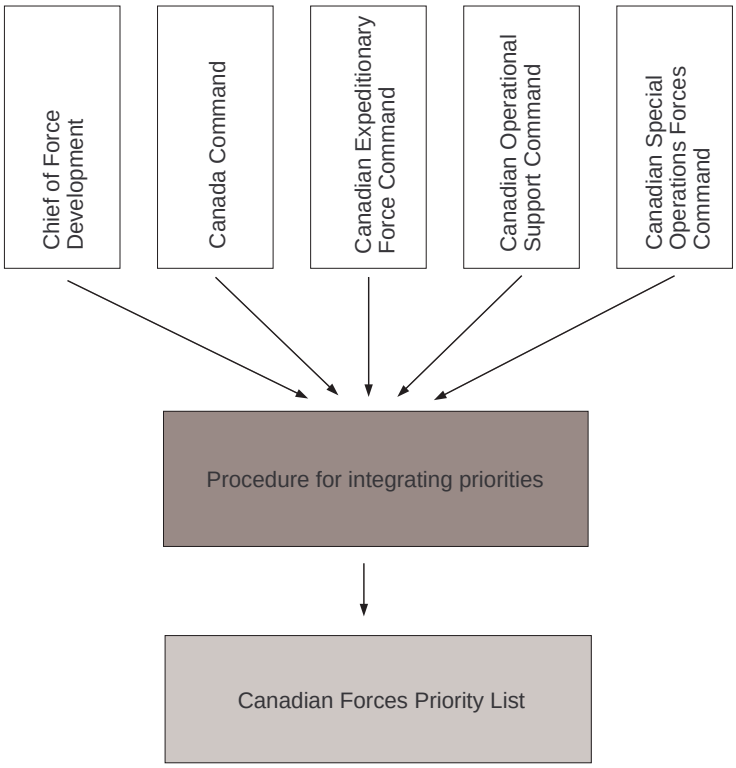

Figure 1: *Notional process for producing the Canadian Forces Priorities List.*

– clear guidance for defence R&D.

The disadvantages of a ranked list are that

– it may be difficult to reach consensus on the ordering of the list;
– the algorithm or method used to integrate the priorities may be contentious;
– it may be difficult to discriminate amongst the priorities with the resolution required to assign each priority a unique rank.

The advantages of an unranked list are that it

– avoids the controversy that is associated with ranking;
– is easier to compile and agree upon.

The disadvantages of an unranked list are that it

– makes no differentiation between the most and least important priorities;
– offers only a small improvement on the status quo (where no CF priorities are used for guidance).

A compromise between ranked and unranked lists is a list whose items are grouped by importance (this is equivalent to a ranked list with ties; all the items within a group are considered to be tied). This can be done by assigning numerical scores to priorities (the more increments on the scale, the more resolving power amongst the priorities), or equivalently, assigning priorities to a pre-determined number of groups (the more groups, the more resolving power). For the purposes of this study, we will consider grouping the priorities into three groups (high, medium and low). The advantages of a grouped list are that it

– is easier to group than rank all priorities individually;
– gives a more realistic impression of the ability to differentiate between the highest and lowest priorities;
– leaves some discretion for guidance purposes.

For example, if the priorities are grouped together, people using the list for comparing R&D projects in the same priority group can still use their judgement to decide which project addresses a higher priority. The disadvantages of a grouped list are that it

– requires an algorithm or method to decide how priorities are grouped;
– may lead to contentious results;
– allows for some personal bias when R&D projects from the same priority group are compared.

Clearly, arguments can be made in favour of any of the three types of lists. However, for now, we will focus on the "grouped" option. A grouped list provides a reasonable compromise between discriminating power amongst the priorities and making the process simple and manageable.

The contributors to the CFPL will first have to categorize or rank their priorities. The combined list of priorities can then be analyzed to determine what priorities should be given overall rankings of high, medium and low.

The scope or length of the CFPL is another important characteristic to consider. The list can be very short and focussed, long and inclusive or somewhere in between. The decision on

the length of the priorities list is somewhat subjective, but consideration of the number of TD projects that are proposed and selected each year provides some guide for a reasonable length. Historically, four to six TD projects are selected each year out of a field of eight to twelve proposals. It is desirable, though not required, to have at least as many priorities as proposals, so that it is possible that each proposal addresses a unique priority. If this is the case then it is especially valuable to have the priorities ranked or grouped (as we have recommended). This means that there should be at least twelve priorities on the CFPL (since twelve TD proposals is the historical maximum). Of course, it is still possible to have fewer than twelve identified priorities. This just increases the likelihood that a TD proposal will not address a CF priority.

At this point, we have not considered the number of organizations that might contribute to the final integrated list. This number will influence how many priorities each organization should contribute. As long as there is not complete overlap amongst the contributed lists, the number of priorities per organization can be less than the desired total number of priorities (which, for the sake of argument, we have assumed to be at least twelve).

For this study, several CF organizations were solicited for lists of priorities. Canada COM, CEFCOM, and CANOSCOM supplied priority lists that were compiled by their S&T liaison officers; see Annex A for the lists. Depending on how one groups the priorities on these lists, the number of priorities provided by the Commands varies from five to twenty. This indicates that obtaining priority lists with adequate numbers of items should not be a problem. There is also little overlap between these lists, so obtaining a total number of priorities greater than or equal to twelve should not be a problem.

In addition to the Commands, another potential source of input for priorities is CFD's list of capability priorities. This list is produced after analyzing the force planning scenarios (see Section 3.1.1 for more details). CFD's list of capabilities currently has approximately twenty items; however, the final number of items may vary depending on which capabilities are "rolled up" into more generic capabilities. As a result, the CFD list should also contribute an adequate number of priorities.

To summarize, the objective of this process is to produce a grouped list of CF priorities. If the items are grouped by priority, that would provide clear guidance without the overhead and potential controversy associated with individual rankings for all the priorities. Since there are up to twelve TD Program proposals each year, it would be desirable (though not required) to have at least twelve priorities identified on the list. This objective should be met easily as several appropriate CF/DND organizations have already been able to supply prioritized lists of adequate length for this study.

4.3 Integration of multiple lists of priorities

The multiple lists of CF priorities (from CFD and the Commands) need to be integrated by someone into a single list to provide effective guidance. While it would be possible for someone associated with the TD Program to do this (e.g. CORA's S&T OR Team), it is suggested that CFD is the ideal body for producing an integrated list for guiding the TD Program, in view of its mandate to oversee capability requirements on behalf of the CF.

4.3.1 Capability Management

One of CFD's most important functions is to perform "capability management" for the CF's Force Development process. The primary output of capability management is a set of preferred capability options for the CF [18]. Preferred capability options are determined in two steps. First, the capability priorities previously identified by CFD and others are compared to the current CF capabilities. This results in capability shortfalls and excesses being identified. The second step involves analyzing the capability areas where shortfalls occur; the output of this analysis is a set of preferred capability options that address the shortfalls.

The capability goals identified by CFD are used as input for the capability management process. In addition, requirements identified by the operational Commands (especially unforeseen operational requirements [UORs]) are forwarded to CFD via SJS. Finally, the Environmental Chiefs of Staff (ECSs) also influence capability management by providing input that is based on their experiences with Force Generation; if capability deficiencies are identified during Force Generation, these deficiencies are communicated to CFD. These multiple sources of input to capability management cover the full range of timescales for which capabilities are required: Horizon 1 requirements are identified by the Commands (via SJS) and ECSs; medium term, Horizon 2 requirements, are identified by the ECSs and CFD; Horizon 3 requirements are identified by CFD. Figure 2 indicates the inputs to CFD's capability management process and the main output of the process: the Strategic Capability Roadmap (SCR).

During the capability management process, CFD analyzes all the identified capability requirements in a holistic manner to determine which capability alternatives should be assigned the highest priority. The ranking of each priority is based on the ranking of the corresponding capability goal (from analysis of Force Planning Scenarios) and the cost of the alternative over its expected life [19]. The cost of each alternative depends on many factors [20]:

– personnel;
– research and development, operational research;
– infrastructure and organization;
– concepts, doctrine and collective training;
– information technology infrastructure;

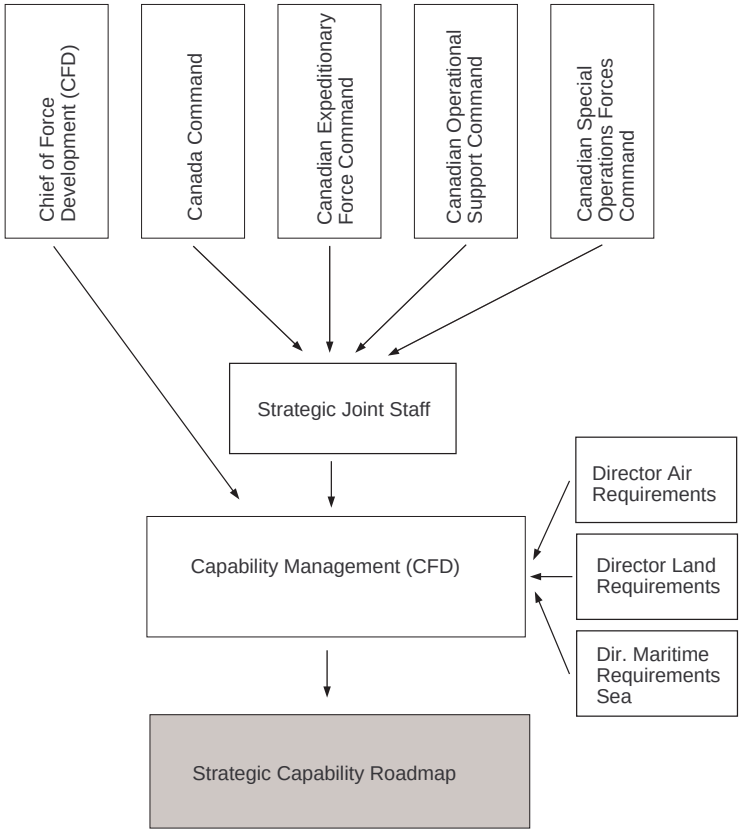

Figure 2: *CFD's process for producing the Strategic Capability Roadmap.*

– equipment, supplies and services.
Collectively, these factors are given the acronym PRICIE. Consideration of all these factors is required to ensure that capabilities that will be generated can be adequately supported.

The list of capability options produced by CFD will be ranked. Previously in this document, we recommended a grouped list (capability options grouped by priority). The main reason for preferring a grouped list over a ranked list was the difficulty in ranking all the items. However, since CFD will produce a ranked list, there is little to gain from turning their ranked list into a grouped list. As mentioned previously, a ranked list will provide more resolution for discriminating amongst priorities and will reduce the potential for bias in the TD Program's selection process.

Since CFD will produce a list of preferred capability priorities, it will provide exactly the type of list required for providing CF guidance to DRDC. Also, the capability management process obtains its input from CFD and the operational Commands, which were previously identified as being the logical contributors to the CFPL. CFD is already tasked to produce a priority list which is ideal for guidance of the TD Program, so it would be inefficient not to adopt the results of this work. In other words, we recommend that the SCR be adopted as the CFPL. From this point forward, we will refer to the SCR only.

CFD reached Initial Operational Capability in the summer of 2007. Full Operational Capability is scheduled to occur in July 2008. This means that CFD will not be able to provide a full list of priorities in time to provide guidance to the next cycle of the TD Program; a complete analysis that produces a prioritized list of capability options could take two years. In the meantime, less detailed analyses by CFD will produce the SCR which could provide interim guidance to the TD Program. Despite the reduced rigour with respect to the final product, this guidance would still be very valuable.

4.4 Approval of the SCR

To be widely accepted, the priorities list that is used for CF guidance must be approved by appropriate bodies in the CF. The Capability Development Board (CDB), Program Management Board (PMB) and more senior Joint Capability Review Board (JCRB) are responsible for approving the output of the main Force Development processes. Capability management is one of these processes, so CDB, PMB and JCRB are already mandated to approve CFD's list. Their approval of the SCR is critical, since it provides the means for the operational Commands and ECSs to express their opinions and it provides a means of obtaining consensus on CF requirements. In matters of capability management, the CDB (chaired by the CFD) is responsible for advising CFD on capability management assessments, options development and prioritization. After CDB approval, the PMB (chaired by the Chief of Program [CProg]) is responsible for reviewing the fiscal constraints of force development initiatives recommended by CFD. Finally, after PMB approval, JCRB

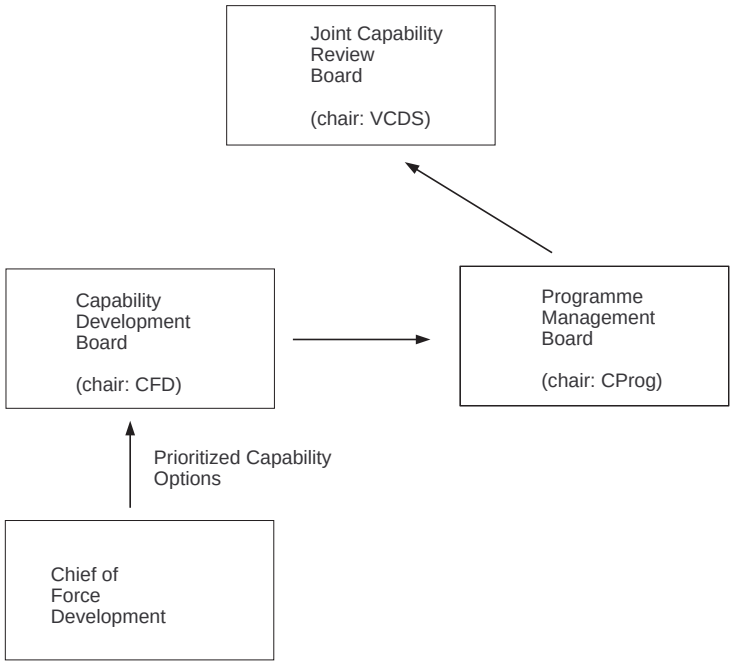

Figure 3: *The approval process for the prioritized list of capability options produced by CFD.*

(chaired by the Vice Chief of the Defence Staff [VCDS]) provides oversight and final approval to the capability/force development process; the JCRB ensures that the prioritization of CFD's capability options is in line with higher policy guidance such as the Canada First Defence Strategy. Figure 3 shows the approval process.

4.5 Translating the SCR into S&T priorities

There are two options for how the SCR can be used by DRDC, industry and academia. The first option is to take the list as is. The second option is to analyze and re-interpret the list in terms of S&T areas that might be able to contribute to CF priorities. For reasons that are discussed in Section 4.6, we recommend making use of both options. The remainder of this section describes how the SCR can be analyzed in terms of S&T areas.

DRDC's DSTs would be responsible for translating the SCR into a list of S&T Options for the SCR (STO-SCR). Each DST would study the SCR and suggest S&T areas relevant to their directorates that might address an SCR item. Not all the items on the SCR will be addressable by S&T, but a single SCR item might have multiple STO-SCR options. For example, if the SCR consists of 10 items (scr-1, scr-2, ... scr-10), there might be three STO-SCR items that address scr-1 (sto-scr-1a, sto-scr-1b, sto-scr-1c); zero STO-SCR items that address item-2; two STO-SCR items that address SCR-3 (sto-scr-3a, sto-scr-3b); one that

addresses SCR-4 (sto-scr-4a); and so on.

The DSTs should review the combined list of proposed STO-SCR items. Any items that are deemed inappropriate by the reviewers should be removed from the combined list. Once the list has passed this first stage of review, the items on the list can be ranked.

The ranking of the STO-SCR should largely reflect the ranking of the SCR, but there should be some flexibility related to other considerations: the technology readiness level (TRL) [13]; "appropriateness" of the technology for the SCR item; and DRDC resources available. The appropriateness of the technology is its ability to deliver the desired effect with respect to an SCR item. For example, if a SCR item is "effective 24 hour a day imaging capability", a passive visible light camera is not appropriate as it can not image very well at night, while an infra-red camera is appropriate as it can be used at any time of day.

If the TRLs, appropriateness and resources available for all items on the STO-SCR were identical, then the ranking of the STO-SCR would directly follow the ranking of the SCR. From the example in the previous paragraph, the ranking of the STO-SCR would be (in order): sto-scr-1a, sto-scr-1b, sto-scr-1c, sto-scr-3a, sto-scr-3b, and so on. However, if there are significant differences in the TRLs, appropriateness and resources for different STO-SCR items, those items with a low TRL (for example) might have a ranking lower than items with a higher TRL, even though the low TRL item addresses an SCR item with a higher priority. It is worth noting that items with a very high TRL (e.g. items for which the technology has been used successfully in operations) are not appropriate for TD projects as the technology has already been successfully demonstrated. As the DSTs have a comprehensive understanding of their S&T areas and their utility to the military, they should be responsible for assessing the TRL, appropriateness and resources available for each of the STO-SCR items. Figure 4 gives an example of how the SCR might be mapped to the STO-SCR. Not all SCR items have a corresponding STO-SCR item (e.g. SCR-2); deviations from the SCR ranking (e.g. sto-scr-4a ranked higher than sto-scr-3b) can also occur.

The STO-SCR items will be ranked by many rankers (an ADM(S&T) board composed of the DSTs, DRDC's Associate DGSTO, and possibly others) based on multiple criteria (SCR ranking, TRL, appropriateness, available resources), therefore this constitutes a multi-criteria consensus ranking problem. In a consensus ranking problem, N people or groups provide rankings of M items. The goal of a consensus ranking algorithm is to determine a single ranking for the M items that best reflects the consensus of the N contributed rankings. A mathematically rigorous consensus ranking algorithm has been developed by Emond and Mason [22] of DRDC Centre for Operational Research and Analysis (CORA). This algorithm determines a consensus ranking by calculating a correlation coefficient for

13. The TRL is a 9-point scale used to assess the level of advancement of a technology. Level 9 is the most advanced, indicating that the technology has been used successfully is real-life missions. Level 1 is the least advanced, indicating that only the basic scientific principles that might underlie a technology have been observed [21].

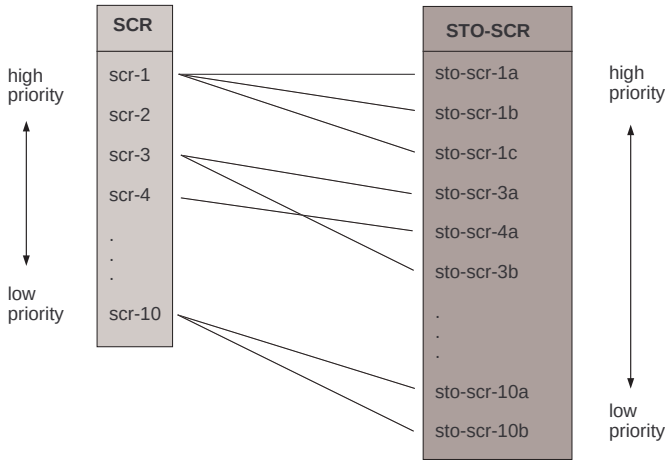

Figure 4: *Example of mapping of SCR items into STO-SCR items.*

the consensus ranking with respect to the input rankings. This method is powerful and general as it allows input rankings with different weights, ties and partial inputs. This algorithm is implemented in the software application called MARCUS (Multi-criteria Analysis and Ranking Consensus Unified Solution) [23], which has been used widely by CORA members for providing decision support (including the ranking of proposals for the TD Program). The ranking process could be facilitated by members of CORA's S&T OR Team as they support the TD Program and are experienced users of MARCUS.

After identifying who will contribute votes in the ranking process, all that remains for ranking the STO-SCR items is deciding the relative weights of the criteria. Since the STO-SCR is supposed to reflect the top-down guidance provided by the SCR, the SCR ranking should be the criterion with the greatest weight. However, the sum of the remaining criteria weights should be large enough to "overrule" the SCR criterion. For these reasons, we recommend that the three non-SCR criteria (TRL, appropriateness, and resource availability) be assigned weights of 1, while the SCR weight should be 2. Consequently, if a ranker believes an STO-SCR item with an inferior SCR ranking (sto-scr-i) ranks higher than a superior SCR-ranked item (sto-scr-s) for all non-SCR criteria, then the overall ranking of sto-scr-s will be lower than sto-scr-i (weight of 3 (= 1+1+1) in favour of sto-scr-i versus weight of 2 in favour of sto-scr-s).

Once the STO-SCR items have been ranked by the ADM(S&T) board, the STO-SCR can be forwarded to the ADM(S&T) for approval. To maintain good communication between CFD (who produce the SCR) and ADM(S&T), the ranked and approved STO-SCR should be sent to CFD to keep them informed about ADM(S&T)'s priority areas (that reflect CFD's SCR). Figure 5 summarizes the proposed process for transforming the SCR into the STO-SCR.

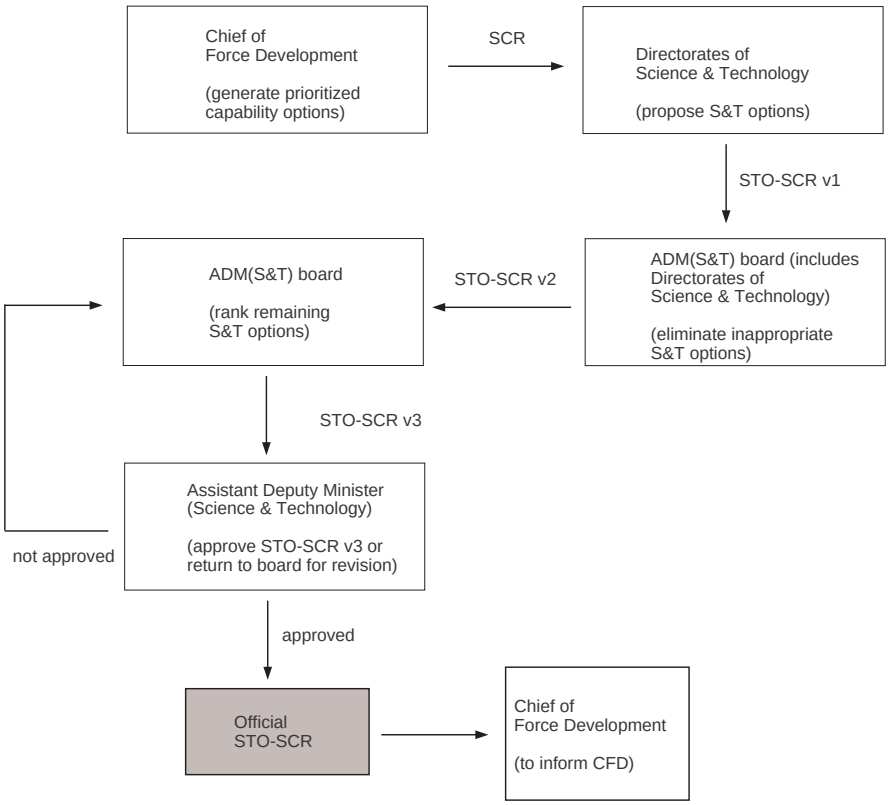

Figure 5: *The process for transforming the Strategic Capability Roadmap (SCR) into the Science & Technology Options for the SCR (STO-SCR).*

It is important to stress that the STO-SCR is not a list of S&T projects. Rather, it is a ranked list of S&T areas that meet SCR priorities. Ultimately, it will be up to defence scientists to propose specific projects that relate to areas identified by the STO-SCR.

4.6 Utilization of the STO-SCR and SCR

We will consider four possible uses of the STO-SCR and SCR:

1. guiding what TD projects are proposed for funding (STO-SCR);
2. ranking TD proposals during the selection phase of the TD Program (SCR);
3. guiding S&T within DRDC in general (not just the TD Program) (SCR);
4. guiding Canadian defence S&T outside DRDC: industry and academia (SCR).

Using the STO-SCR to guide what TD projects are proposed will enhance the military relevance of the TD projects that are proposed and subsequently selected as the STO-SCR is derived from the SCR. The STO-SCR is more appropriate than the SCR as it identifies priority S&T areas and has been approved by the ADM(S&T). Accordingly, it is important that the STO-SCR be completed and approved in time to allow it to be distributed within DRDC in sufficient time to allow proposals to be developed for the TDP selection process.

Using the SCR to rank TD proposals based on military fit will help to address an identified shortcoming of the TD Program: it is not adequately responsive to CF priorities [5]. Also, as the items on the SCR will be ranked, the list will eliminate the perception of bias in the portion of the selection process where military utility and impact are assessed. The STO-SCR is less appropriate than the SCR for ranking TD proposals with respect to military utility and impact as the ranking of STO-SCR items is partially influenced by considerations that are not related to CF requirements, especially S&T factors. S&T merit is already considered separately in the ranking of TD proposals.

It should be noted that the SCR is not intended to unnecessarily constrain the submission of TD proposals. Proposals not associated with the SCR will receive fair consideration and may well receive funding ahead of approved items on the SCR because of outstanding scientific merit. However, it is obvious that proposals in line with the SCR will have the advantage of already satisfying the selection criteria of military utility and/or impact.

The SCR can also be used for DRDC S&T guidance beyond the TD Program. Since the SCR spans Horizons 1, 2 and 3 it applies to the full range of time frames that S&T can address. Again, the SCR would provide clear guidance that reflects identified CF priorities. The STO-SCR is not appropriate to guide S&T programs other than the TD Program as its rankings assumes a preferred TRL range: TRLs from 5 to 7 are typically preferred for TD projects.

Finally, a slightly modified version of the SCR can be used to guide Canadian defence S&T in industry and academia. The SCR would have to be modified by removing those items

that do not require S&T work; in other words, those items where off-the-shelf solutions already exist do not need to be included. CFD will be identifying those items on the SCR that would benefit from S&T, so modification of the SCR should be trivial. Any classified information in the SCR would also have to be removed before distribution to industry and academia. The STO-SCR would not be appropriate for guiding S&T in industry and academia as DRDC capabilities were considered in its construction. The capabilities of DRDC are not necessarily the same as those of Canadian industry and academia.

For all four applications, the SCR or STO-SCR should be provided to those who can directly contribute to Canadian defence S&T. This requires distributing the SCR and STO-SCR to all scientists engaged in defence S&T. To maximize the impact of these lists, it is vital that all S&T personnel are made aware of the priorities of the CF.

5 Challenges

The purpose of the proposed process is to provide guidance; the STO-SCR and SCR are not intended to restrict the submission and selection of TD proposals unduly. Proposals not associated with the SCR or STO-SCR should continue to receive full consideration and, in exceptional circumstances, may rank ahead of proposals that do address the SCR. For this reason, the SCR and STO-SCR should not act as filters. This ensures that innovation is not suppressed in the TD Program.

It is important to realize that there are challenges for successfully implementing the recommendations of this report. Despite the caveat that the SCR and STO-SCR should not be overly restrictive, there may be cultural barriers to implementing centralized guidance. It may be construed as being contrary to the ideals of innovation and creativity. Centralized guidance could also be seen as impinging on the areas of responsibility of the TAGs, DSTs and their military partners. For this reason, it is important that the military partners, who represent the three environments, support the content and priorities of the SCR. Hopefully, this will not be an issue since the environmental Chiefs of Staff have significant influence over CFD's outputs. For this guidance to be successful, it is important that DRDC scientific and corporate personnel and their military partners believe that the TD Program will remain flexible in its application of the SCR and the STO-SCR. If this happens, then acceptance and support for the guidance should be obtained.

The extent to which the SCR and STO-SCR are successful at providing guidance to the TD Program will depend on the resources and time that are available to create and interpret them. Since the SCR has not been produced yet, there is some uncertainty about the type of details it will contain. The level of detail will depend on the resources and time that CFD has available. Similarly, the quality of guidance the STO-SCR will provide depends on the availability of already busy DRDC personnel. Despite these challenges, it is hoped that the perceived benefits of the SCR and STO-SCR will result in their receiving adequate resources to achieve their goals.

A final complication related to the implementation of the process recommended in this report is the fact that at least one other organization in DRDC is studying processes by which the CF can influence DRDC. The Office of the Chief Scientist ADM(S&T) is investigating how the priorities of the CF can influence S&T across all of DRDC and the rest of the department [14], and in turn how ADM(S&T) influences all S&T in DND and the CF through a Functional Guidance document. Ideally the process advocated in our report should be integrated with whatever recommendations are forthcoming from the Office of the Chief Scientist. Effective communication and coordination between DGSTO, who is responsible for the TD Program, and the Office of the Chief Scientist will hopefully lead to complementary processes, or a single comprehensive process for all S&T in DRDC and the rest of

14. All the S&T that is conducted in DND and the CF (not just DRDC) is referred to as the S&T Enterprise.

DND.

6 Conclusions

A new process is proposed that will provide guidance to the TD Program based on the priorities of the CF. The proposed process will produce two lists: the SCR and the STO-SCR. The SCR is a ranked list of the CF's capability priorities. The STO-SCR is a list of DRDC's S&T areas that address specific items of the SCR. The STO-SCR will be created by DRDC's DSTs and will reflect the CF priorities listed in the SCR, DRDC's S&T capabilities, and the appropriateness and TRL of each S&T area.

The STO-SCR can be used to guide what TD projects are proposed each year. The SCR can be used to rank the TD proposals based on military utility and impact. The guidance provided by these two lists will increase the responsiveness of DRDC to the requirements of the CF, and will eliminate a perceived source of bias in the ranking of TD proposals. Even though the production of a complete SCR is likely two years away, it is recommended that the interim SCR be used to create an interim STO-SCR. Both of these documents would have immediate impacts on the TD Program and consequently the S&T output of DRDC.

As outlined in the previous section, there may be challenges to the successful implementation of the recommendations outlined in this report. However, it is hoped that with adequate resources in CFD and DRDC, and careful consideration of potential cultural barriers, the TD Program will continue ensuring that the CF remains scientifically and operationally relevant.

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Annex A: Command priorities lists

Command priorities lists were compiled for this document by the S&T LOs responsible for Canada COM [24], CEFCOM [25], and CANOSCOM [26]. These lists were produced with S&T in mind, so that all items on the list represent priorities that S&T can address. No list was available for CANSOFCOM. The Canada COM and CEFCOM priorities lists are not ranked.

A.1 Canada COM priorities for S&T

- Readiness
  - National Surveillance Plan: coastal and northern
- Planning
  - Vancouver 2010 Olympics
  - Chemical Biological Radiological Nuclear (CBRN) response
- Operations
  - Automated planning tools
  - Operation Process Plan (OPP)/crisis response tool
  - Collaboration and information sharing with Other Government Departments (OGDs)
- Transformation
  - Support Integrated Operating Concept Working Group

A.2 CEFCOM priorities for S&T

- Force Protection
  - Improvised Explosive Device (IED) defeat
    - Review of tactics, techniques and procedures (TTPs) to include formations, vehicles used, protection offered
    - Vehicle load-outs
    - Modifications made to vehicles to improve protection
    - Evaluate shortcomings of Personal Protective Equipment (PPE)
    - Evaluate counter-IED surveillance
    - Identify Friend or Foe (IFF), Combat Identification (ID)
- Command and Control Support
  - Command, Control, Intelligence, Surveillance (C2IS) for intelligence-lead operations
    - Integrated Common Operating Picture (COP)
    - Information needs to be integrated at tactical/strategic levels
  - Command, Intelligence, Surveillance (CIS) architecture that supports C2IS, needs to support all users including missions operating over disadvantaged links (expedition and small mil missions)
  - Blue Force Tracker integration with COP

    - TTPs
    - Concept of operations (CONOPS)
- Training/Preparation/Certification of Forces for Employment
  - Review for gaps and identify best way ahead
- Equip As You Fight
  - Review current operations for Capability gaps regarding:
    - Weapon systems
    - PPE
    - Vehicles
    - ISTAR assets
    - Soldier personal equipment
  - Simulation based acquisition
  - Electronic intelligence
- Integration / Interoperability Issues
  - Interoperability with coalition
  - Integrate separate sources of info internally (ASIC, Int, tactical, operational)
- Long Term Development
  - Process
  - Organization
  - Manning

A.3 CANOSCOM priorities for S&T

- Mounting and supporting second line of operations: identify capability requirements
- Operational support hubs: refined studies on CONOPS, facilities, capabilities, enabling technologies
- Radio-frequency ID and Digitization
  - Impact on business process
  - Improved automation of requirements analyses
- Energy on the battlefield
  - Reduced reliance on fossil fuels
  - Fewer types of fuels required
  - Better batteries or substitutes (e.g. fuel cells)
- Employment and training standards for personnel
  - Identify improvements to training for personnel operation in Canada, or abroad inside/outside bases

List of Abbreviations

ACIL	Aerospace Capabilities Initiatives List
ACTD	Advanced Concept Technology Demonstration
A/JCTD	Advanced Concept and Joint Capability Technology Demonstration
ADF	Australian Defence Force
ADM(S&T)	Assistant Deputy Minister (Science and Technology)
ATD	Advanced Technology Demonstration
C4ISR	Command, Control, Communications, Computers, Intelligence, Surveillance, and Reconnaissance
Canada COM	Canada Command
CANSOFCOM	Canadian Special Operations Forces Command
CANOSCOM	Canadian Operational Support Command
CDB	Capability Development Board
CDE	Capability Development Executive
CDS	Chief of Defence Staff
CEFCOM	Canadian Expeditionary Force Command
CF	Canadian Forces
CFD	Chief of Force Development
CFPL	Canadian Forces Priorities List
CoCom	Combatant Commander
CORA	Centre for Operational Research and Analysis
CProg	Chief of Program
CRS	Chief Review Services
CTD	Capability and Technology Demonstrator
DAR	Director Air Requirements
DG	Director General
DGFDA	Director General Force Development Analysis
DGRDP	Director General Research and Development Programs
DGSTO	Director General Science and Technology Operations
DIS	Defence Industrial Strategy
DLR	Director Land Requirements
DMRS	Director Maritime Requirements Sea
DND	Department of National Defence
DoD	Department of Defense (United States)
DPB	Defence Planning Board
DRDC	Defence Research and Development Canada
DSG	Defence Strategic Guidance
DST	Directorate of Science and Technology
DSTO	Defence Science and Technology Organization
DTS	Defence Technology Strategy
ECS	Environmental Chief of Staff

IED	Improvised Explosive Device
IPL	Integrated Priority List
ISR	Intelligence, Surveillance and Reconnaissance
JCRB	Joint Capability Review Board
JCTD	Joint Capability Technology Demonstration
MARCUS	Multi-criteria Analysis and Ranking Consensus Unified Solution
MoD	Ministry of Defence (United Kingdom)
PG	Partner Group
PMB	Program Management Board
R&D	Research and Development
SA	Scientific Advisor
SCR	Strategic Capability Roadmap
SJS	Strategic Joint Staff
S&T	Science and Technology
S&T LO	Science and Technology Liaison Officer
STO-SCR	Science and Technology Options for the Strategic Capability Roadmap
TAG	Thrust Advisory Group
TD	Technology Demonstration
TRL	Technology Readiness Level
UOR	Unforeseen Operational Requirement
VCDS	Vice Chief of the Defence Staff

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This report outlines options for a process that provides guidance from the Canadian Forces (CF) to Defence Research and Development Canada's (DRDC) Technology Demonstration (TD) Program. First, a survey is presented of the current processes by which operational and capability requirements are used to guide research and development performed by DRDC. After reviewing the current processes, options for an additional, complementary process are investigated. We recommend a simple process by which the new operational Commands and the Chief of Force Development (CFD) contribute to a list of capability and operational priorities. Since CFD is already tasked with producing a Strategic Capability Roadmap (SCR) that includes input from the Commands, we advocate adopting the SCR to guide the TD Program. The SCR can then be translated into priority Science and Technology Options for the SCR (STO-SCR). Both the SCR and the STO-SCR should provide concise, top-down, guidance to the TD Program. The creation and adoption of this type of guidance will not be without challenges; these challenges are elaborated in the main report.

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capability based planning
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