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DEFENCE R&D DÉFENSE

Knowledge management in Defence R&D Canada

A knowledge management audit

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DEFENCE R&D CANADA

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Abstract

Defence R&D Canada undertook a knowledge management audit to determine how well it managed knowledge creation and use and what could be done to improve the use and leveraging of knowledge. A qualitative study was employed using a purposeful random sample and an interview format. Five themes emerged from the results:

1. There is a need to focus on the organizational mission and clarify priorities;
2. Information management tools are required as essential building blocks in a Defence R&D Canada knowledge management initiative;
3. Sharing in-house expertise is critical for knowledge leveraging, business development, cross-disciplinary work and efficiencies;
4. Enhanced exchange of foreign information is required to supplement informal exchanges; and
5. A mutual vision for future technology planning is needed for Defence R&D Canada and the Canadian Forces clients.

Résumé

R & D pour la défense Canada a amorcé une enquête sur la gestion du savoir afin d'évaluer l'habileté de l'agence à gérer la création et l'usage du savoir et de déterminer ce qu'on pourrait faire pour que le savoir soit mieux utilisé et exploité. L'enquête a été menée sous forme d'étude qualitative d'échantillons aléatoires et d'entrevues. Les résultats révèlent cinq besoins :

1. Le besoin de mettre l'accent sur la mission de l'organisation et de clarifier les priorités;
2. Le besoin d'outils de gestion de l'information comme pierre angulaire de l'initiative de gestion du savoir de R & D pour la défense Canada;
3. Le besoin essentiel de partager l'expertise sur place aux fins de l'exploitation du savoir, de l'expansion des affaires, des travaux interdisciplinaires et de l'efficacité;
4. Le besoin d'accroître les échanges d'information avec l'étranger pour compléter les échanges informels;

Le besoin d'établir une vision mutuelle de la planification future de la technologie pour les clients de R & D pour la défense Canada et des Forces canadiennes.

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Executive summary

Defence R&D Canada is exploring methods of capturing and leveraging science and technology knowledge for improved productivity, value and innovation and to support the broader defence S&T community. A knowledge management audit of Defence R&D Canada was undertaken to answer the following questions:

1. What are Defence R&D Canada's current knowledge sources?
2. How well does Defence R&D Canada manage knowledge creation and use? and
3. What can Defence R&D Canada do to improve the use and leveraging of knowledge, (i.e., what are the additional knowledge needs of the organization)?

A qualitative study was employed using a purposeful random sample and an interview format. Fifty-one out of 1032 employees took part, representing 5% of the total workforce. An additional 6 interviews of DRENet Technical Managers were conducted, focusing on the status of the information technology and management infrastructure for future initiatives. Four foci were addressed in the audit:

1. The employees' awareness of sources of knowledge within Defence R&D Canada, and enablers and barriers to their ability to find that knowledge;
2. Defence R&D Canada's ability to respond to requirements in a timely manner by finding knowledge sources internally, and skilled, knowledgeable human resources when required;
3. The enablers and barriers to accessing external knowledge sources and the ability to create partnerships; and
4. The ability of Defence R&D Canada to transmit its knowledge to clients responsively.

Five themes emerged from the results:

1. There is a need to focus on the organizational mission and clarify priorities;
2. Information management tools are required as essential building blocks in a Defence R&D Canada knowledge management initiative;
3. Sharing in-house expertise is critical for knowledge leveraging, business development, cross-disciplinary work and efficiencies;
4. Enhanced exchange of foreign information is required to supplement informal exchanges; and
5. A mutual vision for future technology planning is needed for Defence R&D Canada and the Canadian Forces clients.

Future research, knowledge mapping and pilot studies should be employed to move knowledge management forward in Defence R&D Canada.

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Sommaire

R & D pour la défense Canada étudie des méthodes servant à acquérir et à exploiter des connaissances scientifiques et technologiques en vue d'accroître la productivité, la valeur et les innovations et d'appuyer la communauté générale de la science et de la technologie militaires. Une enquête sur la gestion du savoir a été menée auprès de R & D pour la défense Canada afin de répondre aux questions suivantes :

1. Quelles sont les sources actuelles de savoir de R & D pour la défense Canada?
2. Dans quelle mesure R & D pour la défense Canada réussit-elle à gérer la création et l'utilisation du savoir?
3. Que peut faire R & D pour la défense Canada pour que le savoir soit mieux utilisé et exploité (c.-à-d. quels sont les autres besoins de l'organisation en matière de savoir)?

L'enquête a été menée sous forme d'étude qualitative d'échantillons aléatoires et d'entretiens. Des 1032 employés, 51 ont participé à l'enquête, ce qui représente 5 % de l'effectif. De plus, on a eu six entretiens avec des directeurs techniques du DRENet, où l'accent a été mis sur l'état de l'infrastructure de gestion et de technologie de l'information pour les initiatives futures. L'enquête était fondée sur quatre thèmes principaux :

1. Le niveau de sensibilisation des employés aux sources de savoir au sein de R & D pour la défense Canada et les outils qui les aident à trouver ce savoir ou les obstacles qui les en empêchent;
2. La capacité de R & D pour la défense Canada de répondre aux exigences rapidement en trouvant sur place des sources de savoir et au besoin des ressources humaines compétentes et qualifiées;
3. Les outils et les obstacles liés à l'accès aux sources de savoir externes et la capacité de créer des partenariats;
4. La capacité de R & D pour la défense Canada de transmettre son savoir aux clients selon le besoin de ces derniers.

Les résultats révèlent cinq besoins :

1. Le besoin de mettre l'accent sur la mission de l'organisation et de clarifier les priorités;
2. Le besoin d'outils de gestion de l'information comme pierre angulaire de l'initiative de gestion du savoir de R & D pour la défense Canada;
3. Le besoin essentiel de partager l'expertise sur place aux fins de l'exploitation du savoir, de l'expansion des affaires, des travaux interdisciplinaires et de l'efficacité;
4. Le besoin d'accroître les échanges d'information avec l'étranger pour compléter les échanges informels;
5. Le besoin d'établir une vision mutuelle de la planification future de la technologie pour les clients de R & D pour la défense Canada et des Forces canadiennes.

On devrait mener d'autres enquêtes et des études pilotes et établir une table de correspondances du savoir afin de faire progresser la gestion du savoir à R & D pour la défense Canada.

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Introduction

The Canadian Forces (CF) and the Department of National Defence (DND) face new and changing requirements by the Revolution in Military Affairs.[1] As part of its strategy for anticipating Canadian future military requirements in 2020, Defence R&D Canada has targeted knowledge management (KM) as one of the areas for growth and investment over the next decade. In addition to researching and developing technological capabilities in KM for Canadian Forces (CF) operations, there is also recognition of the potential for KM in Defence R&D program and corporate management. As a science and technology (S&T) organization, Defence R&D Canada is especially interested in how KM can contribute to developing its S&T capability and capacity. The work described in this report was undertaken to identify how KM might be applied to these various issues for Defence R&D Canada.

Background

Defence R&D Canada is a knowledge enterprise. From its inception, it has collected, created, shared, and disseminated scientific knowledge and knowledge products within local, national and international communities. For over 50 years, Canadian defence science employees have advanced creativity and innovation within an organization that places high value on scientific excellence and cooperation. Defence R&D Canada's culture, structure and reward systems have evolved over the years to reflect these core values. New trends in the rapidly changing technological revolution and global economy only reinforce the need for their pursuit. The pace of technological change combined with an increasingly competitive business environment place additional pressure on Defence R&D Canada to maintain its innovative edge. Conversely, new technologies and KM theories offer opportunities to explore new ways of capturing and using knowledge to ensure continued innovation, cooperation and excellence.

In scientific and technological organizations, the most important resources have always been in the minds and social interactions of the employees. Until the recent past, this intellectual capital was reasonably assured through workforce stability. Employees would spend all or most of their careers within a single organization. New employees entering the workplace would work over time with seasoned colleagues to acquire the experience and knowledge required to eventually assume similar leadership roles. This is no longer a viable model. Attrition trends due to downsizing, a mobile workforce and the impending retirement bubble threaten the stability of the corporate memory. The "corporate memory" has either left or will leave, often without formally sharing knowledge with the very organization that most values it. Remaining employees then often find themselves further isolated as solitary subject experts without access to the knowledge that is resident in other colleagues, clients or external sources. Compounding it all is the rising proliferation of the quantity of available information and a decreasing ability to effectively filter that pertinent information.

[1] "This term refers to a major change in the nature of warfare brought about by advances in military technology which, combined with dramatic changes in military doctrine and organizational concepts, fundamentally alter the character and conduct of military operations." From: Sloan, Eleanor. The Revolution in Military Affairs. Directorate of Strategic Analysis. Department of National Defence. http://www.dnd.ca/admpol/org/dg_plan/d_strat/can_rma_e.htm#1 , June 2000.

To provide expert scientific and technological knowledge and leadership to the CF and DND, sustaining long-term innovation in core competencies will be fundamental to Defence R&D Canada's ability to attaining technological and knowledge advantage for the CF. This capability will be dependent upon creating systems to facilitate the gathering and sharing of knowledge between employees, clients and external sources. It will require new methods of transforming intellectual capital into usable knowledge forms. It will also need conditions and a working environment that breed creativity and encourage a culture of intellectual growth and continuous learning. By focusing "on ways to manage how … knowledge is used, and to build systems and mechanisms to facilitate the expression and thereby sharing of ideas and know-how,"[2] Defence R&D Canada will find ways to share existing intellectual resources in creative ways.

To address these issues, a working group was formed in February 2000 to examine how KM principles could be used to enhance the use of expertise and knowledge by employees and clients. The KM Working Group was tasked to examine methods of capturing and leveraging S&T related knowledge for improved productivity and innovation, for knowledge collaboration and support within the broader defence S&T community, and to make recommendations for a way ahead. An examination of the theories and definitions of knowledge management serves to establish a context for these goals. A brief explanation follows.

[2] Koulopoulos, Thomas M. and Carl Frappaolo. *Smart Things to Know about Knowledge Management.* Dover, NH: Capstone, 1999, p. 18.

Defining knowledge management

The knowledge pyramid

The definition of knowledge management begins with a description of the knowledge pyramid. The transition from data to knowledge and beyond is illustrated in Figure 1. It illustrates how value increases and volume decreases while ascending. Facts, often termed "data" in knowledge management models, refer to quantitative units or something given from being experienced.[3] When data or facts are structured and organized into a communicable form, information is created (e.g., words into sentences). Inference transforms information into intelligence, which is an awareness of the aggregates arising from information. With certitude comes knowledge and finally with synthesis is wisdom.[4]

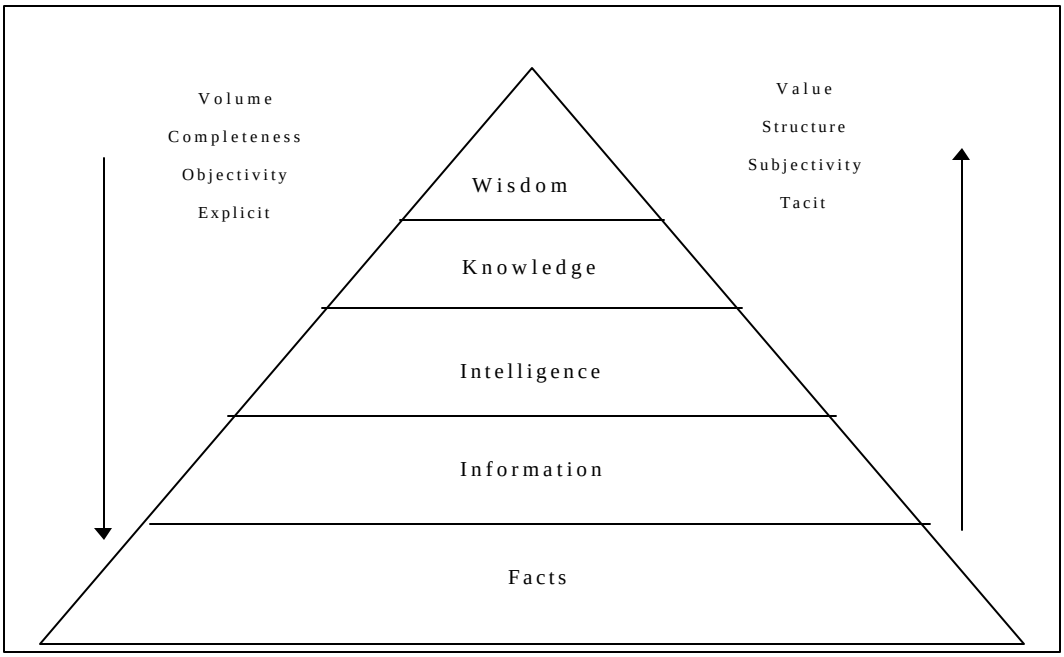

Figure 1: The knowledge pyramid

The U.S. Department of Navy has created a model of enterprise knowledge in which implicit and explicit knowledge are shown as ends of a continuum (Figure 2)[5]. It is much like the pyramid when laid on its side with the base of the pyramid on the right side of corporate capital and the peak on the left side of human capital. Intellectual capital is "the sum total of what your employees know. Its value is at least equal to the cost of recreating this knowledge."[6] The knowledge pyramid is your total knowledge base.

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[3] See Garigue, Robert. "Intellectual Capitalism: Does KM=IT?" *Lac Carling Governments' Review*, p. 24-28, Dec 1999 for one discussion of this hierarchy.
[4] Barquin, Ramon. "From Bits and Bytes to Wisdom: A Proposed Ascending Scale." *Knowledge Management, an e-gov Conference*. 10 April, 2000.
[5] Bennet, Alex. "Building the Knowledge Enterprise." *Knowledge Management E-gov Conference*, Alexandria VA, 10-13 April 2000.
[6] Koulopoulos and Frappaolo, 1999, p.32.

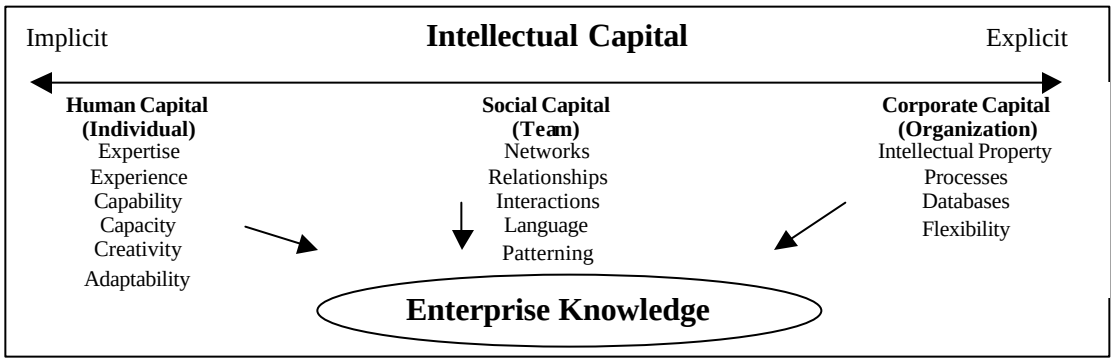

Figure 2: The essence of knowledge management [7]

How knowledge is actually created is fundamental to the development of knowledge management within organizations. Ikujiro Nonaka and Hirotaka Takeuchi[8] have developed a commonly used theory of organizational knowledge creation. They state that knowledge is "a dynamic human process of justifying personal belief toward the "truth." For example, the knowledge that "apples taste good" must be justified either through experimentation, logic or the acceptance of respected testimony. Knowledge, "the fact or condition of knowing something with a considerable degree of familiarity through experience, association or contact," [9] is usually understood by dividing it into the categories of explicit, tacit and implicit.[10]

Explicit knowledge is that which is stated in detail and leaves nothing merely implied. It is termed "codified" or "formal" knowledge because it is most often recorded. It is argued that explicit knowledge has actually returned to information. Tacit knowledge is that which is understood, implied, and exists without being stated. It is informal, experiential, and difficult to capture and share. It is knowledge that cannot be expressed. For example, an individual knows how to reach with his arm to grasp an object, but cannot describe how he knows how to do it. Implicit knowledge, is that which could be expressed, but has not been. It is most often thought of as that which is held in the minds of individuals or in social relationships.

Successful knowledge creation

Tacit and explicit knowledge are the elements used in the Nonaka-Takeuchi model, shown in Figure 3, to illustrate how knowledge creation occurs. Each of four different modes involves the conversion of knowledge from one form to another: socialization, externalization, combination and internalization. While individual knowledge conversion experiences can occur within any one of the modes, the authors argue that successful companies use all four in combination to ensure continuous knowledge creation.

[7] U.S. Department of Navy, 2000.
[8] Nonaka, Ikujiro and Hirotaka Takeuchi. *The Knowledge-Creating Company: How Japanese Companies Create the Dynamics of Innovation*. New York: Oxford, 1995.
[9] Webster's Third New International Dictionary. Springfield MA: Merriam-Webster, 1981.
[10] Polanyi, Michael. *The Tacit Dimension*. Garden City, NY: Doubleday, 1966.

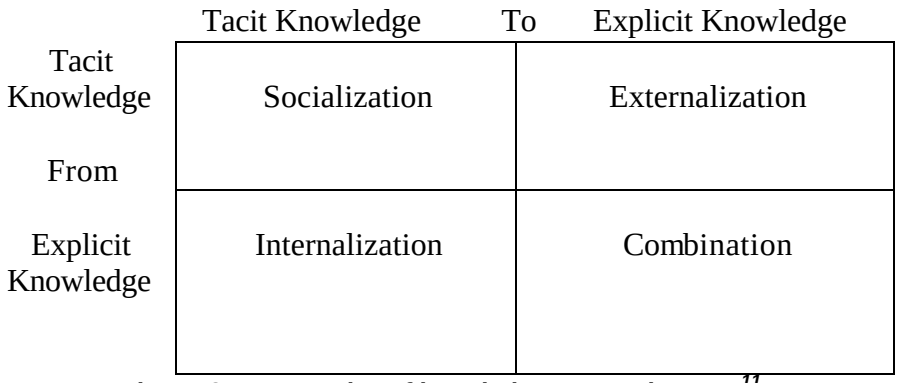

Figure 3: Four modes of knowledge conversion ? [11]

In the first mode, socialization, people share experiences and create tacit knowledge such as: shared mental models and technical skills. Socialization is often non-verbal and tacit knowledge is exchanged through experience. Apprenticeship is an example of how tacit to tacit knowledge conversion works where the apprentice works closely with the master to incorporate inherent skills and premises.

The second mode, externalization, is the "quintessential" knowledge creation process. It is where new knowledge is actually created. This is the conversion of tacit knowledge into explicit through the development and expression of concepts. Tacit knowledge becomes explicit by "taking the shape of metaphors, analogies, concepts, hypotheses or models." It occurs through dialogue or collective reflection or writing.

The combination mode is the conversion of explicit to explicit knowledge and involves combining different bodies of knowledge to create new knowledge. Existing concepts are reconfigured and knowledge is exchanged or combined through various media. Knowledge creation through formal education or training is an example of this third mode.

The fourth mode of knowledge conversion is internalization. It occurs when explicit knowledge is embodied into tacit knowledge in the form of shared mental models or technical know-how. Examples of this conversion are by reading, listening or "trying it out."

The authors argue that effective organizational knowledge creation best occurs through a spiral process where knowledge is converted from tacit to explicit in a continuous and dynamic cycle. It is when tacit knowledge and explicit knowledge interact that innovation occurs. Knowledge creation is facilitated by deliberately managing the cycle. Organizational knowledge creation begins with socialization where individuals share experience and mental models. It develops into externalization where individuals use metaphor or analogy to articulate hidden tacit knowledge that is otherwise hard to communicate. It moves into the combination phase for knowledge to be articulated, shared and expounded. Finally, individuals learn by doing and internalizing the new knowledge. The spiral begins again as the experience-based operational knowledge learned in the first cycle provides a larger knowledge base for continuous innovation and growth.

[11] Reprinted with permission. Copyright credit: Nonaka, Ikujiro and Hirotaka Takeuchi. *The Knowledge-Creating Company: How Japanese Companies Create the Dynamics of Innovation*. New York: Oxford, 1995.

Nonaka and Takeuchi argue that for organizations to achieve successful knowledge conversion, and thus growth and creation, they require five enabling conditions: intention, autonomy, fluctuation and creative chaos, redundancy, and requisite variety. Intention is the clear and comprehensively understood mission and vision of the organization, not platitudes but a clear intent for the organization and its employees. Autonomy is the ability for work groups to work independently within the definition of the intent; it is not individual autonomy. Fluctuation and creative chaos are required to provide a positive tension within the workplace. Research[12] supports the evidence that innovation is more likely to occur in organizations that are changing rather than in those that are secure and more resistant to change. Redundancy is a condition that ensures that adequate communication and information is available to the workers. They have many opportunities to acquire the information that they need and may hear it more than once. In some of the organizations explored by the authors, some groups were given similar tasks, not necessarily to encourage competition, but to increase opportunities for success. Finally, requisite variety refers to building multidisciplinary teams. Success was correlated to the skills diversity of the team.

Knowledge management definitions

Definitions of knowledge management abound and each varies greatly from one usage to another. The meaning ranges from information technology solutions to cognitive interpretations to the dismissal of the term as an oxymoron. A selection of definitions for "knowledge management" was compiled for this project.[13] They include:

> Knowledge Management is the explicit and systematic management of vital knowledge and its associated processes of creating, gathering, organizing, diffusion, use and exploitation. It requires turning personal knowledge into corporate knowledge that can be widely shared throughout an organization and appropriately applied.[14]
>
> Knowledge Management is the collection of processes that govern the creation, dissemination and utilization of knowledge.[15]
>
> Knowledge Management is the explicit, systematic process of cultivating how knowledge is created, shared and translated into action. Significant attention must be given to know-how (competency), know-who (who's who), know-where (repositories) and know-why (motivation).[16]
>
> Knowledge Management is the ability to seek, identify, capture and reuse knowledge in such a way as it saves the organization time, effort and resources, as measured in terms of cost and quality.[17]

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[12] Tushman, Michael L. and Philip Anderson. *Managing Strategic Innovation and Change*. New York: Oxford, 1997.
[13] Waruszynski, Barbara. *The Knowledge Revolution: A Literature Review*. Defence R&D Canada Technical Memorandum 2000-002, 2000.
[14] David Syrme Associates, "Knowledge Management: Making sense of an oxymoron." *Management Insight* No. 2., 1997.
[15] Newman, Brian. "An Open Discussion of Knowledge Management". 1991. *What is Knowledge Management? The Knowledge Management Forum.* http://www.km-forum.org/, 1996.
[16] Owens, David. *Knowledge Management Review*. September/October, Issue (10): 26, 1999.
[17] TTCP JSA AG-9 "Winning Techniques in Technology Management: Knowledge Management," Presentation to NAMRAD. February 2000.

> The conscious strategy of putting both tacit and explicit knowledge into action by creating context, infrastructure, and learning cycles that enable people to find and use the collective knowledge of the enterprise.[18]

For this study, a working definition of knowledge management was created. KM refers to an organization's management of an environment that facilitates the creation and use of knowledge for increased innovation and value. It includes four factors:

1. A milieu that is conducive to and encourages knowledge creation and sharing;
2. Tools and systems to access and share knowledge;
3. The ability to establish and nurture relationships for the creation and exchange of knowledge; and
4. The ability to develop the skills and expertise of employees.

KM differs from information management in that it focuses on the role of the human and encompasses the importance of tacit or implicit knowledge. Information management has been defined as "…the means by which an [organization] efficiently plans, collects, [organizes], uses, controls, disseminates and disposes of its information, and through which it ensures that the value of that information is identified and exploited to the fullest extent."[19] The challenge for organizations, such as Defence R&D Canada, is how to maximize the ability to use all forms of knowledge in the continual growth and innovation of their employees and products. Knowledge management is a response to this challenge.

[18] American Productivity and Quality Center. *Knowledge Management: A Guide for Your Journey to Best-Practice Processes.* Houston: APQC, 2000.

[19] [Queensland, Australia] Information Planning Branch (IPB) Information Standard No. 24 , 'Policies for the management of information within government'. [2000]

Knowledge management business drivers for Defence R&D Canada

Could knowledge management assist Defence R&D in achieving its mission? The 2000 Business Plan identified two performance gaps for the organization: 1) the rusting-out of facilities and obsolescence of equipment and 2) the lack of in-house expertise affecting the quality and quantity of R&D activities and products. Each of these issues have links to KM.

Addressing "rust-out" in R&D information and knowledge management

The need to address the adequate management of Defence R&D information and knowledge has been well documented in recent years. The Information Management Plan, which was prepared for the R&D Branch back in 1995[20], identified the following issues and problems:

- The need to treat information as a corporate resource;
- The need for project costing and tracking;
- Poor Defence R&D visibility with CF clients;
- The DREnet as a "research" network did not always provide operational levels of services; and
- Excessive travel incurred by multi-locations.

Again, at the November 1997 Thrust Leaders and Section Heads Workshop, a number of issues related to the management and use of information were identified: the need for integrated program planning and management tools, a records management policy, a tool for electronic filing (particularly for e-mail) and information sharing tools. These were outlined in the Roadmap to the 21st Century, [21] a document that also recommended movement towards a knowledge management approach.

At that time, the Integrated Information Management Environment (IIME)[22] was conceived as a system that would respond to the requirements identified in the Information Management Plan. While many of the requirements of the IIME remain valid today, technology has advanced since its conception and any proposed implementation would require its re-evaluation. Since the recommendations of the Road Map, efforts have been made across the organization to rectify the need for better information management tools. Most recently, the Collaborative Program Management Environment (CPME), an IM system for the capture of R&D program management information, has been created and is in the early stages of acceptance and use.

The development of information management in Defence R&D Canada has been faced with challenges posed by the high rate of change in related technologies that result in difficulty in planning and implementing effective systems in a timely manner. Other challenges are personnel shortages, the high costs of implementing corporate-wide systems, and the decentralized approach to the management of these issues. Specifically some of the problems are the:

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[20] CGI. CRAD Integrated Information Management Environment (IIME) Prototype: Final Report, June 21, 1996.

[21] Road Map to the 21st Century: Building the Future Together, 1997.

[22] CGI. CRAD Integrated Information Management Environment (IIME) Prototype: Final Report, June 21, 1996.

?? Collapse of traditional paper-based methods of capturing, organizing and retrieving corporate knowledge;
?? Lack of replacement IM for managing electronic information being incorporated into IT systems;
?? Poor or non-existent filtering of information;
?? Organizational or technological barriers within Defence R&D Canada to sharing, capturing, organizing and accessing knowledge and information;
?? Lack of training to exploit existing systems; and
?? Absence of a collective or centralized approach to gaining and providing access to external knowledge and information sources, particularly in innovative ways.

Addressing "lack of expertise"

The reduction in defence spending in the past decade has threatened the state of S&T expertise within Defence R&D Canada, nationally and among the allies. In addition to attrition from these cuts, the competition for valuable human resources in the high technology sector, and soon, the baby-boom retirement rush, all present tremendous human resource challenges. Defence R&D Canada must compensate for lost intellectual resources and corporate memory at the same time as it builds its capabilities in emerging technologies.

Human resources (HR) challenges include:

?? The ability to meet increasing client demands with reduced funding;
?? Attaining the skills to answer the shift from mature to emerging technologies;
?? Attracting and recruiting new skilled S&T staff in a competitive global economy;
?? Maintaining key human resources in a competitive HR environment;
?? Retraining employees for new technologies; and
?? Planning for the impact of the current demographic profile.

In addition, as a member of the government S&T community, Defence R&D Canada will continue to be called upon to participate in advancing the Canadian economy by contributing to S&T knowledge and wealth generation. If its expertise and knowledge base were depleted, it could be prohibited from assuming the totality of its S&T leadership role in the defence community.

Strategic management of knowledge resources would address these challenges in progressive ways. By identifying the existing strengths and weaknesses in Defence R&D Canada's current approach, new strategies and frameworks for appropriate KM approaches could be devised. The first step towards this end is the knowledge management audit.

The KM audit

Objectives

A knowledge audit "[determines] what knowledge is needed, what knowledge is available and missing, who needs this knowledge and how will this knowledge be applied."[23] The audit also identifies enablers and barriers in effective use and leveraging of knowledge. The objective of the Defence R&D Canada KM audit was to answer the following questions:

- What are Defence R&D Canada's current knowledge sources?
- How well does Defence R&D Canada manage knowledge creation and use? and
- What can Defence R&D Canada do to improve the use and leveraging of knowledge, (i.e., what are the additional knowledge needs of the organization)?

To perform the audit, the KM Working Group explored four foci:[24]

- The employees' awareness of sources of knowledge within Defence R&D Canada, and enablers and barriers to their ability to find that knowledge;
- Defence R&D Canada's ability to respond to requirements in a timely manner by finding knowledge sources internally, and skilled, knowledgeable human resources when required;
- The enablers and barriers to accessing external knowledge sources and the ability to create partnerships; and
- The ability of Defence R&D Canada to transmit its knowledge to clients responsively.

Methodology

A methodology[25] was chosen that would provide indicators of major KM themes and issues within Defence R&D Canada. A qualitative study was employed using a purposeful random sample and an interview format.[26] Fifty-one out of 1032 employees took part, representing 5% of the total workforce. An additional 6 interviews of DRENet Technical Managers were conducted, focusing on the status of the information technology and management infrastructure for future initiatives.[27]

Individuals were stratified into subgroups (strata) and were randomly chosen from these subgroups to take part in the study. These strata were divided into four predefined groups which facilitated comparisons between the subgroups: (1) technical staff; (2) defence scientists and engineers; (3) administrative support; and (4) managers. In each location, the same was proportional to the numbers within the categories of that unit of Defence R&D Canada. This varied only in the case of managers, in which one person per location was selected. Semi-structured, open-ended interviews were employed at headquarters and in each of the research establishments in October and November 2000.

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[23] Liebowitz, Jay, et al. The Knowledge Audit. http://userpages.umbc.edu/~buchwalt/papers/KMAudit.htm [1999].

[24] The four foci were adapted from Koulopoulos T. M. and Frappaolo, C. Smart Things to Know about Knowledge Management. Dover: Capstone, 1999.

[25] See Annex A for detailed methodology.

[26] See Annex B for interview questions.

[27] See Annex C for infrastructure questionnaires..

Results

The interview results were reviewed, analyzed and summarized within each of the four foci: internal knowledge sources, ability to locate and organize knowledge sources for internal response, ability to create partnerships and responsiveness to the clients. Each was analyzed and categorized first by occupational group and second by overall themes.

Main knowledge sources

The first set of questions was designed to determine the employees' awareness of sources of knowledge within the Agency and the barriers or enablers for the ability to locate that knowledge. Identifying barriers to, and enablers of, knowledge and information use is necessary to determine how well and organization manages knowledge creation and use. The knowledge management audit revealed a plethora of knowledge and information resources available to employees and rich environment of sharing in Defence R&D Canada. The use of knowledge sources varied somewhat between each of the occupational groups.

Technicians

Technicians are dependent upon the Internet to get information for their daily tasks, particularly for data sheets on products and parts, traditionally published in paper and difficult to keep updated but now freely accessible. Library services, literature and personal contacts are the other main sources.

Technicians experience three primary barriers to knowledge. The first is the inability to accurately articulate their information needs to get the appropriate retrieval when using the Internet. An overload in tasking is a second primary barrier to finding the time for tracking and locating information. Finally, while they find training and conferences very helpful for maintaining and upgrading their skills and knowledge, technicians do not receive as much as they perceive they require.

Scientists and engineers[28]

Scientists and engineers still use the traditional methods of gathering and exchanging scientific and technical information and knowledge: the literature and the "invisible college," (i.e., their network of contacts in their subject fields). This has been bolstered by the advancing use of technology to enhance access to both sources. Although the Internet and other technologies have become very fundamental information gathering tools, personal contacts, particularly with allies and other experts in the field are still essential to information gathering and knowledge exchange.

The largest barrier for scientists and engineers in accessing knowledge and information sources is the lack of desktop access to library and literature services. Obtaining classified technical documents from allied sources is a real frustration for many and a barrier to performance in some cases. The aftermath of downsizing in the 1990s is still

[28] The sample included defence scientists, engineers, and veterinarians and for simplicity will be referred to "scientists and engineers" throughout.

felt in the shortage of support staff to assist them in administrative and technical areas, and has resulted in a lack of time to pursue information and knowledge to support their work. In some cases it has contributed to a feeling of isolation for solitary subject specialists.

Administrative support

Administrative support employees' awareness of sources of knowledge within the organization seems to be primarily based on personal corporate knowledge and their networks of contacts, supplemented by access to online information sources. Electronic information management systems available on DND networks and the Internet, as well as old procedure manuals, are also important tools.

The lack of knowledge about the scientific program is barrier for administrative staff. Encountering barriers to knowledge also occurs most because they are not able to accurately define what information they need (as in Internet searches) or to locate it because records or experts are unavailable when required.

Managers

Managers depend heavily upon international fora, their staff and networks of contacts, as sources of knowledge. Electronic sources of information and documentation are used extensively where available.

Barriers arise primarily from information overload and lack of available time. Mangers depend upon various technologies (e.g., email or video-conferencing), to perform their duties, but they suffer from information overload, and require more synthesized, as opposed to bulk, information. Information systems are required to provide them with accurate, succinct information.

General themes

Overall, there were three main sources of information and knowledge: personal contacts, the Internet and the formal literature.

Personal contacts

The results for the first foci underlined the fundamental importance of personal contact and networks for the exchange of information and the sharing of knowledge by Defence R&D Canada staff. Personal contact is the primary knowledge source and is especially important for administrative support staff. The lab or office colleague is still the first stop for information and knowledge exchange.

Of particular importance are employees' own networks and their knowledge base built up over their own careers. "Knowing whom to call," fellow staff, colleagues, and their own years of on-the-job experiences are among the most dependable knowledge resources. Also of significance to S&T staff are the international partnerships available through The Technical Cooperation Program (TTCP), the North Atlantic Treaty Organization (NATO), bi-lateral and multi-lateral Memorandums of Understanding (MOU). These relationships are important for knowledge, information and data exchange. The allied

counterparts of Canadian scientists, engineers, and managers relate most closely to the same issues dealt within Canada. These contacts are important to the development and growth of subject knowledge, joint R&D projects, leveraging limited resources and science capacity, determining trends in warfare and defence, and ensuring interoperability of allied forces.

It has been long observed, and is now suggested by the results of the knowledge management audit, that for scientific staff, particularly defence scientists, it takes up to 5 years to become knowledgeable in their respective fields and to make the relevant international contacts to be effective and productive. Downsizing and attrition have impacted this learning curve for scientific staff as well as other occupational categories. In an organization that depends on personal contacts for knowledge building, the lack of veteran R&D staff increases the importance of the international relationships.

Internet

The Internet provides a second information and knowledge source, one that has become pervasive in use. It supplements, but does not replace, direct communication. Technologies have been significant enablers for Defence R&D Canada employees. Because the labs are geographically dispersed across Canada, S&T staff sometimes feel remote from colleagues. Email, fax and video conferencing have served to reduce the isolation. Of particular importance is the Internet, which brings both internal government and departmental information as well as external community information to the fingertips of employees. Email is a much-appreciated tool for most staff and has enhanced their ability to communicate with the larger S&T and government communities.

Although all interviewees indicated that they used the Internet, their ability to find accurate and reliable information limits its effectiveness. Staff look to it as a prime information source but often they waste time and become frustrated. This indicates the need for training and the development of portals or other search aids that are particularly relevant to the Defence R&D Canada environment.

Literature

A third important source of knowledge is the S&T literature, both in paper and electronic form. The formal literature, such as scholarly journals and trade magazines, remains vital to knowledge sharing and staff growth and has not been replaced by less formal electronic communication forms as found in Internet sources. Libraries and information services continue to be important information sources for all occupational groups.

Internal Defence R&D Canada library collections have not been able to keep up with the high cost of publications or remain comprehensive for such a multi-disciplinary R&D program. Access to online sources is costly. Downsizing of information services and library personnel has reduced services and the ability to collect and disseminate S&T information. Staff, particularly scientists and engineers, would like better and more comprehensive desktop access to internal and external literature sources

The services of DSIS[29] are still known and used by some staff. It appears that there is not a broad understanding of its role or the availability of the S&T report database through Descartes. There may also be collection gaps in technical areas that have implications for the information needs of the technical workers

Perhaps more than in other types of scientific organizations, defence research requires a broad perspective to be able to respond to client situations and needs. Scientific and technical staff recognize that keeping current in related fields is important to their professional success and growth. Staff in all occupational categories actively attempt to keep current in their own fields and often pursue continuous learning opportunities on their own time. Staff wish to have Defence R&D Canada continue to support opportunities for training and conference attendance, and to broaden this to include technicians and administrative support staff.

Internal response

The objective of the second portion of the audit was to determine Defence R&D Canada's ability to respond to requirements in a timely manner by locating knowledge sources internally and organizing skill sets when required. This foci was perhaps the area for which the organization has greatest knowledge management challenge. Staff in all occupational categories depend heavily on informal networks to locate knowledge and require better information management tools and processes.

Technicians

Technicians depend upon their own years of experience and networks to respond to requirements in a timely manner. Downsizing and attrition have put additional pressures on all staff, making it difficult to either respond to deadlines or access colleagues to acquire the required information. Knowledge in new areas of technology is not always available within the organization. The ability to locate knowledge internally could be improved by increased documentation of procedures and additional training on information searching and retrieval.

Scientists and engineers

Staff shortages and the lack of online information management systems impact on the ability of scientists and engineers to tap existing expertise and meet their deadlines in a timely manner. They depend on informal networks of colleagues, staff officers, military liaison officers and supervisors to gather information and to access experts. Scientists and engineers expressed difficulty in their ability to locate internal experts. As one, relatively new, defence scientist said, "It struck me as soon as I got here that many researchers within the agency have very little knowledge of each others' work." They want improved information management practices, increased human resource pool and desktop access to information resources.

[29] Formerly "Defence Science Information Services" and the "Directorate of Scientific Information Services", DSIS is now a service within DRDKIM (Directorate of R&D Knowledge and Information Management).

Administrative support

As with other groups, administrative support staff depend upon their own experiences and networks to respond to requirements. Formal systems, procedures and back-ups are often not in place in many administrative areas making timely response challenging. There often appears to be a lack of knowledge on the part of the S&T staff about how administrative procedures work and about restraints imposed upon the work by regulations and legislation. This affects the ability of administrative staff to respond and suggests the need for dialogue and consultation.

Managers

Managers respond to requirements in a timely manner because of their own abilities and mechanisms to manage information. They believe that they would benefit from some additional information management tools to manage the shear volume. Gaps in expertise and skill sets exist in new areas of technology and in areas that have been downsized but which are still called upon by clients. The organization is still adjusting and is over tasked for the resources available.

General themes

The ability for Defence R&D Canada staff to respond to deadlines in a timely manner, seems to indicate a strong corporate knowledge base and connectivity, primarily a result of experience and networks of contacts. The most significant obstacle to accessing information and sharing knowledge is the extensive workload that employees experience. Reductions from downsizing, the demands of horizontal government programs (such as Universal Classification System conversion), and change initiatives create time barriers to pursuing additional information or developing their knowledge beyond what is required to achieve core tasks. Organizing skill sets (i.e., gathering together the appropriate human resources for new tasks) presents challenges, especially in new research growth areas where the expertise within the organization does not yet exist.

During the audit, staff consistently requested access to additional online information sources, internal information management systems and mechanisms to identify experts throughout Defence R&D Canada to assist them. However, they are aware that IM systems, if not properly designed, can increase workload rather than reduce it.
Organizing appropriate human resources is particularly challenging in technology growth areas, as outlined in the Technology Investment Strategy.[30] Furthermore, over-tasking of existing human and financial resources, as well as confusion about prioritization of activities, makes it difficult to maintain existing activities and take on new tasks.

Ability to create partnerships

The third portion of the audit aimed to determine the enablers and barriers to external knowledge and Defence R&D Canada's ability to create partnerships, i.e., how well Defence R&D Canada manages knowledge use and sharing to leverage partnerships and external knowledge sources,

[30] Defence R&D Canada. The Technology Investment Strategy. http://www.crad.dnd.ca/public/tis/tis_e.html, [2000].

from the perspective of the employees. Defence R&D Canada does not appear to create significant barriers to acquiring external knowledge or establishing partnerships.

To obtain a complete picture of the KM success of an S&T organization for this foci, a three-point examination of the perspectives of employees, clients and partners would be required. In the past few years, Defence R&D Canada has actively solicited feedback from clients and partners. While not specifically focusing on KM issues, the topics reflect a common focus on Defence R&D Canada's relationships with clients and partners to achieve its mission. Defence R&D Canada partners concur with similar employee' views found in the audit. [31]

Technicians

Technicians actively develop their knowledge of their own and related fields. Opportunities to do this are presented by field trials, cross-disciplinary interaction or project contacts, training and personal interest. Technicians value these interdisciplinary opportunities and the teamwork environment, which also contributes to knowledge building. Technicians do not encounter significant barriers to working with external partners. However, based on their suggestions, improvements could come through more opportunities to meet with potential industrial partners at trade shows and conferences.

Scientists and engineers

Scientists and engineers recognize that defence R&D requires a broader knowledge base than might be required in other organizations so they try to keep abreast in subject fields other than their own specialties. Collaboration, both nationally and internationally, is very important for scientists and engineers and almost all of the interviewees do so on some level. Visiting other organizations and attending meetings and conferences are necessary activities to establish contacts for future collaboration. The current international milieu, in which countries wish to protect the competitive edge of their own industries and intellectual property (IP), presents barriers to free-flowing information exchange with allied partners. Scientists and engineers would like better information exchange with the allies, e.g., increased document exchange and the facility for full public key infrastructure (PKI). Another perceived barrier to partnering is the process surrounding contracting, including regulations and delays caused by sponsor approval.

Administrative support

Administrative support staff primarily keep current through information sent to them on distribution. They work or exchange information with outside agencies and do not experience any real barriers to accessing external knowledge or the ability to create partnerships. Their ability to exchange information or knowledge with outside sources would benefit by additional IM tools, such as access to shared systems.

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[31] The "DRDC Strategic Marketing Plan Draft Research Report" produced by GPC International in 2001 looked at partnerships for the purposes of revenue generation and is more detailed in outlining barriers to collaborative work. They include: the need for Defence R&D Canada to shift from a government to a business model; the high pricing of Defence R&D Canada services; that technology transfer and intellectual property are being held more tightly by Defence R&D Canada; there is a danger of competition with industry; and there is fragmentation within Defence R&D Canada, i.e., between the capabilities of the various labs.

Managers

Managers are heavily involved in the collaboration culture, and are enabled by their contacts internationally and nationally. They monitor the work of allied, academic and industrial collaborators and potential partners. They see few barriers to external knowledge and their ability to create partnerships other than limited human and finance resources.

General themes

Partnering appears to be facilitated and encouraged within Defence R&D Canada. The KM audit results underlined the importance of working in collaborative groups. Defence scientists and managers have long depended upon their relationships with counterparts in allied defence organizations to leverage their research for the advancement of defence S&T and to forecast developments. Membership in international working groups, such as TTCP with colleagues from the United States, the United Kingdom, Australia and New Zealand, is seen as critical to knowledge growth in defence R&D. These working groups are fundamental to the knowledge culture of Defence R&D Canada and are de facto "communities of practice"[32] although not referred to as such by the organization.

The inability to acquire allied documents is the greatest frustration for scientific and technical staff. The ability to have secure transmission of information would be an important enabler. Opportunities for personal interaction with external contacts continue to be important. Time to pursue collaborative opportunities remains limited.

Perhaps one of the most significant barriers to partnership and taking advantage of leveraging opportunities is the impact of geography and structure on the knowledge sharing within Defence R&D Canada. The geographical dispersion of the R&D program across the country makes it difficult for stakeholders, partners and employees to gain a comprehensive understanding of the breadth of the total R&D capabilities and thereby maximize external partnership opportunities.

Knowledge transfer to clients

The fourth and last section of the audit attempts to determine the ability of Defence R&D Canada to get its knowledge to clients responsively, or, how well it transfers knowledge to the CF and DND through products and services. How well an organization transfers its knowledge to its clients through products and services is the "bottom line." A survey of CF and DND clients in 1999, although now dated, reflects many of the concerns of Defence R&D Canada staff, indicating that staff perceptions of client relationships are probably accurate.[33]

[32] Working groups of peers dedicated to a common subject.

[33] The Client Satisfaction Survey produced in July 1999 by AeroVations Associates reflects most of the views expressed by Defence R&D Canada employees during the interviews. The emerging themes from that survey indicated the conflicting perspectives from Defence R&D Canada and client perspectives. The consistent themes were: the differences in expectations of timely responses as they pertain to long term research and applications of emerging technologies; the confusion between research and development by clients (and the need to explain this spectrum to the clients); the ability of Defence R&D Canada to attract and retain high quality S&T workers as well as the need to shift rapidly into new fields; the client perception of the scientists "unwillingness to change"; R&D visibility within the CF; the need for more

Technicians

Technicians believe that Defence R&D Canada provides quality products to their clients. Services could be possibly be improved by staff having more direct exposure to clients, particularly in operations. They feel that they can be innovative in their work. Being more responsive and more innovative would be facilitated by knowing the objectives of projects and well prepared with all the required information, adequate equipment, experience and time. Technicians would also benefit by having a better understanding of the clients' long-term goals, timeframes and project requirements. Technicians share their knowledge and expertise informally in conversations with others. As one said, "the most important part of the day is break, between 10:00 and 10:30, for exchanging information." Many also do it formally through technical reports and presentations.

Scientists and engineers

The ability of Defence R&D Canada's scientists and engineers to get their knowledge to clients responsively is enabled by their direct personal contacts with clients and their knowledge of international science and technology (S&T) and warfare trends. Scientists and engineers can respond quickly in situations where advice and military operational situations require immediate action. They find it more challenging to deliver technologies for their clients in a responsive manner because of the low degree of client engagement in the long-term planning process and the difficulties inherent in the current acquisitions process. In some cases, clients have difficulty articulating long-term requirements, as opposed to shorter-term solutions. The posting cycle presents issues for scientists and engineers and technicians because as soon as the military personnel have acquired the adequate knowledge for long-term R&D planning, they are posted to other positions and the staff must work with new contacts while they build up expertise again.

Scientists and engineers want to know the clients' operational needs and resources, operational strengths and weaknesses, and constraints. They require willingness on the part of the client to work together and they would like opportunities to learn how their CF clients operate in the field. More personal and direct contact, including field experience with operators and client visits are required

The ability of scientists and engineers to respond to client demands in a timely manner and to be innovative have been affected by administrative and management burdens and diminishing resources, particularly in expert human resources. Innovation is linked to available time, which is in short supply.

Administrative support

Administrative support staff's ability to get knowledge to the clients responsively is affected by the level of their involvement in the planning of R&D projects and in their understanding of the requirements of the R&D program. They, like other Agency staff, are often frustrated by delays in administrative processes. They are also frustrated by the lack of time due to work overload as a result of downsizing. Administrative support staff

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interaction with Operational Research; streamlining of the management of research (i.e., Service Level Agreements); and an overlap between the mandates of the labs.

may feel "out-of-the-loop" in the provision of service to the clients. Including them as part of the team in planning would allow them to understand the clients' requirements better and expedite R&D projects. Innovation on the part of administrative support staff would be enhanced by more available time and creative latitude from their managers.

Managers

Managers believe that Defence R&D Canada has the ability to get its knowledge to clients responsively in the form of advice and, when required, in military operational settings, such as overseas missions. For S&T products with a longer life cycle, delivery is hampered by the client's level of focus on the long-term needs and plans, their buy-in and Defence R&D Canada's lack of influence in the acquisitions process. They need more time to explore client needs. Managers feel the impact of loss of core expertise in human resources. They also feel the impact of reduced funding and express a need for more managerial flexibility to increase their abilities to be innovative and more strategic in their approaches.

General themes

The KM audit indicated that agency employees view themselves as having the freedom and resources to be innovative in their work to support the CF and DND. It is one of the aspects of Defence R&D Canada most valued by its employees. They find themselves to be most creative in situations where they have the freedom and organization's trust to perform independently. Staff believe that they would be even more innovative if their time was freed from additional administrative duties. Hiring additional expertise within Defence R&D Canada would also increase the ability to share and grow knowledge.

Staff also believe that defence R&D products are of high quality, even if delivery takes longer to achieve that attribute. They feel that Defence R&D Canada is effective at consultation with clients and that are many mechanisms for understanding CF and DND requirements, both formal and informal. The formal structure for program development in consultation with client groups appears to satisfy the requirements of most scientific and managerial staff. Most believe that it provides sufficient information to plan and deliver their part of the program.

Employees in Defence R&D Canada also believe that the organization produces quality output and will not send out "second rate" products. Although improved quality is linked to increased funding, equipment and human resources, staff also feel that Defence R&D Canada does the best with the available resources.

Of the R&D products that Defence R&D Canada delivers to the CF and DND, the respondents believed that Defence R&D Canada is particularly timely and responsive in providing advice and immediate operational support. Defence R&D Canada's ability to transfer knowledge in the form of defence technology depends on many variables in the defence acquisitions process. It requires a mutual agreement on the balance between research for the long-term defence capability and response to short-term requirements for more immediate operational and tactical purposes. Timely knowledge exchange between scientists and clients and being able to set a mutual horizon would facilitate this knowledge transfer. These views expressed by Defence R&D Canada employees during the interviews mirrored other client feedback. A knowledge management approach may be appropriate in this area.

Of particular concern to all staff is the lack of the required time to work with the client and to be innovative. There is a prevalent concern that Defence R&D Canada is trying to do too much with too little. As one interviewee asked, "Can an organization suffer from burn-out?"

Infrastructure

Additonal interviews with the DRENet Technical managers indicated that Defence R&D Canada is technologically well positioned for future KM initiatives. The population is well connected (98%) to the DRENet and are generally interested and receptive to technological solutions. Throughout Defence R&D Canada, there has been no significant investment in KM or IM systems which would complicate the adoption of new agency-wide initatives.

The issues of security, standardization, bandwidth and governance which were identified during the audit are often common for organizations moving forward in KM or IM. Some arise from the history of geographically separate installations (e.g., security procedures vary across the locations). Other issues such as, bandwidth, have already been managed for the short term, but can be expected to be ongoing challenges as application sizes grow.

Establishing standards for operating systems or software solutions across the organization is a particularly difficult issue because of the multi-system needs in a research environment and the variation of platforms and operating systems as a result. One approach might be to standardize on a concept of "interoperability" where solutions must accommodate many systems as in web-based solutions.

Finally, the approach to governance in IM and KM technological management must adjust to the changing nature of the whole organization. Decision-making and initiating new technological solutions must accommodate early and detailed consultation with IT/IM staff and a decision making process that reflects the culture of Defence R&D Canada. New initiatives must consider adequate lead time on installations, sufficient training and enough trained support.

Defence R&D Canada KM needs

Five major themes emerged from the audit as areas for future knowledge management approaches.

Focus on mission

As indicated above, Nonaka and Takeuchi have written that successful knowledge creation requires an organization to make its "intention" or vision clear.[34] As a client-focused S&T organization, Defence R&D Canada knows this to be true. However, Defence R&D Canada must cope with conflicting multiple priorities. It is currently addressing the challenges of providing a comprehensive R&D program in response to existing CF demands and priorities while responding to new requirements arising from the Revolution in Military Affairs. With a change in status to a departmental Special Operating Agency in 2000, there has also been an increased focus on partnering and revenue generation. Cultural and operational changes to reflect these shifts have already commenced but will require more time and effort. This need for a shift in culture is a key element in KM initiatives and have already impacted other S&T organizations in the past decade.

Information management tools

Staff have become dependent upon personal, rather than corporate, sources of knowledge and information when attempting to respond to deadlines and requirements. Lab employees in all categories have expressed frustration with having to respond to repeated requests for the same information. Many staff, including managers, rely upon their own personal record keeping systems to respond to agency requests. Delays can arise because of the unavailability of staff. In the past few years, during downsizing and increasing electronic information, agency information has been lost through poor information management and lack of documentation procedures. Filing systems, both manual and electronic, require enhancement. Standard operating procedures and policies, which are both universal and accessible to all employees across Defence R&D Canada, do not exist and must be developed.

Staff requests for information management tools indicate their importance as building blocks for effective knowledge management. They would play essential and fundamental roles as building blocks in knowledge capture and exchange. During the audit, staff asked for improved documentation organization and systems, i.e., tools to find out who, what, when, why, and where. They asked for systems that allowed them to enter information once for multiple uses and outputs. In addition to the need for IM tools, staff want knowledge base management tools to assist with knowledge capture and creation on R&D projects. The scientific staff specifically need desktop access to explicit knowledge sources for quick, efficient access to a range of sources to perform their research, i.e., commercial databases, and to the Defence Information Network (DIN).

The Internet is an important tool for locating information and knowledge sources for all staff; however, training and tools are required for its effective use. The quantity and quality of available information is often unhelpful and unmanageable. They require training on effective search and retrieval mechanisms, particularly on query formation.

[34] Nonaka, I. and H. Takeuchi. 1995.

Sharing in-house expertise

The geographical distance between the separate parts of Defence R&D Canada (five labs and a headquarters) limits opportunities for cross-disciplinary discussion or for personnel to meet and discuss issues of common concern. Staff consistently indicated their interest in establishing a mechanism to identify and locate experts in other parts of Defence R&D Canada. This need has many implications: the ability to build expertise in new employees, cross-disciplinary pollination, ensuring that program knowledge is shared with administrative staff for an effective R&D team, effective business development and visibility of the R&D program to clients.

The issue of establishing expertise in defence R&D is a particularly critical issue because of the specialized and often classified nature of the work. Experts in defence science and technology are developed rather than hired. New employees encounter lengthy learning curves requiring significant investment of time and resources.

Efforts must be made to develop human resources in growth areas and to address recent (i.e., within the past five years) technology developments. This will require focused recruiting and mentoring programs. Of particular immediacy is the need to hire and train new technicians. Continuous learning is required for the professional development of all staff and should involve more opportunities for training and attendance at conferences for all categories of staff.

A further issue for Defence R&D Canada is the relationship between scientific staff and administrative staff. Sharing expertise across Defence R&D Canada would perform two functions: it would help to include all staff in the Defence R&D team working for a common client group, the CF and DND. It could also improve efficiency. During the audit, there often appeared to be a disconnection between scientific and support operations. Administrative staff wished to be informed of operational requirements in the early stages of projects in order to anticipate and assist in the smooth execution. Likewise, scientific staff often expressed frustration at the process, which they view to be cumbersome. Improved communication and team building with requisite variety could alleviate some of these issues.

Enhanced exchange of foreign information

The importance of leveraging relationships with allied counterparts cannot be overstated for Defence R&D Canada. Opportunities to exchange information and to participate in joint collaborative projects are fundamental to scientific advancement and the interoperability of the CF with allied nations. In this sense, Canadian defence scientists have many opportunities for tacit knowledge exchange.

The restrictions on accessing foreign defence R&D publications, however, can be frustrating to both scientific and information services staff. Access to the defence S&T literature of other countries depends on both national security and economic considerations. It is the subject of exchange agreements, which staff would want to see enhanced where possible. They also recognize a growing need for secure data communication and Internet "virtual laboratories" to collaborate with their foreign counterparts, as well as nationally between labs, to facilitate information exchange. Recent events have only reemphasized the need for effective information and knowledge exchange with allies. In other words, the exchange of explicit knowledge requires enhancement.

Mutual R&D and client vision

Defence R&D Canada's mission is to ensure that the CF remains technologically prepared and relevant. To do so, it must sustain long-term innovation in core competencies to maintain the technological and knowledge advantage. Defence R&D staff recognize the importance of sharing Defence R&D Canada's knowledge and vision with clients. Much of this is explicit knowledge, exchanged during formal discussion, creation of service level agreements, publications, workshops and symposia. Working in operational settings, field trials, and exercises and military and civilian exchanges, to gain tacit knowledge of the clients' needs, is also crucial. This is particularly true at the technical level where tacit knowledge is gleaned by working within the environment in which the technology or science will be employed.

Differences in opinions between the clients and Defence R&D Canada staff about the balance of short and long-term requirements indicate a need for a more effective approach to sharing knowledge between Defence R&D Canada and its clients to develop the future vision of Canadian Defence R&D. There is a need for Defence R&D Canada to examine the R&D cycle to improve the early transfer of knowledge to clients through advice, products and documentation. The mutually shared vision of S&T organizations and their client groups, whether within the government or the general public, will ensure knowledge creation, exchange and the achievement of goals. Forecasting defence technologies for the future 20 years and building an R&D program to achieve these goals requires mutual visioning and knowledge.

To better know CF client needs, two requirements were identified. First there is a need to harmonize the long-term client and R&D visions. Mechanisms for developing and sharing this vision are required for long-term planning. Second, more opportunities to experience the clients' operational settings to gain a better understanding of the applications of R&D would also be helpful for exchange of tacit knowledge to the scientific and technical staff.

Further areas for KM study

The results of the KM audit was a preliminary examination of KM in Defence R&D Canada in the fall of 2000 and as such, provided a "snapshot" of the situation at that time. The audit identified areas that would benefit from knowledge management approaches. Many of the issues are already being addressed other Defence R&D Canada initiatives such as in career management, rewards and recognition, culture change, and IM planning. Others will be incorporated into an overall KM Strategy and Framework. Yet others will receive the focussed efforts of new initiatives. The audit's results also suggest opportunities for further study. Some possibilities include: knowledge creation in Defence R&D Canada, enabling conditions for defence R&D, knowledge mapping for defence R&D, and pilot studies.

Knowledge creation in Defence R&D Canada

Nonaka and Takeuchi's knowledge conversion quadrant with its four knowledge conversion processes of socialization, externalization, combination and internalization, might be used as a model to examine knowledge creation processes within Defence R&D Canada. In Table 1, the five themes identified in the KM Audit are compared to these four processes. A in-depth analysis could reveal the relative strengths and weaknesses of knowledge conversion in this defence R&D organization and identify areas for targeted attention. One area that appears to be of particular interest is the means by which knowledge conversion could impact client relations and cooperation.

Table 1: Knowledge Conversion for Defence R &D

Theme / Conversion	Focus on Mission	IM Tools	In-house Expertise	Explicit International Knowledge	Mutual Vision
Socialization (tacit to tacit)	X		X		X
Externalization (tacit to explicit)	X		X		X
Combination (explicit to explicit)		X			X
Internalizat ion (explicit to tacit)		X	X	X	X

Enabling conditions for defence R&D

Similarly, Nonaka and Takeuchi's enabling conditions, (i.e., intention, autonomy, fluctuation and chaos, redundancy and requisite variety), might be employed as measurements for innovation or technology transfer to industry and the Canadian Forces. William Johnson has applied this methodology to R&D partnerships with interesting results.[35] Other example questions that might be explored are:

?? Is Defence R&D Canada's current focus on mission sufficient organizational intention for successful knowledge management?
?? Do teams or groups have the autonomy required to be innovative and creative?

[35] Johnson, W.H.A. *Technological Innovation and Knowledge Creation: a Study of the Enabling Conditions and Processes of Knowledge Creation in collaborative R&D Projects.* PhD Thesis. Schulich School of Business, York University, Toronto, July 2000

?? Does the fluctuation and chaos experienced by the staff as a result of change actually facilitate innovation or is it counterproductive to defence R&D?
?? Will the introduction of IM tools to Defence R&D Canada provide sufficient redundancy for improved knowledge management?
?? Is the condition of requisite variety in teams culturally ingrained in the current R&D approach?
?? Can requisite variety in teams and projects be maximized as it relates to a mutual vision with the Canadian Forces client?

The examination of these topics could also serve to identify appropriate strategies for knowledge management within the Defence R&D Canada context.

Knowledge mapping for defence R&D

A knowledge map inventories the information and knowledge that is used, generated, and required and it "displays the whereabouts and structure of knowledge holdings that allow users to navigate the organization's resources and expertise."[36] The KM Audit in Defence R&D Canada searched for themes for a broad approach to knowledge management. Further work in knowledge mapping could provide the framework upon which to build future knowledge management activities.

Building a knowledge map would begin with the creation of a taxonomy, or an ontology, representative of the organization's knowledge structure and common understanding. It would evolve through a scaling process as specific organizational processes were examined and mapped. For example, the preparation of service level agreements involves many knowledge exchanges and captures. A knowledge map would identify these entities and processes, link them into the broad taxonomy, expand the taxonomy and link to appropriate knowledge sources. The final product would be a tool that users could access to facilitate both the creation and use of service level agreements.

Pilot studies

Many issues arose during that audit which would be appropriate for pilot study. Of the knowledge management needs identified during the audit, one of the most significant was the requirement to access expertise throughout the organization to improve internal efficiency. This issue has been selected for further study as one for which the application of KM for increasing knowledge sharing, networking and productivity in Defence R&D Canada might be demonstrated. The objective is to apply ongoing Defence R&D Canada KM research to methods in which employees can access the inherent expertise and experience of Defence R&D Canada and establish broad internal networks. The objective of the pilot would be to reduce learning curves in new employees and thereby increase their contribution and satisfaction within a shorter time frame than at present.

Maintaining the premise of requisite variety, the KM Working Group will expand its membership for the purposes of the pilot study. Defence scientists from the Defence Research Establishment Valcartier, IM/IT, Human Resources and communications staff, along with industrial partners, will work together on this study in 2002. The KM product will be a combination of portal

[36] Duffy, Jan, 1999, p. 96

technology, training and mentoring and will target a test group of new employees. The results of the pilot will serve as recommendations for future KM initiatives in Defence R&D Canada and contribute to the future Knowledge Management Strategy and Framework.

Conclusion

Knowledge management is a fundamental component of any S&T organization. Of importance is how effectively its knowledge resources and potential are managed and exploited. For Defence R&D Canada, the knowledge management audit identified areas of both strength and opportunities for enhancement. Captured opportunities will assuredly contribute to an improved workplace, collaboration, and defence R&D products and advice.

The facilitation of successful KM depends much upon the culture of the organization and the willingness of the staff to share in the knowledge conversion process. Consistently throughout the interviews, Defence R&D Canada staff indicated their openness to sharing what they know with others. Over one half of technicians indicated that they feel that they already share their knowledge willingly and while scientists and engineers freely share their expertise currently, they do see advantages for increased knowledge sharing. Administrative support staff and managers similarly believe that they already share their knowledge and expertise with others simply for the asking.

How then might KM expand within Defence R&D Canada? Respondents indicated that they might increase their sharing behaviour if there were new mechanisms for sharing. This could include information and document management tools, Web publishing opportunities, and publications that publicly highlight Defence R&D Canada S&T accomplishments. Staff would also increase sharing for appropriate rewards, often as fundamental as a simple thank-you. Although pay increases and additional resources are always desirable, staff value the acknowledgement of their contributions and interest from the organization in their work and requirements. Some recognize that incentives would arise from increased discussion opportunities and the ability to develop one's expertise. For administrative and technical staff, increased invitations to seminars, training and conferences would enhance knowledge sharing.

In knowledge management, Defence R&D Canada has the opportunity to leverage existing strengths in its knowledge base for to achieve its mission and vision. The willingness of the staff to both currently share and increase their sharing of knowledge bodes well for the future success of the organization. These attributes will contribute significantly towards achieving the vision of excellence in defence R&D.

Annex A: Research methods and procedures

Type of study

Exploratory research was undertaken to meet the objectives of the Defence R&D Knowledge Management Audit and employed a qualitative study. Three factors determined the choice of methodology for the study. First, existing survey fatigue within the population might have prevented the ability to acquire a sufficient sample size. Second, interviews could permit the exploration of issues in more detail than would a questionnaire. Third, a representative study could require a sample of up to 25% of the total population. Given time limitations, interviewing 50-60 people was seen as sufficient.

A preliminary study was chosen as a first step. This would allow the KM Working Group to identify important issues in knowledge management in Defence R&D Canada. Should the study results have indicated a need for a more comprehensive study, a follow up study employing focus groups to validate findings would have been conducted. After the completion of the interviews and analysis, it was determined that further study was not required at this point in time.

Semi-structured interviews

One-on-one, semi-structured, in-depth interviews were employed. Probing questions were put forward to learn and understand more about the KM issues affecting the respondents. The interviewer sought to elicit the tacit knowledge of the subgroup participants. The interviews were not tape-recorded, but every effort was made to capture the words and intent of the respondents.

Interview questions were designed by the KM Working Group to address each of the four foci. Probing questions for each of 10 questions were also devised to assist in bringing out the various aspects of each foci. The interview team members engaged in role-playing exercises to determine the suitability of the questions. Revisions were made accordingly.

Pre-testing

The questions were pre-tested and validated over the telephone or in person by a small sample of 7 employees from across four broad occupational categories: 1) technical staff, 2) defence scientists and engineers, 3) administrative support, and 4) managers. Representatives from each research establishment and headquarters were included. The questions were tested in both French and English. The responses were used to determine the clarity of the questions, and whether they would evoke responses relevant to the intent of the questionnaire. The questions were revised accordingly. The respondents in the pre-test sample were not included in the main study

Sampling techniques

Fifty-one out of 1032 employees took part in the KM audit, representing 5% of the total Defence R&D Canada workforce. An additional 6 interviews with the Technical Points of Contact for the DRENet (i.e., network managers) occurred and these focused on the status of information technology and infrastructure management for future initiatives.

Due to the investigative nature of this study, a combined purposive sampling method was used to add credibility to the study. By employing this approach, the researcher was able to uncover a

variety of experiences within particular groups, producing in-depth interviews with detailed information. This method is necessary when a purposeful sample is large and one needs a better handle on the population to be studied. The intent is not to generalize to a broader population, nor to ensure representativeness across the organization.

Individuals were stratified into four pre-defined subgroups (strata), as outlined in Table 2, and randomly chosen from these subgroups to take part in the study. This facilitated comparisons between the subgroups. The sampling approach had to correspond with the respondents' availability and willingness to be interviewed.

Table 2: Defence R&D Canada population by location and classification

Classification	Population and Sample												
	DRES		DCIEM[a]		DREO		HQ		DREV		DREA[g]		DRDC
	T[b]	S[c]	T	S	T	S	T	S	T	S	T	S	Final
Technicians[d]	53	3	35	2	23	1	-	-	92	5 (4)[h]	63	3	13
DS/Eng/VM[e]	44	2	46	2	78	4	23	1	105	5	68	3	17
Administrative Support	46	2	35	2	33	2	42	2	136	7 (5)[h]	46	2	15
Managers[f]	8	1	8	1	9	1	16	1	12	1	11	1	6
Planned Total: 54/1032	151	8	124	7	143	8	81	4	345	18	188	9	51/54
Final Total	151	8	124	7	143	8	81	4	345	15	188	9	51/1032
Final %	15	16	12	14	14	16	8	8	33	29	18	17	100%

[a] Includes AVRS at NRC
[b] Total Population
[c] Sample Size
[d] Includes Technologist (EG), Electronics Technician (EL), Chemists (CH), and those Computer Science (CS) working specifically on the R&D Program
[e] Includes Defence Scientist (DS), Engineer (Eng), Veterinarian (VM)
[f] Includes Assistant Deputy Minister (ADM), Director General (DG), Deputy DGs, Chief Scientists, Directors, Scientific Section Heads
[g] Includes Dockyard Lab (Pacific)
[h] Final Sample

The sampling frame was the Department's PeopleSoft database. When the human resources records of names, locations and classifications were received, they were out-of-date and required some clean-up before being used. This was done by eliminating the names of former employees from the list and moving some names to other Defence R&D Canada locations within the list. Using a table of random numbers, samples of Defence R&D Canada's workforce were selected for both the pre-test and the main interview survey.

Employees were contacted by telephone to determine their willingness to participate. If they declined or were unreachable due to temporary duty or other commitments, the next name in the sample was contacted. The interview team was unable to obtain enough available respondents to complete the proposed sample size for DREV.

Interview process

An interview schedule was prepared. Chief Scientists in each of the labs and Directors in headquarters were contacted directly by telephone or in person to ask for the establishment's or directorate's participation, confirm the suitability of the interview schedule and assist with the facilities for the interviews at their site. A follow-up email confirmed the intent, schedule and procedures of the visit. The email advised that, although they were encouraged to participate, there was no obligation for employees to do so. Each Chief Scientist was asked to disseminate that information as appropriate for the respective location.

Personnel selected for the sample were contacted directly by telephone by members of the interview team to seek their participation. The interviewers explained the format and assured the participants of the confidentiality of their answers. Interview times were scheduled. Subsequently, email messages were sent directly to the participants at least one week prior to the interviews. The messages confirmed the interview times, gave assurances of voluntary and confidential participation and included an interview guide and questions.

Members of the KM Working Group conducted interviews at Headquarters and in each of the labs from mid-October to mid-November, 2000. Concurrent interviews were scheduled every 2 hours and each interview was intended to be 45 minutes to 1 hour long. The interviews consisted of the questions sent out to the participants as well as probing questions to explore the issues in detail. The complete list of questions is found within Annex B.

Infrastructure inventory

In the second part of the audit, interviews with the DRENet Technical Points of Contact were conducted to determine the current information technology infrastructure of Defence R&D Canada. They also were intended to determine whether there are any technical barriers to future knowledge management and sharing initiatives. The interviews were also intended to identify the existence and location of current information and knowledge management tools.

The information was gathered during the same time frame as the employee interviews were conducted. Arrangements for these interviews were made by calling the TPoCs directly to set an interview time during the scheduled visit to their respective labs. The questions (in Annex C) were sent by email ahead of time.

Defence R&D Canada employees were very cooperative and generally willing to participate despite their time restrictions. The KM Working Group is grateful for their participation and the opportunity to learn more about Defence R&D Canada, its employees and the R&D program, and particularly, the enablers and barriers to knowledge use and creation.

Analysis

The methodology was limited by the small size of the sample and a non-representative sampling technique. Consequently, the results of the study are considered to be indicative rather than conclusive. They cannot be generalized to the entire population or be considered representative. Using inductive analysis, the results were coded and grouped by categories or themes within each of the occupational groups. The groupings were numbered in order of frequency of responses. All responses were considered to be of importance during the analysis. Because the analysis is based on a qualitative interpretation of the data, it also is limited by the possibility of subjective interviewer bias. The evaluated results of the audit, therefore, constitute a preliminary analysis of KM within Defence R&D Canada. The analysis identified common themes and issues.
It is assumed that the results are indicative of Defence R&D Canada situation at the time of the interviews.

Annex B: Interview questions

Employees' awareness of sources of knowledge within the Agency and the barriers or enablers for the ability to locate that knowledge:

1. **What are the sources of information or knowledge that you use for your work**?
   a. Can you provide the names, locations and details of those sources (e.g., databases, libraries, people, organizations, associations, conferences, forums, seminars, books, Internet sites)?
   b. Do you participate in any electronic knowledge-sharing forums?
   c. Do you participate in any (face-to-face) formal or informal knowledge sharing forums (e.g., committees, meetings, others)?
   d. Do you use other electronic systems, such as video conferencing or collaborative software? (details, locations)

2. **In general, do you consider it easy or difficult to access information or knowledge sources**?
   a. What helps you access these sources? Examples?
   b. What prevents your access? Examples?

Agency's ability to respond to requirements in a timely manner by locating knowledge sources internally and organizing skill sets when required:

3. **Can you find the information that you need to respond to requests and demands in a timely manner? Yes/No**
   a. What are some examples of what enables you to find the information to meet your deadlines?
   b. What are some examples of possible barriers that you encounter when trying to meet your deadlines?

4. **Are you able to find the appropriate expert advice within the Agency when you need it? Yes/No**
   a. What assists you in locating the expert advice?
   b. Do you encounter any challenges when locating the expertise that you require?
   c. Does the Agency have the skilled people that you need to access to perform new tasks?
   d. Which of the required expertise is available in the Agency?
   e. Which of the required expertise is not available in the Agency?

5. **Do you have any recommendations that would allow you to be more effective in your work**?
   a. (Financial resources, if stated)…What would additional financial resources provide?
   b. (Human resources, if stated)…What additional human resources are required?
   c. Are you aware of any information or knowledge management systems that might assist you? If so, please give some examples.
   d. Would you suggest any changes or improvements to the organization or working conditions that would assist you? If so, please give examples.

Enablers and barriers to external knowledge and the ability to create partnerships:

6. **Do you monitor the activities and trends of your competitors? Yes/No**
    a. If yes, how? Please provide examples.
    b. Who would you view as your competition?
    c. Do you keep current in your own field? How?
    d. Do you develop your knowledge of related fields? How?
    e. Do you attempt to keep current with non-related fields? How? Examples?

7. **Do you collaborate with people outside the Agency on work related issues**?
    a. If so, how?
    b. Is there anything that assists you in collaborating, e.g., electronic forums?
    c. Are there any barriers that you encounter in establishing external partnerships?
    d. What would facilitate your knowledge or information exchange with external sources?

Ability of the Agency to get its knowledge to clients responsively:

8. **How do you determine what products and services your clients need**?
    a. What must you know about your clients to serve them better?
    b. Could you recommend a way that you could come to know your clients and their requirements better?
    c. If yes, what conditions must occur to allow you to do this?

9. **In general, how long does it take to get one of your ideas from the initial concept to the first operational use**?
    a. Is this an acceptable time frame?
    b. Does this allow for a quality product?
    c. What could improve the time?
    d. What could improve the quality of the product?

10. **Does your current work situation allow you to be innovative[37]? Yes/No**
    a. What would allow you to become more innovative in your work?
    b. In which conditions have you found yourself to be the most innovative?
    c. How do you share your knowledge and expertise with others?
    d. What would give you incentive to increase your own knowledge sharing?
    e. What systems or tools does the Agency have at this point to facilitate knowledge sharing?

Can you think of anything else to contribute to the development of knowledge management strategies in the Agency?

[37] Peter Drucker defined "innovation" as "*applying new knowledge to tasks that are new and different.*" in *Managing for the Future: the 1990's and Beyond*. 1992.

Annex C: Technology infrastructure questionnaire

Infrastructural Diagnostics[38]		
Inventory question	**Yes/No**	**Comments**
Do all employees have access to the DREnet locally? If not, who does not and why not? Are there any technical or security concerns about anyone's level of connectivity or access?		
What conditions must be met for an employee or a contractor to have access to the DREnet? How is this managed?		
Does your lab's network support remote access locally?		
Does your lab publicize and encourage the availability of remote dial-up access through the VPN or AT&T? How?		
Does your lab currently use an intranet (within the DRE)?		
Does your lab currently use the Agency intranet (Descartes)?		
Does your lab currently use the DWAN [i.e., DIN]? How many accounts? How many workstations? For which applications, e.g., email, DIN, FMAS, etc.?		
Does your lab currently use an extranet for collaboration outside of the Agency?		
Does your lab use video conferencing? For which situations?		
Does your lab use any specific decision support systems? (DSS are computer-based tools to support human decision-making that make use of data and models to handle complex semi-structured problems, e.g., GroupSystems®)		
Is your lab standardized on a single computer operating system, e.g., Windows, Mac/OS, Unix, Linux, etc.? If not, what are the different ones used by your employees?		

[38] Adapted from Tiwana, Amrit.The Knowledge Management Toolkit, Upper Saddle River: Prentice-Hall, 2000.

Does your lab currently use GroupWare or collaborative platforms such as Lotus Notes? If so, which ones?		
Does your lab extensively use mobile computing solutions such as PalmPilots? If your lab does not officially use such solutions, do your employees use these in high numbers? What percentage?		
Does your lab currently deploy something like a skills database? Explain. Give location and contact details.		
Does your lab currently use document management solutions, eg., DOMUS? Which ones? If yes, can you list the primary reason why?		
Does your lab currently use a project management tool for tracking projects and assignments? Examples of such tools include MS Project. If so, which ones?		
Have you converted to Outlook/Exchange? If not, when is the planned implementation?		
What kind of RDBMS do you use, e.g., ORACLE? For which applications?		
Does your lab acquire software through site licenses? In which cases?		
What are the challenges to implementing lab-wide or Agency-wide software solutions?		
Do you have any concerns about your lab's involvement in future group IT/IM/KM initiatives for the Agency?		

Knowledge processes and technology enablers [39]		
Knowledge objective	**Technology enablers**	**What currently exists? (IP address if applicable)**
Find knowledge	Knowledge-bases; search and retrieval tools that scan both formal and informal sources of knowledge; employee skills yellow pages.	
Create new knowledge	Capture of collaborative decision-making processes; DSS tools; rationale capture tools; Notes databases; decision repositories; externalization tools.	

[39] Ibid.

Package and assemble Knowledge	Customized publishing tools; information refinery tools; push technology; customized discussion groups.	
Apply knowledge	Search, retrieval, and storage tools to help organize and classify both formal and Informal knowledge.	
Reuse and revalidation of knowledge	Customer support knowledge bases; discussion databases; past project record databases and communities of practice.	

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14. ABSTRACT

(U) Defence R&D Canada undertook a knowledge management audit to determine how well it managed knowledge creation and use and what could be done to improve the use and leveraging of knowledge. A qualitative study was employed using a purposeful random sample and an interview format. Five themes emerged from the results:
1. There is a need to focus on the organizational mission and clarify priorities
2. Information management tools are required as essential building blocks in a Defence R&D Canada knowledge management initiative
3. Sharing in-house expertise is critical for knowledge leveraging, business development, cross-disciplinary work and efficiencies
4. Enhanced exchange of foreign information is required to supplement informal exchanges; and
5. A mutual vision for future technology planning is needed for Defence R&D Canada and the Canadian Forces clients.

(U) R & D pour la défense Canada a amorcé une enquête sur la gestion du savoir afin d'évaluer l'habileté de l'agence à gérer la création et l'usage du savoir et de déterminer ce qu'on pourrait faire pour que le savoir soit mieux utilisé et exploité. L'enquête a été menée sous forme d'étude qualitative d'échantillons aléatoires et d'entrevues. Les résultats révèlent cinq besoins :
1. Le besoin de mettre l'accent sur la mission de l'organisation et de clarifier les priorités
2. Le besoin d'outils de gestion de l'information comme pierre angulaire de l'initiative de gestion du savoir de R & D pour la défense Canada
3. Le besoin essentiel de partager l'expertise sur place aux fins de l'exploitation du savoir, de l'expansion des affaires, des travaux interdisciplinaires et de l'efficacité
4. Le besoin d'accroître les échanges d'information avec l'étranger pour compléter les échanges informels
Le besoin d'établir une vision mutuelle de la planification future de la technologie pour les clients de R & D pour la défense Canada et des Forces canadiennes.

15. KEYWORDS, DESCRIPTORS or IDENTIFIERS

(U)

Defence R&D Canada

Canada's leader in defence
and national security R&D

R et D pour la défense Canada

Chef de file au Canada en R & D
pour la défense et la sécurité nationale