Industry Canada Industrie Canada

Review of the Radio Science Branch of the Communications Research Centre Canada

Final Report

Prepared by:

Performance Management Network Inc.

Prepared for:

Radio Science Branch
Communications Research Centre Canada

March, 2001

Canada

Table of Contents

Executive Summary

This review of the Radio Science Branch is being undertaken in order to assist CRC management in determining the extent to which the programs and activities of the Branch are appropriate and effective in meeting government needs for expertise in radio science. In addition, the review identifies opportunities to improve the performance of the Branch and its effectiveness.

CRC has had a research program linked to radio science for over 20 years. Since that time, radio science research has continued under various organizational structures. In 1998, the Advanced Antenna Research Group joined the Branch.

The Radio Science Branch has expenditures of about $3.3 million annually. These consist of salaries for 37 person years of effort provided by about 32 permanent and 5 revenue-based and temporary staff, and $1 million for operational and minor capital expenditures. Revenues and special funds provide about $400,000 or 12% of Branch expenditures.

The review addressed two major issues related to relevance and quality, and examined a number of questions which addressed specific aspects of each issue. Detailed analysis and discussions on the various questions can be found in the main body of this report.

It is clear that, overall, the Branch is appropriately and effectively positioned to fulfill the role of a government research laboratory in the field of radio science. However there is some concern that the Branch is not effectively responding to the needs of some of its public sector clients and stakeholders. Based on the responses of clients and knowledgeable stakeholders interviewed, the Branch is providing valuable and important services to clients, through the generation of results of a technical or strategic nature difficult or impossible to achieve without the contribution of the Branch. Clients rate the quality of research, services and equipment highly. However, there is concern that loss of qualified staff has left the Branch less able to meet client needs.

An overview of the evidence and conclusions for each issue, followed by recommendations for change is provided below.

Issue 1: To what extent are the programs and activities carried out within the Radio Science Branch relevant and effective in terms of the appropriate role for government laboratories?

Based on a review of recent literature and the 1996 federal review of government S&T entitled "Science and Technology for the New Century", it is clear that the Canadian government expects its scientific laboratories to fulfill a dual role in support of both public interest and economic growth and wealth creation. This is reflected in the CRC mission statement. These two roles can be complementary, particularly in the case of standards and regulations. In the case of radio science, the social and cultural well being of the public needs to be supported through an efficient, effective, and accessible Canadian wireless communications system based on internationally accepted standards, and the private communications systems developers need appropriate scientific knowledge and technical assistance which help them develop and provide quality communications systems. Policy studies support the role of government S&T as providing technical support to the

development of national regulations and guidelines compatible with international systems. This is as true of radio communications as of other areas of commerce. The Branch is well positioned to fulfill this role for the Canadian public and private sector radio communications.

The need for Branch capabilities in radio science is once again being recognized. As the lower frequencies are being fully utilized, new higher frequencies are being required, and the characteristics of radiowave propagation at these higher frequencies need to be studied. The Canadian wireless communications industry has lost much of its technical capability through downsizing and, in many cases, the Radio Science Branch is the principal source of high level expertise and knowledge about radiowave propagation and high frequency systems in the country.

A review of Branch programs and projects, analysis of clients and collaborators, and feedback from the client survey, staff and expert interviews show that the Branch has the expertise and capability to fulfill these complementary roles, supporting both public and private interests within the Canadian and international broadcast community. However, although there are some exceptions, by and large, the Branch has not been proactive in working with others to apply its knowledge to practical problems. In addition to its expertise and research capabilities, clients and partners of the Branch would like it to provide other types of services, such as the provision of information, advice, and strategic intelligence. Some of those interviewed would like the Branch to make a greater effort to make them aware of technical developments and other emerging issues on a regular basis.

Another need in the wireless communications community is for highly qualified personnel with experience in higher frequency communications systems. A number of the skilled staff of the Branch have been hired away to fill these needs in other organizations. The Branch works with the university community to support the training of graduate students, which also provides additional resources for Branch research and development projects. Some of these students are hired by CRC following completion of their studies.

Relevance - Recommendations

The first two specific recommendations that follow identify specific aspects of a more proactive approach by the Branch to identify and meet the needs of clients and stakeholders.

Develop Long Term Relationships with Key Stakeholders

The Radio Science Branch should meet with major clients and stakeholders to develop strategic long-term plans that identify the most effective means of working together and supporting their needs. This applies in particular to Spectrum Engineering and other CRC Branches who can benefit greatly from the knowledge and expertise in the Radio Science Branch. The partners need to identify how the research capabilities of the Radio Science Branch can best be put to use to meet the needs of these stakeholders. The challenge is to match the capabilities of the Radio Science Branch to perform longer-term research with the shorter term applied nature of the partners and stakeholder needs.

Communications, Networking and Awareness Building

The Branch should move to address the expressed desire in the wireless communications community for improved access to strategic knowledge of technical developments and emerging issues. Communicating with the broader stakeholder community about Branch initiatives and perspective on emerging issues should become a higher priority, and the Branch should develop mechanisms to accomplish this objective. The review of the Broadcast Technologies Branch identified a number of possible mechanisms that seem appropriate for the Radio Science Branch as well. They include regular workshops possibly aligned to the specific needs of various stakeholder groups; a periodic newsletter with information about Branch projects, strategic intelligence from international meetings; and a web page with basic information about the Branch priorities, as well as similar information as in the newsletter described above.

The Branch should also try to identify an association or group associated with the Canadian wireless communications community which could serve as a partner to disseminate strategic information from the Branch about emerging technical and regulatory issues.

It is likely that a combination of approaches will be more effective than a single one.

Maintain Multiple Complementary Roles

It is clear that the Radio Science Branch is uniquely positioned to meet needs of both the public and private sectors within the Canadian wireless communications community and that insight into the needs of one group contributes to the Branch's ability to meet the needs of the other. The Radio Science Branch should continue to maintain a balance among its various roles, developing new knowledge and expertise and providing advice and services to meet both public and private sector needs in a complementary manner. The provision of high quality technical support for Canadian wireless communications policies, standards and regulations in the public interest also helps provide the private sector with an efficient and effective regulatory infrastructure within which to work.

Issue 2: To what extent does the quality of research, advice and services provided by the Radio Science Branch meet the needs of clients and collaborators?

The issue of the appropriateness of the quality of research and services was reviewed through a number of complementary methods. Based on the client survey results and in-depth interviews, the large majority of clients and collaborators are generally highly satisfied with the quality of research and technical services provided by the Branch, and have confidence in the results obtained. Clients and informed stakeholders also agree that existing services are highly relevant to the needs of the wireless communications community. When clients were asked to rate their satisfaction with the Branch's contribution to a specific project, the average rating was 8.2 out of 10. This is a high rating, indicating a positive relationship between the Branch and the clients surveyed. However, some interviewees from Spectrum Engineering and other CRC Branches were concerned about a mismatch between the Branch's focus on longer term research, and their needs for support for shorter term applied and developmental projects. In the past, this has at times led to the Branch's unwillingness to meet their requests for assistance.

A number of clients thought that the quality of research, and breadth and depth of scientific and technical capability is now lower than it has been due to the large number of vacancies, now approaching 25% and inability to retain qualified professional staff. Many noted that there has been a significant loss in the past several years of highly qualified staff, leading to a loss of important research and testing capabilities in the Branch.

For those interviewees who had worked with other communications laboratories, the Branch also compared reasonably favourably. In some cases, these other organizations were large national laboratories much better funded than the Branch, so in that respect clients noted that the comparison may not be fair. Clients rated the quality of Branch equipment and facilities, quality of personnel, and overall responsiveness to client needs slightly better than these comparable organizations.

Quality - Recommendations

Hiring and Retention of Qualified Staff

The Radio Science Branch should treat the hiring and retention of qualified professional staff as a priority. Hopefully, as the overheated technology sector of the economy returns to a more normal level, potential employees will consider working in the Branch more seriously. As a short term measure, other avenues should be explored, such as working with university professors on sabbatical, secondments from other organizations, and increased use of graduate and post-graduate students.

The Broadcast Technologies Branch has had good success over the past year in finding qualified staff to fill a number of vacancies, and it may be useful for the Radio Science Branch to consult with them to determine their approach.

Focus More on Application of Knowledge for Benefit of Clients

The stated mission of the Radio Science Branch is to develop new knowledge in radio science and to help apply that new knowledge. Evidence suggests that, in the past, the Branch has focused more on the former and less on the latter. In the future the Branch should review its overall strategy, with a view to moving the mix more towards assisting others in utilizing and applying the knowledge of the Branch. As a government research group providing scientific and technical support to public and private sector clients, the focus needs to be on balancing the complementary objectives of developing knowledge in priority areas to meet the emerging needs of key clients and sectors.

1.0 Introduction

1.1 Background

As outlined in the Treasury Board review documents, departments and agencies must conduct reviews of major policies and programs to provide senior management with objective information about the extent to which programs are relevant and are achieving objectives. This information is to be used to provide accountability for the use of public funds and to assist management in improving program performance. The Communications Research Centre Canada (CRC) is, accordingly, in the process of undertaking reviews of each of its Research Branches over a period of time.

Government policy with respect to the role of government research laboratories has evolved considerably over the 1990s, and CRC management is interested in whether the activities and objectives of the Radio Science Branch remain appropriate and effective in meeting government needs. In making this assessment, it is important to determine who the beneficiaries of Branch activities are, and what benefits they receive.

Recently, government has asked departments and agencies to ensure that they monitor client perspective on the quality of services and interactions, and the benefits that the clients receive. In addition, a review provides an opportunity to obtain client perspective on a number of aspects of the Branch, including the capabilities of Branch staff, quality of research and facilities, advice and test results, and client relations.

This review of the Radio Science Branch follows a similar review of the Broadcast Technologies Branch completed in November 1999, and employs similar methodological approaches.

Based on input from CRC management and their requirements for information to demonstrate accountability and support decision-making, the following issues have been developed. Each issue has a number of questions to help define information and analytical requirements.

1.2 Study Issues

Issue 1: To what extent are the programs and activities carried out within the Radio Science Branch relevant and effective in terms of the appropriate role of government laboratories?

1.1 Is there a continuing need for the research and testing facilities provided within the Radio Science Branch programs?

1.2 Who benefits from the Radio Science Branch programs? In what manner?

1.3 How effectively is the Radio Science Branch meeting Canadian public and private sector needs for information and advice about existing and emerging radio science knowledge, technologies and systems?

1.4 In what manner does the Radio Science Branch contribute to the mission of CRC?

1.5 Is the Radio Science Branch within CRC filling an appropriate role for government?

Issue 2: To what extent does the quality of research and services provided by the Radio Science Branch meet the needs of clients and collaborators?

2.1 In what manner do publications from the Radio Science Branch meet Canadian and international needs for new knowledge.

2.2 Do clients and collaborators have confidence in the quality of research, testing and other services provided by the Radio Science Branch?

2.3 Are Radio Science Branch services relevant to the needs of clients?

2.4 Are the capabilities of Radio Science Branch staff and the quality of facilities appropriate to the needs of clients and collaborators?

2.5 What is the nature and extent of collaborations with other CRC branches and with other organizations?

1.3 Methodology

This section presents a summary of the methodological approach developed to gather appropriate evidence to reach credible conclusions on the study issues and questions. (A detailed description of the approach can be found in the **Planning Report for the Review of the Radio Science Branch** that was used as the basis for this study.) The methodological approach is based on the commonly accepted practice of using several complementary analytical methods to gather multiple lines of evidence to arrive at credible findings and conclusions. For each question, there is at least one major source of evidence with additional supplementary sources as appropriate. Each of the methods used was adjusted to the specific information sources and requirements.

Based on the information provided in the preliminary document review, interviews and preparation of the Branch profile, the following sources were used to collect evidence for the study:

- CRC and Branch document and file review and analysis;
- analysis of Branch publications for the past four years (1997 to 2000);

- interviews with managers and senior staff from the Radio Science Branch and other CRC branches;
- survey of 29 partners, collaborators and clients of the Branch (face-to-face and telephone interviews using a standardized questionnaire) taken from a list provided by the Branch;
- in-depth interviews with informed stakeholders; and,
- case studies of three major Branch projects, one from each research group.

In addition, an integration and analysis phase reviewed and synthesized pertinent evidence from the various sources in order to provide more credible conclusions on the various questions and issues. Where appropriate, results from the review of the Radio Science Branch are compared to those found in the previous review of the Broadcast Technologies Branch.

Reviews of this nature are essentially applied social science. Each particular methodological approach has specific strengths and limitations. Careful combining of methods can minimize the limitations and provide more credible conclusions than available from a single source.

Table 1 summarizes the strengths and limitations of each of the methodological approaches.

Table 1: Strengths and Limitations of Method

Method	Strength	Limitation
Document Review	Provides factual background information to support other sources.	Usually does not relate directly to review issues. Must be complemented with other methods.
Publication Analysis	Provides factual information about scientific outputs of Branch, collaborators and intended audience.	Captures evidence of quality of scientific outputs and collaboration partners (part of the issues).
CRC Staff Interviews	Staff input is essential to provide background and context. Have detailed knowledge about strength and extent of networking.	Input is combination of fact and perception. Needs to be confirmed from other sources (i.e., for quality of service, compared to those of clients).
Client Survey	Important source of partner and client perspective on relevance, benefits arising from working with Branch, quality of services.	Clients chosen from list provided by Branch - may not be representative. Numbers too small to generalize. Perception is not fact – comments may not reflect reality, cannot be proven.
In-depth Interviews	Experienced, well-informed individuals provide important strategic perspective unavailable elsewhere.	Not representative of stakeholder group, perspectives are personal, possibly biased.
Case Studies	Provide in depth probing of roles, relationships and outcomes and impacts.	Not representative or generalizeable, usually chosen from among best projects to demonstrate nature and extent of benefits which can occur.

2.0 Radio Science Branch Profile

2.1 Background

CRC is the Canadian government's primary communications research organization. It was originally formed in 1969 as an agency of the Department of Communications, having evolved from previous military communications objectives to a new civilian role. In 1993, CRC was made part of Industry Canada, the federal government's major industrial and economic development agency. The corporate goals of CRC are:

- to be at the forefront of communications science and technology in order to offer insight to the government for the formulation of industrial strategies, regulations and policies in the public interest;
- to be recognized nationally and internationally as a leading centre of excellence in communications technology R&D addressing Canadian needs and as a primary source of independent technical and scientific advice;
- to be a catalyst and central player in a web of industrial and institutional partnerships to ensure Canada maintains its world leadership position in the development and application of communication technologies; and,
- to make sustained and measurable contributions to the growth of an entrepreneurial, innovative communications industry in Canada.

2.2 Description of Branch[1]

The mission of the Radio Science Branch is:

> *to study and quantify the physical limits to the reliability, quality and performance of radio systems, in order to increase the existing body of knowledge on radio phenomena, and provide scientific and technical information and advice to government and industry to help them plan, select and implement the best wireless systems, networks and services for Canada.*

The research of the Branch provides foundation knowledge and technology to support CRC's research in terrestrial wireless, satellite communications, and broadcast technology. The Branch also provides technology development and testing, and advice to government (Industry Canada's Spectrum Engineering, Department of National Defence – DND and Canadian Security Establishment – CSE) and private industry related to satellite and terrestrial wireless communication systems. In support of this mission, the Branch conducts research in three areas: radiowave propagation; electromagnetic compatibility; and microwave antennas. These research programs are described in greater detail below.

[1] For a more complete description of the Branch, please see the report Profile of the Radio Science Branch, November 16, 2000, which was developed in preparation for this review.

Radiowave Propagation research has several objectives: to study and model radiowave propagation for terrestrial and earth-space telecommunications systems in frequency bands from 1 MHz to 100 GHz; to evaluate the influence of radio propagation phenomena on systems and technology, and techniques to mitigate negative effects; and to disseminate information and provide advice to Industry Canada, DND and other governmental and non-governmental organizations to support improved spectrum management and design of terrestrial and satellite communications systems.

Facilities include an Earth-Space Propagation Measurement Facility to measure 20.2/27.5 GHz satellite beacon signal level, radiometric sky noise at 12/20 GHz and meteorological quantities; a Terrestrial Fixed Propagation Measurement Site to measure vertical profiles of atmospheric refractive index and related environmental factors; and a Radio Channel Characterization Laboratory to measure complex signal / channel impulse response from 30 MHz to 60 GHz.

Research is focused on finding technical solutions to the increased demand for radio communication. This demand has led to two initiatives, exploration of methods to increase the efficiency in use of the radio spectrum, and the extension of communications into the 20 to 100 GHz range. The new knowledge obtained about propagation phenomena supports the development of radioclimatological models and engineering tools to support improved design capabilities for future systems. As well, the knowledge is available to support Industry Canada's broadcast spectrum management and development of regulatory frameworks.

Electromagnetic Compatibility research objectives are to characterize the electromagnetic environment and determine its impact on electronic and electrical devices and systems. The government, through Spectrum Engineering, has created an Environmental Task Group, to which the group belongs, to study these effects. Specific projects include studying the operational environment of large antennas, determining the potential for interference of digital TV signals on various medical devices, and examining the coupling of external fields to enclosed printed circuit boards.

The group is also working with DND to study the electromagnetic hardness of various electrical and electronic systems and to examine the use of high power microwaves to neutralize landmines.

Advanced Antenna research objectives are to investigate and develop state-of-the art hardware and software technologies applicable to low-profile structures and active and passive antenna arrays at microwave and millimeter wave frequencies. The group's experimental activities are centred around an Antenna Test Facility, which includes a far field measurement system for frequencies of 1 to 50 GHz, and a near field measurement system for frequencies up to 65 GHz. The group has numerous projects involving other CRC branches, universities, other government departments, and industry. The results of the group's work are provided to Industry Canada Spectrum Engineering, DND, and other government departments and agencies to support the development of new wireless

communications systems and regulations, and to Canadian industry for commercial exploitation.

The research, development, testing, and advisory activities carried out by these three research groups result in a number of outputs which are listed below:

- new knowledge;
- new and improved standards and test procedures;
- research and test results;
- technical advice and assistance;
- new and improved products and services; and,
- trained highly qualified personnel.

2.3 Resources

In 2000-2001 Radio Science Branch had a budget of $3.3 million, which is approximately 5% of CRC's total budget. These resources are used to fund 37.3 full-time equivalent staff, with a salary budget of $2.3 million, and $1 million in operating funding. **Table 2** below, provides a breakdown of the sources of funding and utilization of resources, based on the 2000-2001 Operational Plan. A-base funding provides almost 80% of operational resources. External funding sources include DND, Spectrum Engineering, CIDA and industry. DND is the largest single source of external funding, providing almost $300,000 in salary and non-salary funds, and Spectrum Engineering provides $85,000 in direct project specific funding. Of the 37.3 full-time equivalent personnel, 32.3 are provided from A-base funding and the other 5 from contract revenues, grants and special funds. This includes co-op students, post-doctoral fellows and exchange personnel.

Table 2: Branch Resources

	FTEs*		O&M FUNDING ($000s)					
	A-Base	Other***	A-Base	Spectrum	IP	Cont. In	Other	Total
VPRS**	4		68				66	134
RVEP	15	0	270	40	6	22	10	348
REMC	6.3	1	126	35		46	6	213
RAAT	7	4	140	10		30	142	322
TOTAL	32.3	5	604	85	6	98	224	1,017

* Salary budget is $2.3 million
** Includes VP and Branch administration and support
*** Includes project paid employees, graduate, co-op and other students, and contract employees

2.4 Reach

The Radio Science Branch has a number of Canadian and international public and private sector partners, collaborators and clients with whom they interact. Within the public sector, they include the following:

- Canadian communications regulators (Industry Canada Spectrum Engineering Branch);
- Department of National Defence;
- Canadian Space Agency;
- universities;
- international telecommunications regulatory agencies; and,
- other foreign government agencies.

In the private sector, the branch works primarily with Canadian wireless communications services and manufacturing firms.

The total number of organizations with which the branch has significant interactions is estimated to be 30 to 40. However, taking account of multiple interaction partners in some organizations such as Spectrum Engineering and universities, the total number of interaction partners rises to approximately 50.

2.5 Intended Results

The intended results of Branch activities and interactions vary by type of partner or client. For public sector partners, intended results include:

- technically informed communications policy and regulatory decision making within Canada;
- best use of the communications radio frequency spectrum;
- Canadian influence in international broadcast and telecommunications policy and regulatory bodies; and,
- support for the development and use of advanced communications systems by DND, CSE and CSA.

For private sector partners intended results focus on the improved competitiveness of the Canadian wireless communications services and equipment manufacturing firms and sectors.

2.6 Radio Science Branch Performance Framework

As demonstrated in the previous sections, this review will follow the practice begun with the review of the Broadcast Technologies Research Branch of CRC, completed in 1999, which made use of the performance framework approach to describe the Branch. This approach describes the essential components of a program in terms of five broad categories. They are:

- activities (what program staff and management do);
- outputs (direct products of program activities);
- reach (individual organizations and groups directly and indirectly involved in or "reached" by program activities, includes co-delivery agents);
- direct outcomes (direct results of interaction between program and those reached, includes knowledge transfer, attitudinal and behavioural changes); and,
- ultimate impacts (follow direct outcomes, usually longer term, should link directly to program objectives).

These five categories can be further condensed into three groups – resources (activities, outputs), reach and results (direct outcomes, ultimate impacts) – which answer the three basic performance questions of:

- **HOW** are we going to allocate resources to provide activities and outputs which achieve program objectives?
- **WHO** do we need to work with and influence to achieve program objectives? and,
- **WHAT** is the logical result of doing these things with these people and organizations?

In completing the profile of the Radio Science Branch, a performance framework was developed for the Branch, shown on the following page as **Exhibit 1**. As can be seen, the Branch performance framework presents a strategic view of the main elements of the Branch operations, its target clients and partners as well as intended immediate and longer-term results. This framework will be used in this review as the basis for comparing aspects of the actual performance of the Branch to the intended performance.

Exhibit 1: Radio Science Branch Performance Framework

Mission Statement: To study and quantify the physical limits to the reliability, quality and performance of radio communications.

Resources: 37.3 full time equivalent employees, $3.3 million in total funding ($2.6 million A-base, $700,000 external)

HOW?	WHO?	WHAT do we want?	WHY?
Resources	**Reach**	**Results**	
activities / outputs	users / clients / co-deliverers / beneficiaries	Direct outcomes	ultimate impacts
Research, Development and Testing - radiowave propagation - electromagnetic compatibility - advanced antennas Development and Operation of Test Facilities Publications / Test Results Advice / Assistance Management - projects - contracts - staff - networks - communications, marketing - reporting	Federal Government: - Spectrum Management - DND - CSA - CIDA Universities - Canadian - Other International Regulatory Agencies - ITU-R - URSI Other Government Agencies - NASA - NATO Telecommunications and Electronics Firms	Technically aware policy and regulatory decision making Improved use of technology by government agencies Canadian influence in international standards development Awareness, use of Canadian capability Increased awareness of propagation, electromagnetic noise and interference, and antenna information, technology and applications, international developments by government and industry New and improved products, processes and systems	Best use of spectrum Technically effective, efficient public communications policy, regulations Improved government decision making in use of communications technology Canadian influence in international regulatory system Canadian policies and regulations aligned with international requirements Increased competitiveness of Canadian broadcast and telecommunications manufacturers More informed, appropriate decisions by public and private sector wireless communications stakeholders

3.0 Program Relevance

Issue 1: To what extent are the programs and activities carried out within the Radio Science Branch relevant and effective in terms of the appropriate role for government laboratories?

Five specific questions related to program relevance have been identified in order to examine various aspects of this issue. These include:

- continuing need for Branch research and testing facilities;
- nature and extent of benefits and beneficiaries;
- Branch effectiveness in providing information and advice on emerging trends;
- Branch contribution to CRC mission; and,
- appropriateness of Branch activities and programs for a government research agency.

Each question is studied in detail in the following sections, followed by a general summary and recommendations. Analysis of this issue will include reference to the profile of the Radio Science Branch found in the preceeding section, and the Branch performance framework found in Exhibit 1, which identify the various types of services and their characteristics, from R&D to communication and awareness building.

3.1 Is there a Continuing Need for the Research and Testing Facilities Provided within the Radio Science Branch Programs?

3.1.1 Context

The issue of continuing need represents one of the basic questions which must be answered about all government programs. In this case, there are many aspects to the question, linked to the multiple roles the Branch is expected to perform in support of both the public and private sectors. Need should be considered from at least three perspectives: the country; the wireless communications community at large; and, individual public and private sector organizations.

This question was examined using evidence from three major sources. These include the client survey, in-depth stakeholder interviews, and CRC staff interviews. Of particular importance was the input from the major public and private sector clients, namely Industry Canada Spectrum Engineering and representatives of the Canadian wireless communications sector.

Further discussion related to continuing need is provided in several sections that follow. In particular Section 3.2 examines the beneficiaries of the Branch's activities and programs and the benefits that result from their interactions with the Branch, and Section 3.5 reviews the appropriate role for government research agencies.

3.1.2 Detailed Findings

Client Survey

The issue of continuing need for the Branch's capabilities by individual organizations was addressed by several questions in the client survey. One indication of the continuing need for the Radio Science Branch is the long-term relationships which the Branch has had with the majority of these organizations. Of the 29 respondents, eight had worked with the Branch for ten years or more; eight for between five and ten years; and thirteen for less than five years. While not asked directly if they would continue to work with the Branch, the positive statements of the importance and value of their relationship with the Branch by the large majority of respondents is a good indicator that the Branch continues to meet at least some of their needs.

Survey respondents were asked to rate the relevance of the Radio Science Branch capabilities to their organization on a scale of 1 to 10, with 1 being not at all relevant and 10 being extremely relevant. The average rating for this question was 8.1, a high rating. In some cases, respondents from organizations with a broad product mix or mandate, were responding only in terms of that part of their business to which Branch capabilities were a good fit. Of the 29 respondents, 4 gave ratings of 6 or less. Ratings from the four representatives of Spectrum Engineering tended to be low, with several respondents indicating that there was not a good fit between their needs for applied solutions and the long term research interests of the Radio Science Branch. This is an issue which reappears throughout this study.

To probe whether there were additional needs which the Branch could address, respondents were asked to identify new or improved capabilities which the Branch could add to better meet their needs. Most were unable to identify any, however a few respondents made specific suggestions. Most related to a more proactive relationship between the Radio Science Branch and their community, not additional technical capabilities. For example, several respondents surveyed wanted the Branch to improve its communication with the broader community and improve networking efforts. As will be discussed in more detail later, clients see the Branch as a valuable source of strategic intelligence and want better access to it.

Survey respondents were also asked why they worked with the Branch. As the question was open ended, with no list of prepared options, there were a variety of responses. The most frequent related to the strong technical capabilities of the Branch, as reflected in the high level of capabilities and expertise of staff and the facilities and equipment.

Evidence suggests that for many clients, the Branch provides unique services otherwise unavailable in Canada. Respondents were asked to consider, for specific projects identified by the Branch, what effect not having access to the Branch would have had. Of the 29 specific projects examined, there would have been major negative effects for 28 (97%) and minor effects for the other one. Negative effects include the following:

- project would not have gone ahead without Branch participation;

- project would be less complete, information less reliable;
- loss of credibility due to absence of Branch participation;
- major delays; and,
- increased costs.

While there may be some concern that the clients surveyed were selected by the Branch and may not be representative of Branch interactions with all clients, indepth discussions with knowledgeable clients and corroborating evidence from multiple sources indicate that the Branch is meeting important needs for many of its clients and the Canadian wireless communications community which are not available elsewhere in Canada.

CRC Staff Interviews

Evidence from interviews with individuals from other CRC Branches shows that other Branches find the knowledge within the Radio Science Branch to be relevant to their needs. Several interviewees described positive, rewarding collaborations with the Radio Science Branch. In many cases, relationships are informal, such as information exchange and advice. In others, where a funded project is involved, a more formal collaboration is formed. As was found with some interviewees from Spectrum Engineering, some from other CRC Branches identified cases in the past where Radio Science Branch managers have not responded to requests for assistance from other Branches. The reason given was that there was little or no research involved, simply development or application of existing knowledge, which was not within the mandate of the Branch. In other cases, the project schedule was too short, and did not accommodate the long time frame needed for the Radio Science Branch to conduct new research. In some cases, other Branches have had to develop their own capability in specific areas closely linked to Branch capabilities.

In-depth Interviews

It is clear from discussion with representatives from Spectrum Engineering and other informed stakeholders that the Branch has played a critical role in the development of Canada's wireless communications policies and guidelines. However, in recent years, the relationship between the Branch and Spectrum Engineering has languished. Spectrum Engineering funds to support contract research at CRC have diminished from $2 million in the late 1980s, to about $600,000 at present. At the same time, Spectrum Engineering has focused its contract funding on shorter term, applied work. These two factors have reduced the level of interaction with the Branch, which has traditionally focused on longer term research initiatives. However, Spectrum Engineering continues to fund Branch research, and there are indications that the relationship is improving.

Discussions with researchers at Canadian universities show that the universities value their relationship with the Radio Science Branch. The testing equipment and opportunities for physical measurement complement the capabilities found at universities, which in most cases, do not have the same quality and breadth of measurement equipment and facilities. This capability is valuable for students seeking practical experience in a research environment.

3.1.3 Conclusions

Evidence collected in this review indicates strongly that the Canadian public and private sectors both have a clear and continuing need for the research capabilities and facilities of the Branch. Clients and stakeholders have spoken of the importance they place in having access to the expertise within the Branch. This applies to the Canadian federal government through Spectrum Engineering, private sector wireless communications firms and international radio communications organizations. In terms of the relevance of the Branch to meeting their needs, those surveyed rated the Branch 8.1 out of 10, a high rating. However, there is evidence of a mismatch between the Branch's longer term research and the shorter term, applied nature of many requests for collaboration or assistance. In order to maximize the relevance and usefulness of Branch research to clients, the Branch and major client groups will have to determine how Branch capability can best mesh with client needs, and agree upon common longer term research interests. The wireless communications community will continue to require access to the expertise and technical knowledge in the Branch, as higher frequencies come into use and existing knowledge about radiowave propagation requires updating.

In addition, the branch is ideally suited to provide support to universities in the training of highly qualified personnel (HQP) in radio science to meet the growing need in this area, within both CRC and other public and private organizations in Canada.

In addition to the traditional research and testing services provided by the Branch, which are needed and appreciated, there is evidence from the interviews that clients would appreciate and benefit from additional services related to building awareness and communicating with the broader client community. These include:

- more formal and better communication about Branch research initiatives; and,
- access to the strategic intelligence which the Branch gains about standards, regulations and technology through participation in international standards meetings.

3.2 Who Benefits from the Radio Science Branch Programs? In what Manner?

3.2.1 Context

An analysis of the number and types of individuals and organizations benefitting from Branch activities and the nature of those benefits is central to the issue of program relevance. The question will be analyzed in terms of direct and indirect beneficiaries, and the nature and extent of program outcomes and benefits that result from Branch activities and interactions with other organizations.

The Radio Science Branch performance framework is a useful reference for this issue, as it provides a strategic perspective on the intended beneficiaries and impacts of the work of the Branch. As shown in Exhibit 1, the question has two parts related to Branch reach (beneficiaries) and results (direct outcomes and ultimate impacts). Note that both the public

and private sectors are directly involved. In examining this issue, most methodological approaches provided information of value. Primary sources were Branch documentation, client interviews and case studies. Staff interviews also provided useful information. In many cases, similar evidence was found in more than one source.

3.2.2 Detailed Findings

Document Review

Several sources were used to examine the clients and collaborators of the Radio Science Branch. One came from the lists of clients and collaborators of the three research groups within the Branch, which were provided as the basis for the interviews and surveys. A summary of this information is shown in **Table 3**, under the categories of Canadian and non-Canadian industry, universities and government (including defence).

Table 3: Radio Science Branch Clients, Collaborators and Partners*

Radio Science Branch	Canadian University	Canadian Industry	Canadian Government	International University	International Industry	International Government
Radiowave Propagation	3	4	2	2	1	1
EMCompatibility	2	3	3	0	0	2
Advanced Antenna	4	6	3	0	1	1

*Based on client lists provided by Branch

Assuming that a complete or representative list of clients and collaborators was provided, analysis shows that the types of clients and partners, which the Branch works with directly, closely parallel those identified in Exhibit 1. A second source, a list of partners and collaborators of each Branch, compiled by CRC in fall, 2000, as part of a corporate review of networking and partnerships, confirmed this.

The publications for the three groups within the Radio Science Branch can also be examined to shed light on collaborations. In particular, co-authors can be analyzed to determine which type of organization they are from. **Tables 4**, **5**, and **6** present summaries of the co-authors for refereed publications and published conference proceedings for the period from 1997 to 2000 for the Radiowave Propagation, Electromagnetic Compatibility and Advanced Antenna Groups within the Radio Science Branch respectively. (This analysis focuses on formal research linkages only, and does not attempt to examine productivity of the three groups in terms of publications, or other types of relationships with clients such as contracting in or out.)

Table 4: Publication Analysis of Radiowave Propagation Research Group

Year	Total Number	Number with Canadian University Co-authors	Number with Canadian Industry Co-authors	Number with Canadian Government Co-authors	Number with International University Co-authors	Number with International Industry Co-authors	Number with International Government Co-authors	Number with Other CRC Co-authors
'97-'98	13	1	3	0	1	3	1	0
'98-'99	22	2	3	0	7	5	4	0
'99-'00	15	3	2	1	5	0	2	0
'00-'01*	17	1	1	0	3	1	2	0

* preliminary data

Table 5: Publication Analysis of Electromagnetic Compatibility Research Group

Year	Total Number	Number with Canadian University Co-authors	Number with Canadian Industry Co-authors	Number with Canadian Government Co-authors	Number with International University Co-authors	Number with International Industry Co-authors	Number with International Government Co-authors	Number with Other CRC Co-authors
'97-'98	9	1	0	0	0	0	0	0
'98-'99	11	5	0	1	0	0	0	0
'99-'00	4	1	1	1	0	0	0	0
'00-'01*	9	1	0	0	0	0	0	0

* preliminary data

Table 6: Publication Analysis of Advanced Antenna Group

Year	Total Number	Number with Canadian University Co-authors	Number with Canadian Industry Co-authors	Number with Canadian Government Co-authors	Number with International University Co-authors	Number with International Industry Co-authors	Number with International Government Co-authors	Number with Other CRC Co-authors
'97-'98	25	16	2	2	1	0	0	1
'98-'99	23	16	1	1	1	0	0	1
'99-'00	11	7	0	1	0	0	0	0
'00-'01*	19	8	0	0	0	0	0	2

* preliminary data

This detailed publication analysis also confirms the general conclusions of the previous analysis. It is interesting that there is considerable variation year over year, depending on the nature of specific projects. As can be seen, the Advanced Antenna Group has a large number of co-authorships with Canadian universities. This observation will reappear in the examination of other questions.

It is also worth noting that, except for the Advanced Antenna Group, there are no co-authorships with other CRC Branches. These data confirm the previous evidence suggesting a relatively low level of formal interactions with other Branches within CRC. In the case of the Advanced Antenna Group, its expertise in antennas is sought by other Branches, and it has responded by participating in a number of in-depth collaborations.

An analysis of the co-op and graduate students working at the Branch was also carried out. A total of 28 students have worked at the Radio Science Branch during the period 1998 to 2000. As expected from the publication analysis, the Advanced Antenna Group had the most students (19), followed by the Radiowave Propagation Group (6) and the Electromagnetic Compatibility Group (3). To some extent, the number of students is reflective of the number of universities with active programs in these areas. However, the Advanced Antenna Group has been proactive in working with university researchers and encouraging students to participate in Branch projects. Although information is not complete, there is evidence that these students, after completion of their degrees, have moved to employment in the public and private sectors. In fact, seven have been hired at CRC. Five have joined the private sector, at organizations such as NORTEL or other communications firms. Three graduate students from the Royal Military College are now in the Canadian military, where their knowledge of radio science and communications systems will be put to good use.

The following list has been developed, based on the source of information described above. It identifies the various types of public and private sector organizations with which the Radio Science Branch works, and the types of activities and projects for each:

- Spectrum Engineering (Canadian government broadcast policy and regulation, spectrum allocation);
- Canadian defence organizations (technical support, testing of wireless communications systems, antennas, EM compatibility);
- Canadian wireless communications firms (technical support for system development, development of antennas, testing of systems);
- Canadian electrical, electronic equipment manufacturers (testing of electromagnetic interference, shielding);
- Canadian broadcast consulting and engineering firms (technical services related to communications system design and engineering, signal coverage);
- Canadian universities (wireless communications related research);
- international telecommunications firms (radiowave propagation issues);
- other government and international research groups (radiowave propagation, telecommunications research); and,
- international wireless communications standards bodies International Technical Union-Radio (ITU-R) (development of international standards).

It is important to note that this list of clients and collaborators provides no information about the relative intensity of Branch interactions with each group. In some cases, work is performed on a cost recovery basis under contract, while in other cases, resources come

from the internal Branch budget. In addition, the relative effort towards each group varies according to the specific projects and initiatives underway at any particular time.

Client Survey

The client survey gathered information on the benefits and impacts resulting from specific interactions between the Branch and the clients surveyed. Respondents were asked to focus on a single project and identify whether specific results had or will occur as a result of the project. For those results which have or will occur, respondents were also asked to rate the involvement of the Branch in achieving the results on a scale of 1 to 10, with 1 representing not at all involved and 10 being completely responsible for the result. **Table 7** contains a summary of the survey data.

Table 7: Project Results Identified in Survey

Result *	Has Occurred (#)	Will Occur (#)	Importance of Branch Role
Solution to technical problem	21	3	7.3
New knowledge	26	1	7.4
Increased scientific / technical capability	26	0	7.3
Reduced development time	8	0	7.3
New / improved product	10	0	7.2
New / improved process	3	3	6.4
Cost savings / greater efficiency	2	2	6.3
Increased competitiveness	2	6	6.3
Increased sales	3	4	6.6
New / improved policies / regulations	5	4	7.3

* from a prepared list read to respondents

The respondents who said that the result will occur is made up of two groups. In some cases, projects have not been completed, in others the project has been completed and the result has not yet occurred, but is still likely to occur in the future. This is particularly true of commercial results such as sales and competitiveness.

The list of possible results in Table 7 reflects a progression from immediate to longer term results. It begins with the most immediate and likely results, being new knowledge and solutions to technical problems as well as increased scientific or technical capability being developed in or transferred to the client organization during the project. These results can be found for all types of projects with all types of clients. Increased technical capability within the client organization is a particularly desired result, as it leaves the organization in a better position to make its own technical decisions without continuing support. As can be seen, this group of results occurred in over 85% of those surveyed.

The next group of results relating to products and processes occur further downstream from research and testing. While they can occur in public sector organizations, products in particular tend to be associated more with private sector organizations. This is the reason for the reduced occurrence of these results.

The next three types of results (cost savings / greater efficiency, greater competitiveness, increased sales) are clearly private sector benefits, and are unlikely to be found in public sector projects. This is the reason for the lower frequency. In addition, the length of time between R&D and the achievement of commercial results is probably responsible for the larger number of results that are expected to occur compared to those that have already occurred. The rating for the Branch's role is somewhat lower due to the increased involvement and leadership from the client organization in achieving these downstream benefits and the concomitant reduced role for the Radio Science Branch.

The final category of results reflects a different stream of results, namely public sector impacts. It is related to one of the main roles of the Branch, namely involvement in the development of new and improved government policies, regulations and guidelines nationally and internationally. About a third of the clients surveyed and projects identified relate in some way to this principal role of the Branch. It is likely that the rating of the importance of the Branch's role is higher for this result due to the specific expertise and capability of the Branch in this type of project.

Respondents were also asked to identify any other results, none were given.

In addition to providing information about the results from a specific project, respondents were also asked to provide a more general sense of the value of the Branch to their organization. They were asked to rate the importance of the Branch to their organization's success on a scale of 1 to 10, with 1 being of no importance and 10 being of major importance. The average rating of the 25 respondents who answered the question was 6.4, with 11 giving a rating of 6 or below. This is not unexpected, for several reasons. Some clients and partners have several lines of business and those related to Branch capabilities may be a relatively small portion. In addition, a number of the people interviewed were collaborators with the Branch, and not in a client relationship.

Staff Interviews

Interviews with staff from other CRC Branches revealed that, in several cases, Radio Science Branch participation in projects was critical to success. In the case of the “Milton” project, which tested wireless communications systems, the role of the Advanced Antenna group was critical in the successful development of an integrated communications system.

Case Studies

The case studies probed more deeply into the relationships between the Radio Science Branch and selected partners and the impacts of specific projects on the participants and the broader community. The individual case studies support the evidence from the client

survey, identifying benefits at the partner organization level as well as the broader community level.

These case studies show the various ways research can influence both public and private sectors. In the case of CRC Predict, this successful product is embedded in Spectrum Engineering's software to calculate the distribution pattern of communications systems. It is also embedded in Northwood Technologies' modelling software package "deciBel Planner", which is sold worldwide as a tool to help determine propagation coverage patterns of communications systems, and CRC's CRC COV, which is also used to analyze the distribution coverage of broadcast systems. The three case studies involving CRC Predict, the SkyWave Mobile Communications Inc. antenna development and EMSCAN EM probe development all demonstrate how work of the Branch is directly linked to the commercial success and growth of small firms involved in communications systems and telecommunications services.

3.2.3 Conclusions

The beneficiaries of the Radio Science Branch fall into two major groups, public and private, reflective of the dual mission of CRC. They include primarily Canadian organizations, although there are some foreign ones.

The primary direct beneficiary is the Government of Canada, through the provision of technical support and advice to Spectrum Engineering in support of wireless communications policies, standards, regulations and guidelines. The Branch also, participates in ITU-R deliberations on behalf of Canada and helps set the international guidelines for wireless communications. Spectrum Engineering relies on the Branch for these services, as there is no other Canadian source of equivalent capability. The indirect beneficiaries are the Canadian public, through the provision of a technically effective, regulated public radio and television broadcast system.

The second beneficiary group is the Canadian wireless communications sector, made up of communications systems developers and service providers, which benefits from specific projects to solve technical problems as well as general advice and information.

The third is the Canadian university researchers working in various aspects of wireless communications. The Radio Science Branch contributes to their joint mission of developing new knowledge and training highly qualified personnel for the Canadian public and private sectors.

Another group of public and private sector beneficiaries is the foreign and international wireless communications community, including universities, industry and government research organizations as well as international wireless communications standards and regulatory groups, principally ITU-R. Canadian public and private sector clients benefit from the Branch's activities with the international community.

Branch clients and partners benefit through access to research, technical information, advice and assistance, test data provided by the Branch through collaborative and in-house R&D as

well as participation in national and international conferences and international standards and regulatory fora.

Clients receive important technical benefits from projects with the Branch. These include new knowledge, solutions to technical problems, increased scientific and technical capability, new and improved products and processes, and reduced development time. These technical impacts often result in economic and organizational benefits, including cost savings, and in the case of private sector firms, increased competitiveness and sales. Public sector clients report new and improved policies and regulations arising from interactions with the Branch.

Exhibit 2 summarizes the various types of impacts and benefits that clients and the broader wireless communication community receive, based on information from the case studies and client survey.

Exhibit 2: Impacts of Branch Programs

Project Incrementality (influence)	Direct User Impacts	Industry Sector / Supply Community Impacts	Economy / Societal Impacts
Involvement X helped in completing the project more quickly x helped in completing the project more thoroughly x helped do R&D that otherwise would not have been done x major role in project success S minor role in project success	Technical results X new or improved product S new or improved process X advancement of knowledge X increased technical capabilities S improved quality control X new skills internally ? increased efficiency / improved productivity x technology transfer Policy / legislative results ? policy behavioral changes ? agreement / accord S legislative / regulation X acceptance of standards Commercial results S increased sales S increased market share S increased profitability S cost savings Organizational effects S increase in jobs S diversification S expansions S strategic alliances / partnerships S achievement awards / recognition	S production process efficiencies x increased science and technology information S increased sales ? cost savings p changes to industry structure (e.g., concentration, competitiveness internationally) ? spin-off companies x technology infrastructure (e.g., standard scientific and engineering data, industry standards, test protocols, and instrumentation) x training of technological problem-solvers whose talents can be applied in many areas x establishment of standards	? reduced consumer costs ? protection of environment ? improved energy efficiency savings ? improved public health and safety ? education / awareness S public service efficiency gains S increased employment ? reduction in subsidies

x = occurs often
S = occurs sometimes
p = potential (future)
 = does not occur

3.3 How Effectively is the Radio Science Branch Meeting Canadian Public and Private Sector Needs for Information and Advice about Existing and Emerging Radio Science Knowledge, Technologies and Systems?

3.3.1 Context

Radio science is the foundation for wireless telecommunications. As the existing allocated radio frequency spectrum becomes more crowded, new higher frequency spectrum is opened up. Use of this higher frequency spectrum requires new research and data to adjust existing models and provide assurance in determining use of the spectrum. Similarly, higher frequency antennas are required, often with exacting physical dimension requirements to meet design criteria. For that reason, much of the discussion in Section 3.1 on the continuing need for the radio science research and testing facilities is relevant to this question in a general sense, and will not be repeated. Examination of this question will focus narrowly on Branch effectiveness in meeting needs for information and advice. Provision of information and advice on new and emerging issues falls into one of the defined categories of services that can be provided by the Radio Science Branch to the client community. Sharing of information gathered during ITU-R meetings is one example. In the previous review, the Broadcast Technologies Branch was found to be very effective in this area, and clients were very appreciative of the information. Incremental costs are relatively low and the number of recipients of the information can be quite large, including some outside the range of the more focused services. Access to strategic intelligence is highly valued in all organizations, and of particular importance in high technology sectors such as wireless communications. The role of the Branch in providing information and advice on emerging international trends in both standards and technology should be considered as part of its core mandate.

The primary source of information used to examine this question is the client survey that provides the perspective of representatives of the Canadian public and private wireless communications sector.

3.3.2 Detailed Findings

Client Survey

The client survey provided information directly related to answering this question. Respondents were asked whether the Branch helped make their organization aware of emerging trends. The majority (19) said yes and 8 said no. Of those who said yes, some stated that the information exchange was very informal, and occurred as part of ongoing discussions. One respondent who said no, volunteered that he wished the Branch would provide that service to his organization. Those respondents who said that the Branch did keep them informed were next asked to rate both the importance of that help and how well the Branch does at keeping them aware. As usual, a scale of 1 to 10 was used in both cases, with 1 being very low and 10 being extremely important or extremely well respectively. In the case of the importance, the average rating was 6.7, with 8 of the 19 respondents giving a rating below 7. In some cases, respondents stated that there was no expectation that the Radio Science Branch had an explicit role in this area. In terms of rating how well the

Branch does at providing help, the average rating was 6.4, with 8 of the 18 who responded giving a rating below 7.

These ratings for the Radio Science Branch are lower than in the previous review of the Broadcast Technology Branch. For comparison purposes, the average rating for importance of the Broadcast Technology Branch was 7.3, and for how well the Branch did, 7.9.

Other information in the survey supported the conclusion that the Radio Science Branch is not very proactive in sharing information. As mentioned previously, in discussing weaknesses and making suggestions for additional services, several respondents stated that the Branch could do a better job of communicating with the community and sharing intelligence.

Staff Interviews

Information from other CRC staff, discussed in Section 4.3 which follows, suggests that other CRC Branches would also value knowing more about Branch projects and initiatives, as well as strategic intelligence received from international standards meetings and other sources. This information would help them understand where interests coincide and joint projects would be appropriate.

In-depth Interviews

Discussions with informed stakeholders revealed that the Radio Science Branch is at a disadvantage compared to the Broadcast Technologies Branch in sharing information. The Broadcast Technologies Branch has several industry associations that are the natural vehicle for sharing and disseminating information. The Radio Science Branch does not have similar opportunities. One individual mentioned the Antem Conference, a biennial Canadian event sponsored by the Radio Advisory Board of Canada, which he felt could serve as a vehicle for networking and sharing information among at least part of the wireless communications community.

3.3.3 Conclusions

Evidence from both clients and CRC Branches shows that the Radio Science Branch does not do a particularly good job of sharing information on emerging trends in radio science. Ratings from the client survey for how well the Branch keeps clients aware of emerging trends are below those for the Broadcast Technologies Branch (average of 6.4 compared to 7.9). The Radio Science Branch has a more difficult task, as it has no obvious mechanisms through which to distribute information, such as Industry or Technology Associations.

More generally, evidence suggests that the Branch is not proactive. Many respondents noted that when they ask for assistance it is generally provided, however, they observed, with some exceptions, that the Branch is not in general actively networking or building relationships.

3.4 In what Manner does the Radio Science Branch Contribute to the Mission of CRC?

3.4.1 Context

The mission of the CRC is:

- to be the federal government's Centre of Excellence for communications R&D ensuring an independent source of advice for public policy; and,
- to help identify and close the innovation gaps in Canada's communications sector by engaging in industrial partnerships, building technical intelligence and supporting small and medium technology enterprises.

The work of the Radio Science Branch will be examined in terms of its relationship to both aspects of the CRC mission statement. The analysis will not include new evidence, but will draw to a large extent on evidence and discussion from the other sections related to the issue of relevance.

3.4.2 Detailed Findings

Evidence presented in Section 3.2 on benefits and beneficiaries is pertinent to this question. The role of the Branch in providing Spectrum Engineering with technical information and advice to support public broadcasting policy and regulations, and spectrum allocation is directly aligned with the first section of the CRC mission statement. Comments from respondents to the client survey identify the Branch's strong technical capability and test equipment as important strengths which make it a desirable partner for private sector firms. The Branch's participation in international standards organizations work is also an important factor in helping ensure that government policies and regulations are consistent with international standards.

In terms of its role as a Centre of Excellence, many clients say that the Branch is a unique source within Canada with the technical expertise, equipment and facilities, credibility and reputation required for a number of the projects. Loss of access to the Branch's services would have caused major negative impacts for many of the projects, ranging from time delays and greater costs to inability to proceed. One international expert stated that the Branch was considered internationally to be one of a small number of centres of excellence in specific important aspects of wireless propagation research.

Section 3.3 focused on the role of the Branch in providing strategic intelligence on emerging technologies. Those discussions will not be repeated here, but the Branch could play a larger role in this area, which is directly linked to CRC's mission to build and share technical intelligence.

Detailed discussion in later sections on the issue of the quality of Branch research and services (Section 4) shows clearly that clients and collaborators rate the quality of Branch capabilities and services highly, both in terms of development of new knowledge and capabilities of staff.

Evidence also shows that the Branch supports small and medium telecommunications sector firms, electronic equipment manufacturers, and related engineering and consulting firms in a number of ways.

3.4.3 Conclusions

It is clear that the strategies and priorities of the Radio Science Branch are aligned to the mission statement of the Communications Research Centre Canada, and that the Branch is helping achieve the CRC mission, primarily in terms acting as a Centre of Excellence for radio science research and knowledge. The Branch is less active in building technical intelligence, but does help small and medium firms in many ways. All major projects and initiatives can be shown to provide development of new knowledge, public policy advice or support to the Canadian wireless communications industry.

3.5 Is the Radio Science Branch within CRC Filling an Appropriate Role for Government?

3.5.1 Context

This question, to a large extent, requires a comparison between the present strategic positioning of the Branch and government policies on the role of government research agencies. To address the question, we reviewed a number of policy documents and studies, findings on beneficiaries and benefits discussed in subsection 3.2, as well as relevant information from expert interviews.

3.5.2 Detailed Findings

Document Review

In its 1996 review of government S&T entitled "Science and Technology for the New Century", the government identified three interrelated goals as the focus of future federal S&T activities. They are:

- the application and commercialization of S&T to create jobs and economic growth;
- using S&T to improve the quality of life and social well being of Canadians; and,
- achieving and maintaining excellence in the advancement of knowledge.

These three objectives can be restated in terms of using S&T to support industrial development and economic growth, including support for individual private firms, using S&T for public good through improved policies and services to the public, and continued creation and development of knowledge, particularly to support the achievement of the first two goals.

As well as these three goals, the government identified a number of operating principles in its 1996 review. One of specific interest to CRC and the Radio Science Branch is:

positioning Canada competitively within emerging international regulatory, standards and intellectual property regimes.

Another source of information about the appropriate role for the federal government can be found in the reports of the Council of Science and Technology Advisors (CSTA). CSTA, a group of representatives of the S&T advisory councils of federal science based departments and agencies, was formed in the late 1990s as part of the 1996 federal S&T strategy. CSTA has recently produced a report on the roles of government in performing S&T and its capacity to deliver entitled "Building Excellence in Science and Technology (BEST)". The BEST report makes an important statement by defining excellence as a composite of quality, relevance and useful outcomes. This is an important point, since much S&T literature describes excellence strictly in terms of quality without reference to relevance or utilization.

This point is directly relevant to the Radio Science Branch, which seems in the recent past to have focused on conducting high quality research with less attention to ensuring its useful application through supporting partners with specific needs.

3.5.3 Conclusions

Based on an examination of the federal government objectives for S&T, the objectives and capabilities of the Radio Science Branch are well positioned to support a number of roles appropriate for a government research agency. These include research and development, technical support, testing and advice:

- to the Canadian and international wireless communications standards and regulatory community, in support of the public interest and social well-being of Canadians; and,

- to the national and international private wireless communications sector, including systems developers and technical service firms, and consultants, in support of a viable communications industry, wealth creation and economic growth.

In particular, the Branch is recognized as a neutral, credible source of scientific data and analysis on wireless communications issues and can be relied upon to present a technically accurate, unbiased perspective. The Branch is encouraged to take a more proactive role in working with others to ensure the application of the knowledge and expertise present in the Branch.

The Radio Science Branch performs a number of complementary roles in support of both public and private sectors. First and foremost, the Branch provides support to the Canadian wireless communications policy and regulatory system through its relationship with Spectrum Engineering. This is linked to the "quality of life and social well-being" goal of the government. The Branch's ability to support Spectrum Engineering and its role in developing national and international policies and regulations are also directly linked to the government objective of ensuring an economic, legal and regulatory environment conducive to innovative activity". This is an appropriate role for the Branch, and evidence suggests that the Branch needs to do a better job of fulfilling that role.

3.6 Relevance - Summary

Based on a review of recent literature and the 1996 federal review of government S&T entitled "Science and Technology for the New Century", it is clear that the Canadian government expects its scientific laboratories to fulfill a dual role, in support of both public interest and economic growth and wealth creation. This is reflected in the CRC mission statement. These two roles can be complementary, particularly in the case of standards and regulations. In the case of radio science, the social and cultural well-being of the public needs to be supported through an efficient, effective, and accessible Canadian wireless communications system. This system should be based on internationally accepted standards, and the private communications systems developers need appropriate scientific knowledge and technical assistance which help them develop and provide quality communications systems. Policy studies support the role of government S&T in providing technical support to the development of national regulations and guidelines compatible with international systems. This is as true of radio communications as of other areas of commerce. The Branch is well positioned to fulfill this role for the Canadian public and the private sector radio communications industry.

The need for Branch capabilities in radio science is once again being recognized. As the lower frequencies are being fully utilized, allocations of new higher frequencies are being required, and the characteristics of radiowave propagation at these higher frequencies need to be studied. The Canadian wireless communications industry has lost much of its technical capability through downsizing and, in many cases, the Radio Science Branch is the principal source of high level expertise and knowledge about radiowave propagation and high frequency systems in the country.

A review of Branch programs and projects, analysis of clients and collaborators, and feedback from the client survey, staff and expert interviews show that the Branch has the expertise and capability to fulfill these complementary roles, supporting both public and private interests within the Canadian and international broadcast community. However, the Branch has not been active in working with others to apply its knowledge to practical problems. In addition to its expertise and research capabilities, clients and partners of the Branch would like it to provide other types of services, such as the provision of information, advice, and strategic intelligence. Some of those interviewed would like the Branch to make a greater effort to make them aware of technical developments and other emerging issues on a regular basis.

Another need in the wireless communications community is for highly qualified personnel with experience in higher frequency communications systems. A number of the skilled staff of the Branch have been hired away to fill these needs in other organizations. The Branch works with the university community to support the training of graduate students, which also provides additional resources for Branch research and development projects. Some of these students are hired by CRC following completion of their studies.

3.7 Relevance - Recommendations

The first two specific recommendations that follow identify specific examples of how the Branch could take a more proactive approach to identifying and meeting the needs of clients and stakeholders.

3.7.1 Develop Long Term Relationships with Key Stakeholders

The Radio Science Branch should meet with major clients and stakeholders to develop strategic long term plans which identify the most effective means of working together and supporting their needs. This applies in particular to Spectrum Engineering and other CRC branches who can benefit greatly from the knowledge and expertise in the Radio Science Branch. The partners need to identify how the research capabilities of the Radio Science Branch can best be put to use to meet the needs of these stakeholders. The challenge is to match the capabilities of the Radio Science Branch in performing longer term research with the shorter term applied nature of the partner and stakeholder needs.

3.7.2 Communications, Networking and Awareness Building

The Branch should move to address the expressed desire in the wireless communications community for improved access to strategic knowledge of technical developments and emerging issues. Communicating with the broader stakeholder community about Branch initiatives and perspectives on emerging issues should become a higher priority, and the Branch should develop mechanisms to accomplish this objective. The review of the Broadcast Technologies Branch identified a number of possible mechanisms that seem appropriate for the Radio Science Branch as well. They include regular workshops, possibly aligned to the specific needs of various stakeholder groups; a periodic newsletter with information about Branch projects and strategic intelligence from international meetings; and a web page with basic information about the Branch's priorities as well as similar information in the newsletter described above.

The Branch should also try to identify an association or group associated with the Canadian wireless communications community which could serve as a partner to disseminate strategic information from the Branch about emerging technical and regulatory issues.

It is likely that a combination of approaches will be more effective than a single one.

3.7.3 Maintain Multiple Complementary Roles

It is clear that the Radio Science Branch is uniquely positioned to meet needs of both the public and private sectors within the Canadian wireless communications community and that insight into the needs of one group contributes to the Branch's ability to meet the needs of the other. The Radio Science Branch should continue to maintain a balance among its various roles, developing new knowledge and expertise and providing advice and services to meet both public and private sector needs in a complementary manner. The provision of high quality technical support for Canadian wireless communications policies, standards and

regulations in the public interest also helps provide the private sector with an efficient and effective regulatory infrastructure within which to work.

4.0 Quality

Issue 2: To what extent does the quality of research, advice and services provided by the Radio Science Branch meet the needs of clients and collaborators?

The wording of this issue is intentional as it applies to the Radio Science Branch. While it is not always recognized among researchers nor in the management and reward systems governing public sector R&D organizations, research quality is not an end in itself, but rather the means to an end. In the case of CRC, the mandate is to perform relevant research to meet the technical needs of public and private sector stakeholders and clients. This issue is related to the question of the appropriate strategic mix of activities. These include on one hand, research in-house and with collaborators to build knowledge and increase scientific and technical capability and, on the other, contract research, testing, product and process development, and advice which utilize existing knowledge. As noted, resource utilization needs to be carefully balanced between building and utilizing capability. This concept is clearly included in the government goals for S&T, discussed in Section 3.5, which include both building new knowledge and also utilizing current capability for economic growth and social well-being. The quality of research should be sufficiently high to meet the needs of the identified client group, but utilization of capability to achieve results is the real objective, as shown in the Branch performance framework in Exhibit 1. It should be noted that there is a range of requirements for research quality, with those of scientific collaborators being in most cases the highest.

In the case of services, the concept of quality is expanded beyond staff expertise and capabilities, to include elements of 'client friendliness' such as responsiveness, ability to meet deadlines, and quality of facilities and equipment. This issue will be examined from this broader perspective of the relationship between quality of research and services and the needs of clients and collaborators.

As the needs of clients are the basis for determining quality, the primary sources of evidence to address these questions are the client survey along with some information taken from documentation and expert and staff interviews.

4.1 In what Manner do Publications from the Radio Science Branch Contribute to Meeting Canadian and International Needs for New Knowledge?

4.1.1 Context

This question can be considered as a more specific examination of the impacts of Radio Science Branch activities and projects, viewed through the lens of Branch publications.

Research organizations need to interact with their client community using a balanced mix of approaches. One primary method for those organizations with a mandate to support particular communities is through direct contact with target client groups through collaborations, contract research and advice. In addition, every research organization, except for those involved in commercially or defence confidential research, disseminates their

research results to the larger research community through conference presentations and publications.

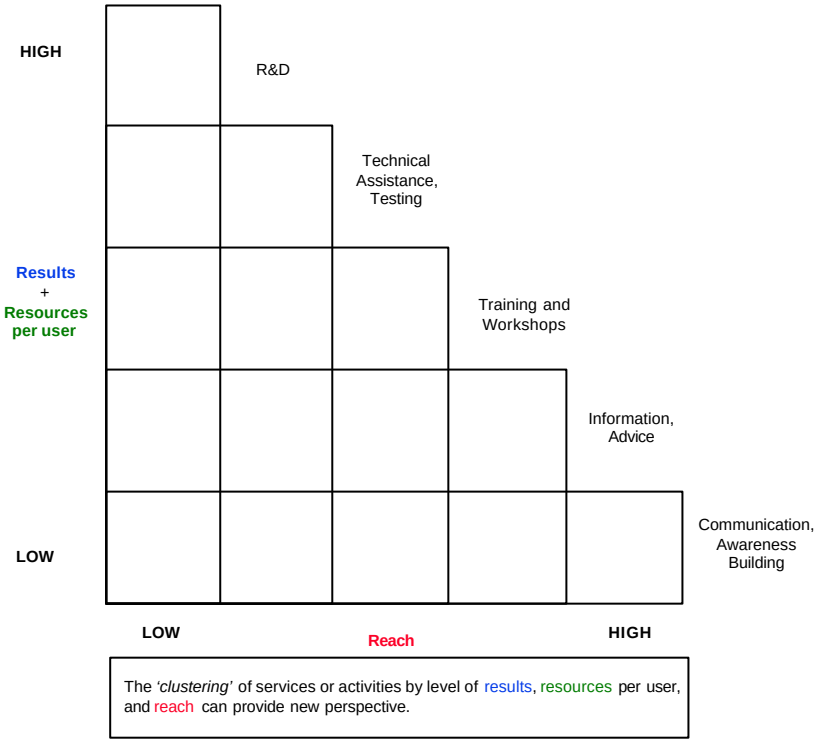
In fact, the types of services which a research organization can provide to its clients and collaborators can be classified in terms of the level of effort or resources required for each "service" provided and the extent of "reach" or number of clients or recipients reached by each service. **Exhibit 3** presents a summary of the main types of services and their characteristics. For example, an R&D project is typically very resource intensive and has only one or a few participants. Using this classification, an R&D project has a high cost per client or user, and a small reach (one or a few clients). At the other extreme from R&D projects is knowledge dissemination, community awareness building and communication through publications, newsletters or via a website, which has a relatively low cost per recipient and can reach a large part of the target client group. Between these extremes are:

- in-depth technical assistance and testing to existing protocols;
- training and workshops; and,
- short-term information dissemination, such as conference presentation.

The results or impacts expected from these different types of services also varies, with the largest and most direct impact per client or recipient expected from those services which have the highest cost per user. For this reason, the direct impact of publications on most individual clients is not expected to be high. However, the integrated effect of a small impact on a large number of recipients can be very large. This type of analysis required careful consideration of the types of effects various publications have on the different types of readers.

This question will be addressed through an examination of the Radio Science publications, complemented by information obtained from staff and client interviews.

Exhibit 3: Types of Activities and Services Classified by Level of Resources, Reach and Results



Source: Steve Montague, The Three Rs of Performance: Core concepts for planning, measurement, and management, Performance Management Network Inc., 1997, p 120.

4.1.2 Detailed Findings

Document Analysis

In addressing this issue, publications from the Radio Science Branch were examined in terms of intended audience. There are a number of types of publications. These include:

- refereed papers in specific journals either targeted to specific audiences or for widespread distribution;
- published proceedings from conferences, which can be targeted or of general interest;
- publications for international radio organizations, such as ITU-R and URSI;

- contractor reports, containing the results of contract research projects; and,
- CRC research reports, which contain technical results of Branch research.

Each of these different types of publications has an audience, which may or may not be similar to others.

Publications in refereed journals, such as the IEEE, tend to have the widest audience. While they include Canadians, these audiences are international in scope. These publications contribute to the advancement of worldwide knowledge, and can be considered as part of Canada's contribution to the worldwide supply of fundamental and applied knowledge in radio science. While the audience for these publications is worldwide, the subject matter covers issues of interest to the Radio Science Branch, its co-authors and stakeholders, and the research results published are linked to Canadian priorities. This is true of all published reports from the Branch.

While published proceedings from conferences can have a similar audience, they are often more focused on a particular problem or subject which is the theme of the conference. For example, last year, the Radio Science Branch had published conference proceedings in the Sixth Ka Band Utilization Conference, and the Symposium on Antenna Technology and Applied Electromagnetics. These conferences and publications have a more focused audience than many journals. The actual publications from these conferences were of interest and benefit to those interested in efficient utilization of spectrum and the practical application of LMCS, both areas with important application in Canada, as well as other countries.

Documents written for the ITU-R and URSI are also part of Canada's contribution to the international radio science community. These publications and contributions present the results of research and analysis relevant to the needs of these organizations, and serve Canada's interests as well, by keeping areas of importance to Canada on the agenda of these international regulatory bodies. The research data are used as the basis for setting international guidelines for use of radio spectrum, an area of international importance. It is in Canada's interest to have scientifically based, internationally agreed upon regulations and protocols for the use of radio spectrum. Spectrum Engineering also participates in these international meetings and often collaborates with the Radio Science Branch on presenting the Canadian position.

Contractor reports contain the results of specific projects that an organization has contracted with the Radio Science Branch to undertake. In some cases, these reports are confidential, and are available only to the organization that funded the research. In these cases, the direct effects of the research are available only to the contracting organization. However, in almost all projects, the Radio Science Branch benefits through an increase in staff knowledge and expertise.

CRC research reports typically contain technical data and analysis which may not be suitable for a refereed publication or presentation at a conference, but is worthy of being captured

and presented in report form. These publications are available for distribution to anyone with an interest in the subject.

Staff Interviews

Discussions with Radio Science Branch staff identified other publications that were not otherwise identified. For example, one senior scientist with the Radiowave Propagation Group is coordinating the preparation of and making a major contribution to a handbook on terrestrial path propagation on behalf of the ITU-R. This handbook is intended to be a fundamental tool that all designers working in terrestrial communications will be able to utilize. Much of the knowledge and expertise developed over the years within the Radio Science Branch will contribute to the content of the handbook. This handbook is an example of one of the ways in which Radio Science Branch knowledge is shared with the international radio communications community and contributes to a rational regulated worldwide communications system.

Some staff from other CRC branches commented that they make use of relevant data and analysis in publications from the Radio Science Branch in their research and development initiatives.

In-depth Interviews

One of the perceived strengths of the Radio Science Branch is the number and quality of refereed publications and conference presentations. A number of interviewees with a broad knowledge of the Branch and CRC stated that one of the important deliverables of the Branch is the publications and presentations. Some interviewees commented that the Radio Science Branch was contributing to CRC's credibility as a research organization through extensive publishing.

4.1.3 Conclusions

The Radio Science Branch has a number of different types of publications. These include refereed papers, conference proceedings, ITU-R and URSI contributions, Contractor reports and CRC reports. Each type of publication has a different purpose and reaches a different audience. Refereed publications in well known journals such as IEEE have the broadest reach and the most general audience. Conference proceedings tend to be more focussed and linked to conference themes. ITU-R contributions are focused on priority areas of interest to the international communications community, usually linked to developing international guidelines and recommended techniques for systems development and analysis.

However, in all cases, Branch contributions are linked to Canadian interests, as well as contributing to international needs for new radio science knowledge in the form of data, analysis, models, and tools.

4.2 Do Clients and Collaborators Have Confidence in the Quality of Research, Advice, Testing and Other Services Provided by the Radio Science Branch?

4.2.1 Context

This is a basic question to be addressed during all reviews of research organizations. While the narrow interpretation of the question relates only to client confidence in the quality of Branch research and services, it will be examined from a number of related perspectives, including examination of the quality of Branch staff, publications, and reports.

This question focuses on the perspective of existing clients and collaborators. As most of the clients and collaborators interviewed have relatively long-term, established relationships with the Branch, which are continuing, the answer seems on the surface obvious, without the need for further discussion. These clients and collaborators continue to work with the Branch, so they must have confidence. However, there is considerable additional evidence from the client survey and other sources that will be used to address the question in more detail.

4.2.2 Detailed Findings

Client Survey

A number of questions in the client survey relate to client perspective on the quality of Branch research and services and on the quality of Branch staff.

While respondents were not asked directly for their opinion about the quality of Branch research, they were asked to identify the strengths of the Branch. The single most frequent response was the scientific expertise, credibility and testing capabilities of the Branch, embodied in the technical competence and expertise of staff and the quality of equipment and facilities. Respondents were also asked why they worked with the Branch. Again, the most frequent response was related to the scientific and technical capabilities of the Branch staff and availability of high quality testing equipment and facilities. In many cases, the Branch is the primary source of technical assistance for clients in the area of radiowave propagation research, electromagnetic interference analysis and antenna design and testing. In others, the Branch is a full partner in collaborative research in wireless communications. These responses provide further evidence of the confidence clients and partners place in Branch research capabilities, advice and technical services.

In probing the quality of services, respondents were asked to focus on a specific project, and rate specific features of the Branch, in terms of importance and satisfaction. The rating was on a scale of 1 to 10, with 1 being extremely low, and 10 being extremely high (either in importance or satisfaction, depending on the question). **Table 8**, which follows, presents a summary of the results.

Table 8: Client Ratings of Branch Features Related to Service*

Branch Feature	Importance to Respondent	Satisfaction with Feature
Branch's understanding of your needs	8.7	8.7
Quality of equipment and facilities	8.6	8.2
Availability of facilities	8.5	7.7
Importance of Branch / satisfaction with Branch's contribution to project	8.7	8.2

*29 respondents

These data need to be interpreted carefully. Firstly, as mentioned previously, the sample of respondents was chosen by the Branch, and had successful projects as well as established relationships with the Branch. As such, they are predisposed to be positive and supportive. In spite of this caution, the average ratings are all very high and indicate a high degree of satisfaction and confidence with these features of the Branch from this sample of clients.

Note that the survey data gives high ratings for both understanding of needs and quality of equipment, which supports the qualitative information discussed previously.

The high ratings for the importance of the Branch to the project and the respondents' satisfaction with the Branch's contribution reflect the central role played by the Branch in supporting these clients needs through these specific projects chosen for examination.

An additional set of questions related to the quality of various Branch features asked respondents to identify other research organizations that they found comparable in some way to the Branch. Most (19 of 29) were able to identify at least one other organization similar to the part of the Radio Science Branch with which they worked. They were asked to identify it and compare the Radio Science Branch to the other organization on a number of features. The other organizations identified are:

- Defence Research Establishment Ottawa (DREO);
- National Research Council of Canada (no longer);
- COMSAT laboratories (U.S. commercial);
- Rafael (Israel);
- University of Manitoba ;
- U.S. Naval Test Centre;
- David Florida Laboratory, CRC;
- McGill University;
- SPAR/EMS;
- Laval University;
- NASA Centres; and,
- Rutherford Appleton Laboratories (United Kingdom).

It can be seen that there is a wide variation in location and size among the named organizations. DREO and NRC are both federal government laboratories in Ottawa, near CRC. Others are Canadian universities. Yet others are foreign government or private sector laboratories.

Table 9 below contains the average ratings for those 19 respondents who compared the Branch to another organization. The scale used was 1 to 10, with 1 being the Branch is much poorer and 10 being the Branch is much better than the comparable organization. A rating of 5 was used for equal. It is important to note that care must be taken in interpreting the average ratings due to the small number of respondents.

Table 9: Comparison of Branch to Other Organizations

Feature	Average rating
Quality of personnel	5.2
Quality of facilities and equipment	5.1
Responsiveness	5.8
Overall	5.5

Most clients rated the Branch as equal to or somewhat better than comparable organizations. Note that the Branch received the highest relative rating for responsiveness. However, it is important to compare the Branch's rating of 5.8 to the 7.8 received by the Broadcast Technologies Branch in the review conducted in 1999. The Broadcast Technologies Branch was perceived by clients to be highly client oriented and responsive to their needs. This data indicates that the Radio Science Branch could do better in terms of responsiveness to client needs.

While these ratings may seem low, they are probably realistic. The Branch is being compared with other similar research organizations, in some cases, also in the Canadian federal government in Ottawa. In other cases, the comparable organizations are foreign world class laboratories, with considerably more resources, staff and facilities.

The quality and capabilities of staff are critical to the quality of research and testing. This is discussed in more detail in Section 4.4. Many interviewees expressed concern that the overall quality of staff has dropped recently due to the Branch's inability to retain qualified staff.

Several interviewees gave specific examples of how the high quality of Branch research and staff contributed to the success of their project. In one case, the interviewee stated that the technical competence, integrity, foresight and credibility of one Branch senior scientist, who was made Chair of an international team of researchers working on a multiyear project, made a major contribution to the success of the project. In another case, the results of a collaborative project with Branch staff, which were presented to the ITU-R, were accepted without reservation. This was considered by the interviewee to be testimony to the quality and credibility of the research of the Radio Science Branch.

Case Studies

In the case study on the development of an advanced antenna as part of a wireless communication system on behalf of SkyWave Mobile Communications Inc., the client stated that having the antenna designed and tested at the Radio Science Branch at CRC helped assure customers of its technical quality, increased the credibility of the product and contributed to its commercial success. Similarly, the communication community's confidence in the quality of research carried out at the Radio Science Branch was a factor in the acceptance of CRC Predict and its commercial success.

4.2.3 Conclusions

Evidence collected from all sources clearly shows that major clients, partners, and collaborators have a high degree of confidence in the quality of research, testing, and other services provided by the Branch. When compared to other similar laboratories, the Branch was considered by clients to be broadly comparable in terms of quality of staff, test equipment and facilities, and somewhat better in terms of responsiveness. However, there was considerable concern among some interviewees about recent loss of qualified staff, leading to reduced technical capability and quality of work.

4.3 Are Radio Science Branch Collaborations and Services Meeting the Needs of Clients?

4.3.1 Context

This question is to some extent a restatement of the first three questions under the issue of Branch relevance (Sections 3.1, 3.2, 3.3). Each of them addresses the question from a different perspective. The detailed discussions and analysis associated with these questions will not be repeated here, however, the general observations will be restated where appropriate.

Once again, the fact that important public and private sector client groups have long term relationships with the Branch and express high degrees of satisfaction with the technical expertise, facilities and equipment, and testing services available from the Branch provides a generally positive sense of the relevance of the Branch to the needs of existing clients. However, it is also important to remember that some clients were less satisfied with their access to the Branch and the willingness of the Branch to respond to their needs. There is also the concern about staff departures and lack of depth, which is likely a factor in the ability of the Branch to respond to client needs.

The client survey included two specific questions directly related to relevancy, and those results are presented here.

4.3.2 Detailed Findings

Client Survey

Clients surveyed were asked to rate the relevance of the capabilities of the Branch to the needs of their organization, once again using a rating scale of 1 to 10, with 1 being completely irrelevant and 10 being extremely relevant. All 29 respondents answered this question, and the average rating was 8.1. In some cases, respondent organizations have many types of activities, with only some that relate to wireless communications research. In several of those cases, respondents based their ratings on the relevance of the Branch to that part of their organization. As an example, one person said that relative to the project being discussed, Branch relevance was 8, but in terms of the overall company needs that extend far beyond radio science, the rating was 4.

Four interviewees gave ratings below 7, and three of these were from Spectrum Engineering representatives. This evidence reemphasizes the problems that have been evident in the relationship between the Branch and Spectrum Engineering. There is recent evidence that special attention is being given to determine solutions to these problems, and there is evidence of progress.

As another indicator of the relevance of current Branch services, the large majority of clients were unable to identify additional services or capabilities to better meet their needs. As discussed in Section 3.1, the most frequently mentioned need was for more proactivity on the part of staff of the Branch in reaching out to the community, and better communication and awareness of Branch initiatives and new developments in radio science.

In-depth Interviews

Information from in-depth interviews confirmed findings from the client survey. As discussed in Sections 3.1 and 4.1, there is a sense that in the past, the Radio Science Branch was very focused on conducting research and developing knowledge, with less focus on working with others to ensure application of that knowledge. Other CRC Branches and Spectrum Engineering in particular expressed concerns in this area.

4.3.3 Conclusions

Clients and experts both agree that existing Branch capabilities are highly relevant to the needs of the major stakeholders in the Canadian wireless communications community. However, many feel that the Branch needs to spend more effort working with others to ensure the utilization and application of its knowledge and capabilities, and to be more proactive in sharing its knowledge with the wider Canadian wireless communications community. Some interviewees identified additional potential services related to these areas, including the following:

- increased communication, sharing of knowledge with Branch partners and clients; and,
- more proactive networking.

Evidence also suggests that the Branch should put more effort into client relationships and providing more responsive, client oriented services.

4.4 Are the Capabilities of Radio Science Branch Staff and the Quality of Facilities Appropriate to the Needs of Clients and Collaborators?

4.4.1 Context

Once again, the generally positive response of Branch clients and experts to many of the other questions under Issue 1 and in Section 4.2 and 4.3 immediately preceding are relevant to answering this question in the affirmative. In addition, however, the client survey directly addressed this question, and those results will be presented and discussed here, together with some input from the in depth interviews.

4.4.2 Detailed Findings

Client Survey

One obvious way to examine the relationship between Branch capabilities and client needs is to ask the clients. Survey respondents were asked to rate their satisfaction with several specific features of staff related to capabilities and service. Once again, a scale of 1 to 10 was used, with 1 being not at all satisfied and 10 being very satisfied. Those results are shown in **Table 10**.

Table 10: Client Survey Perspective on Branch Staff

Staff Feature	Average Rating
Scientific / technical competence	8.7
Responsiveness	8.3
Ability to meet deadlines	7.7
Overall quality	8.4

These results are broadly indicative of a satisfied client group, with confidence in the technical capabilities and supportiveness of Branch staff. However, there is useful information in some of the comments that accompanied these responses.

Several respondents observed that overall Branch competence and capability had dropped recently compared to the past, due to the loss of knowledgeable staff. This has resulted in a loss of both depth and breadth of expertise. An examination of the organization chart of the Branch reveals that, of the 33 full time equivalent positions in the three research groups in the Branch, there are 8 unfilled positions, almost a 25% vacancy rate. There is no doubt that this staffing level seriously affects the overall quality and level of research, development and services from the Branch. It is almost certainly the cause of some of the inability of the Branch to respond to the needs of others for support.

The question of deadlines is always a difficult one for research laboratories to deal with and client surveys often provide relatively low ratings in this area. On one hand, research is by nature uncertain, and cannot be held to production type schedules. However, when dealing with clients and partners, it is important that they understand and are made aware of any problems in meeting planned schedules. Ability to meet deadlines received the lowest of the ratings collected in this category. While it may appear low, this rating is comparable to those of other public sector organizations, and is in fact higher than that received by the Broadcast Technologies Branch (7.3) in last year's review.

Another aspect of the capabilities of staff involves their ability to understand the needs of clients. Table 8 in Section 4.2 presented clients' rating of importance of and satisfaction with the Branch's ability to understand their needs. The average ratings are 8.7 out of 10 for both, which reflect a generally high level of importance and satisfaction. While the question asked about the Branch, it is clear that it is the staff of the Branch who are responsible for understanding client needs. In spite of these generally high ratings, there were several comments suggesting that the Branch needed to improve its responsiveness to client needs.

With respect to facilities, the same table (Table 8) presented clients' rating of the importance of and satisfaction with the quality of Branch equipment and facilities. The average ratings of 8.6 and 8.2 respectively indicate a high degree of satisfaction by most clients and collaborators with the equipment and facilities. There was one comment about the need for additional antenna reference standards to be available for testing.

While these data do not directly address the question of meeting needs, the satisfaction of clients with capabilities of staff and quality of facilities can be considered a reasonable proxy.

In-depth Interviews

As discussed previously, knowledgeable stakeholders spoke favourably about the appropriateness of Branch capabilities for meeting the needs of clients and collaborators. Collaborators also agreed with this perspective. There were no negative or cautionary comments on this question, other than the concern about vacancies and difficulties in maintaining a full complement of experienced staff.

4.4.3 Conclusions

Based on the information available, the large majority of clients surveyed feel that the scientific and technical capabilities of staff are highly satisfactory, of high quality and relevant to their needs. However, as mentioned previously, there were some concerns about the unwillingness of the Radio Science Branch to respond to requests for support for projects that do not have a significant research element. This limits the ability of others to tap into the expertise of the Branch. As previously mentioned, the loss of qualified professional staff was also identified as a concern by some as it affects the present and future capabilities of the Branch.

4.5 What is the Nature and Extent of Collaborations by the Branch within CRC and with Other Organizations?

4.5.1 Context

CRC was reorganized in 1998 into five branches, each with a Vice President. The branches are:

- Radio Science;
- Broadband Network Technologies;
- Broadcast Technologies Research;
- Satellite Communications; and,
- Terrestrial Wireless Systems.

The nature of collaborations between the Radio Science Branch and other branches and corporate groups is examined in this section. In addition, collaborations between the Branch and organizations external to CRC, including universities, other government laboratories, and private sector laboratories are reviewed. Primary sources of information for the analysis include document review, publication analysis and staff interviews.

4.5.2 Detailed Findings

Document Review

Analysis of the Activity Reports for the Radio Science Branch for the past three years, and discussions with Radio Science Branch managers and staff identified a few collaborations with other branches of CRC and other organizations, which are listed below.

Internal to CRC

- experimental antennas and advice in support of VPTWS on the "Milton" project;
- development of prototype antennas for VPSC "EHF Satcom briefcase terminal" project;
- development of microstrip patch antennas for digital radio broadcast trials for VPBT;
- with VPBT, continued integration and application of CRC–Predict within CRC-COV; and,
- development of 30GHz LMCS transmit/receive unit for the new CRC Wireless Testbed..

External

- with the Defence Research Establishment Ottawa, investigation of the effects of high strength electromagnetic pulses on the operational capability of military equipment, and the potential use of high strength electromagnetic pulses to neutralize land-mines;

- with NASA, collection and analysis of Advanced Communications Technology Satellite (ACTS) data;

- with Health Canada, in collaboration with VPBT, to study the effects of digital TV signals on medical equipment; and,

- with the University of Eindhoven in the Netherlands on mobile radio propagation.

A review of the client and project list discussed in Section 3.2 reveals a number of projects with external colleagues which have at least some dimensions of collaborations. These include the projects with universities (RMC, Manitoba, McGill) here in Canada and abroad, as well as some with foreign private sector organizations.

A review of joint authorships of Branch publications, previously discussed in Section 3.2 and summarized in Tables 4, 5 and 6 also revealed a number of collaborations between Branch staff and individuals in Canadian universities, industry and government as well as corresponding foreign organizations.

The Advanced Antenna Group in particular has had a large number of collaborations with Canadian university research groups, usually involving graduate students. This is a deliberate strategy of the group. Several researchers from this group have adjunct professorships at Canadian universities (Carleton and University of Manitoba). These relationships assist in fostering these collaborations.

Given the fundamental nature of the work of the Radio Science Branch, it is perhaps surprising that the Radiowave Propagation and Electromagnetic Compatibility Groups do not have more collaborations with universities. It may be that there is not much capacity in Canadian universities in these areas.

The Radiowave Propagation Group has the most international collaborations, with foreign universities, industry and government. This is reflective of the international scope of much of its work.

It is interesting to note that, except for the Advanced Antenna Group, there are almost no joint authorships of published papers or conference proceedings with staff from other CRC branches. One might have expected more, as the fundamental knowledge within the Radio Science Branch was applied in other branches.

Staff Interviews

Evidence from staff interviews corroborates the evidence from the publication analysis, as most collaborations between the Branch and other CRC branches are informal and occur between staff members as required to exchange information. In fact, revenue generation pressures discourage collaborations, unless in the form of a subcontract or directly linked to Branch objectives, as helping another branch can mean using A-base resources to help achieve the objectives of the other branches. Many of the collaborations identified through document review were also mentioned during the staff interviews. Collaborations with the CRC Broadcast Technologies Branch are quite common. As noted previously, the Advanced Antenna Group has had many collaborations with university groups. It was noted in the Review of the Broadcast Technologies Branch that collaborations between Branches with a scientific research focus, such as the Radio Science Branch, and applications focused branches have been a problem, as their overall objectives are not well matched.

A major long term collaboration has recently been developed between the Advanced Antenna Group and the antenna group of DREO. These two groups have decided to pool their resources and are building and equipping a new antenna measurement facility at the CRC antenna measurement site.

Interviews with staff from other CRC branches confirmed that most branches are relatively independent and work primarily with external clients and partners, not together. Collaborations do occur on an as needed basis, if they meet the needs of both parties. It was also pointed out that branches wishing to establish collaborations with others should give as much notice as possible to potential partners, in order to allow them to adjust their research schedules.

4.5.3 Conclusions

The Branch has a significant level of collaboration with other public and private sector laboratories, usually in the areas of radiowave propagation research or antenna design and testing.

However, except for the Advanced Antenna Group, there is less evidence of formal collaborations with other CRC branches. Most interactions are informal, and at the level of individual staff members, or through subcontracts which provide funding. The Branch does have some formal collaborations with groups within other branches of CRC, and others with Canadian and foreign universities, industry and government. The adjunct professorships of Branch staff are instrumental in the university-based collaborations, and help provide access to basic research knowledge.

4.6 Quality - Summary

The issue of the appropriateness of the quality of research and services was reviewed through a number of complementary methods. Based on the client survey results, and in-depth interviews, the large majority of clients and collaborators are generally highly satisfied

with the quality of research and technical services provided by the Branch, and have confidence in the results obtained. Clients and informed stakeholders also agree that existing services are highly relevant to the needs of the wireless communications community. When clients were asked to rate their satisfaction with the Branch's contribution to a specific project, the average rating was 8.2 out of 10. This is a high rating, indicating a positive relationship between the Branch and the clients surveyed. However, as stated previously, some interviewees from Spectrum Engineering and other CRC branches were concerned about a mismatch between the Branch's focus on longer term research and their needs for support for shorter term applied and developmental projects. In the past, this has at times led to the Branch's unwillingness to meet their requests for assistance.

A number of clients thought that the quality of research and the breadth and depth of scientific and technical capability is now lower than it has been due to the large number of vacancies, now approaching 25%, and inability to retain qualified professional staff. Many noted that there has been a significant loss in the past several years of highly qualified staff, leading to a loss of important research and testing capabilities in the Branch.

For those interviewees who worked with other communications laboratories, the Branch also compared reasonably favourably. In some cases, these other organizations were large national laboratories with much better funding than the Branch, so in that respect clients noted that the comparison may not be fair. Clients rated the quality of Branch equipment and facilities, quality of personnel, and overall responsiveness to client needs slightly better than these comparable organizations.

4.7 Quality - Recommendations

4.7.1 Hiring and Retention of Qualified Staff

The Radio Science Branch should treat the hiring and retention of qualified professional staff as a priority. Hopefully, as the overheated technology sector of the economy returns to a more normal level, potential employees will consider working in the Branch more favourably. As a short term measure, other avenues should be explored, such as working with university professors on sabbatical, secondments from other organizations, and increased use of graduate and post-graduate students.

The Broadcast Technologies Branch has had good success over the past year in finding qualified staff to fill a number of vacancies, and it may therefore be useful for the Radio Science Branch to consult with them to determine their approach.

4.7.2 Focus More on Application of Knowledge for Benefit of Clients

The stated mission of the Radio Science Branch is to develop new knowledge in radio science and to help apply that new knowledge. Evidence suggests that, in the past, the Branch has focused more on the former and less on the latter. In the future the Branch should review its overall strategy, with a view to moving the mix more towards assisting others in utilize and apply the knowledge of the Branch. As a government research group

providing scientific and technical support to public and private sector clients, the focus needs to be on balancing the complementary objectives of developing knowledge in priority areas to meet the emerging needs of key clients and sectors.

NOTE:
Minor editorial changes were made to this report in order to prepare the document for posting to the Internet (including removal of standard Appendices such as a list of interviewees and questionnaires). Readers wishing to receive a copy of the original version of this report should contact the Audit and Evaluation Branch at Industry Canada.

Case Studies

Radiowave propagation prediction software - Northwood Technologies Inc.
Microstrip patch antenna development - SkyWave Mobile Communications Inc.
Electromagnetic field probe array - EMSCAN

[2] List of names, affiliations and projects as provided by the Branch to choose survey sample and expert interviews for the Review

Case Study – Radiowave propagation prediction software

Development and use of radiowave propagation modelling software (CRC-PREDICT) to predict attenuation of signals under various terrain conditions.

Project Overview

The CRC Propagation Research Group has a long history in attenuation prediction modelling of radiowaves, extending back to the 1970s. In the 1990s, new prediction algorithms were developed, based on applied new wave theory, which resulted in the first version of CRC-PREDICT. This new prediction software was initially used by the federal government Spectrum Engineering Branch for specific applications in radio and television broadcasting. It was found to be an improvement over past models and in the late 1990s became part of the regulatory requirements for firms designing broadcasting systems.

CRC-PREDICT was also used within CRC to support other requirements. It was built into CRC–COV, a software package developed to support the analysis of coverage for various digital audio and digital television broadcast systems.

In 1997, Northwood Geoscience (since renamed Northwood Technologies Inc.), a small firm which had been focused on applications related to modelling of geographical and geoscience information, was contracted by the Spectrum Engineering Branch to develop a radiowave propagation modelling product for digital audio broadcasting, which incorporated CRC-PREDICT. Based on this work, the firm realized the great potential in propagation signal pattern analysis for wireless telecommunications network planning. They developed deciBel Planner, a wireless network design software package which incorporated CRC-PREDICT. With this product, Northwood has successfully penetrated the North American market, and is moving into the European and Far East markets as well.

Profile of the Partners

The development of the program to predict the attenuation of radiowave signals due to local terrain features was carried out by scientists at the Radio Science Branch at CRC, with some funding support from the Spectrum Engineering Branch.

This Branch of Industry Canada is the federal government group responsible for the allocation and use of radio, television and other communication spectrum in Canada. In support of the Canadian Radio-television and Telecommunications Commission, the Branch also investigates issues related to actual and potential interference between different sources.

Northwood Technologies Inc., based in Ottawa, was formed in the early 1990s, and originally focused on geographical information systems (GIS) products and services. In the late 1990s, Northwood became interested in other related applications for their GIS expertise, and moved into the development of radiowave propagation modelling tools for broadcast systems planning. The part of their business linked to sale of products used in the design and build-out of wireless

telecommunications networks has grown rapidly recently. Northwood had 40 employees in March, 2000, and as of early 2001, has doubled the number of employees to 80.

Roles and Relationships

As mentioned previously, the Radio Science Branch developed the original version of CRC-PREDICT in the early 1990s. During the next few years, the software was improved incrementally. The Spectrum Engineering Branch, which contributed funds to the development of the software, was very interested in using the package for analysis of licensing applications for TV and FM radio broadcasting in the 80-100 MHz frequency band. Spectrum Engineering adopted version 2.08 of the software as a tool for use in broadcast licencing applications. In 1995-96, CRC-PREDICT was rewritten in C language, instead of FORTRAN.

In 1997, Northwood, which had expertise in spatial modelling, was contracted by the Spectrum Engineering Branch to develop a specific product for digital audio broadcast planning, based on CRC-PREDICT. This initial contract convinced Northwood to diversify their business into wireless networks planning. They developed a commercial product, known as "deciBel Planner", to be sold to telecommunications system planners, which incorporated CRC-PREDICT as the basic propagation prediction tool.

Attribution

Staff at the Radio Science Branch have been solely responsible for the development of CRC-PREDICT, from the first version 2.0, through the various improved versions which were developed throughout the 1990s. Radio Science Branch staff developed CRC-PREDICT based on modelling of wave theory combined with experimental measurements to confirm the accuracy of the predictions. Spectrum Engineering Branch helped fund the development of CRC-PREDICT and also development of applications for its use.

CRC-PREDICT is used directly by the Spectrum Engineering Branch as a tool for broadcasting analysis in general, and in particular for planning for new broadcasting applications (eg. assignment of frequencies, considerations of potential interference).

CRC-PREDICT has also been incorporated into several successful software packages with the assistance of Radio Science Branch staff. CRC-COV, developed by the Broadcast Technologies Research Branch at CRC, is used to analyze broadcast coverage for digital radio and television broadcast systems for a variety of transmitter configurations and signal characteristics.

As mentioned previously, CRC-PREDICT is incorporated into the main telecommunications system planning tool "deciBel Planner" of Northwood Technologies Inc., which is sold worldwide. Northwood's President stated recently that having access to CRC-PREDICT was the basis for Northwood's very successful diversification into the telecommunications system planning business.

Impacts

CRC-PREDICT has made a major contribution to the Canadian and North American broadcast regulatory system. Since the mid 1990s, CRC-PREDICT has been used as part of the Canadian broadcast licence application process, to determine TV and FM radio broadcast patterns and analyze the likelihood of interference with other signals. It has also been used to investigate complaints to the Canadian Radio-television and Telecommunications Commission about interference. Recently, CRC-PREDICT has been used to plan for digital audio broadcasting across Canada, in terms of planning for allotment of frequencies and checking for possible interference with other users.

CRC-PREDICT has also made a significant contribution to the Canadian private sector economy. It has been instrumental in the diversification and growth of Northwood Technologies Inc. In 1997, Northwood built its telecommunication systems planning tool around CRC-PREDICT. Since then, CRC-PREDICT has become the cornerstone of the propagation modelling component of deciBel Planner, Northwood's premier network planner sold worldwide. As it contains one of the most precise deterministic propagation algorithms on the commercial market, CRC-PREDICT represents a critical component of the deciBel Planner value proposition, having a proven track record of building accurate network coverage models for wireless carriers worldwide. Northwood has 5 – 10% of the North American market share in this area, with revenues of over $15 million, and is increasing that share rapidly. Northwood has as customers major North American telecommunications firms such as Bell, Telus, Nextel and Leap Wireless. Northwood has begun expanding by opening offices in Europe and working with partners in Asia, which are the fastest growing markets for wireless telecommunications. Northwood is growing rapidly, moving from 30 employees in September, 1999, to 80 in early 2001, in a period of eighteen months. In fact, Northwood has changed its name recently to Northwood Technologies Inc. to reflect the broadening of its capabilities and interests.

CRC-PREDICT is also a key element in CRC-COV, developed by CRC's Broadcast Technologies Research Branch. CRC-COV has been used by Spectrum Engineering Branch and the private sector to model digital broadcast system performance.

CRC-PREDICT and CRC-COV are known internationally, and have contributed to the reputation and credibility of CRC as a research institution.

Licences/Royalties/Revenues

Licensing of the various versions of CRC-PREDICT has directly resulted in revenues of over $120K for CRC during the period 1995-2000. In addition, licensing revenues for CRC-COV, which incorporates CRC-PREDICT as a key element, were over $300K during the same period.

Individuals Interviewed

Mr. Royce Trenholm	Manager, Spectrum Engineering Branch, Industry Canada
Dr. Jim Whitteker	Scientist with Northwood Technologies Inc., formerly with the Radio Science Branch, CRC
Mr. Johannus Hill	President, Northwood Technologies Inc.
Mr. René Voyer	Research Manager, Broadcast Technologies Research Branch, CRC

CRC Predict – Program to Calculate Communication Signal Attenuation Due to Terrain

Project Incrementality (influence)	Direct User Impacts	Industry Sector / Supply Community Impacts	Economy / Societal Impacts
Involvement x performed R&D, product development and testing essential to project success ? responsible for technical management of project x helped do some useful R&D that otherwise would not have been done	Technical results x new or improved product x new or improved process x advancement of knowledge x increased technical capabilities ? improved quality control x new skills internally x increased efficiency / improved productivity x technology transfer Policy/legislative results x policy behavioral changes x agreement / accord x legislative / regulation x acceptance of standards Commercial results x increased sales x increased market share x increased profitability x cost savings Organizational effects x increase in jobs x diversification x expansions ? strategic alliances / partnerships ? achievement awards / recognition	x production process efficiencies x increased science and technology information x increased sales x cost savings ? changes to industry structure (e.g., concentration, competitiveness internationally) ? spin-off companies x technology infrastructure (e.g., standard scientific and engineering data, industry standards, test protocols, and instrumentation) ? training of technological problem-solvers whose talents can be applied in many areas x establishment of quality standards	? reduced consumer costs ? protection of environment ? improved energy efficiency savings ? improved public health and safety ? education/ communication/ awareness x public service efficiency gains x increased employ ment ? reduction in subsidies

? has not occurred
x has occurred
p potential in future

Case Study – Microstrip patch antenna development

Development of a microstrip patch antenna for compact mobile satellite terminal

Project Overview

In 1997, SkyWave Mobile Communications Inc. was formed, and took up residence in the CRC Innovation Centre. Their major objective was to design and build a compact mobile satellite terminal, to be linked to the INMARSAT stationary satellite. The terminal design included a requirement for a compact antenna to be fully integrated into the electronics package.

In 1998, the Advanced Antenna Technology Research Group of the Radio Science Branch was given a contract to design and build the antenna for this terminal. The design specifications for a microstrip patch antenna, operating at L band (1.5 – 1.6 GHz) were very demanding, as the antenna was required to fit within the small 12cm x 12cm x 4cm instrument package. The antenna design was successful and became an integral component of the terminal produced for commercial use.

The terminal has many uses, typically related to relaying information from the site to the satellite and then to the firm requiring the information. Applications can be passive, such as monitoring of location or instrumentation, or active, such as turning equipment on or off, depending on the data or information provided. One interesting application is using the terminal as part of a floating fish finder in a buoy, used by the Spanish to locate tuna.

In 1999, the Advanced Antenna Technology Research Group was asked again to support the development of a military version of the terminal. This project was also successful, and resulted in an award by the U.S. Department of Defence for outstanding work.

The civilian and military versions of the compact mobile satellite terminal designed and developed with the aid of the Advanced Antenna Technology Research Group are the principal products of SkyWave Mobile Communications Inc. These terminals are critical elements in a wide variety of systems utilizing satellite links to provide two-way communications to remote or mobile users around the world.

The firm has enjoyed considerable success, growing from 4 employees in 1997, to the present level of 30 in early 2001.

Profile of the Recipient/User

SkyWave Mobile Communications Inc. is a startup telecommunications firm involved in providing mobile two-way communications links via satellite for various remote or mobile monitoring or data transfer applications. The firm began business in 1997 and has experienced rapid growth over the past four years since its inception. SkyWave has recently moved to offices in Kanata, Ontario and has annual revenues of about $5 million.

Project Profile

The project began in 1997, when CRC opened its Innovation Centre. The firm moved in soon after the Centre was opened and began to design the electronics component of its system. In 1998, the Advanced Antenna Technology Research Group became involved in designing and developing a compact antenna for the terminal to demanding specifications and constraints in physical size. The firm management knew that in order to achieve technical and commercial success, it would be important to design the antenna as an integral part of the communications system. Several designs were tried out, with prototypes developed in the CRC model shop being tested before the final version was accepted. The design developed by the Group proved successful, meeting specifications. A similar project in 1999, involving design of a military version of the terminal, was also very successful.

Roles and Relationships

The President of SkyWave Mobile Communications Inc. had worked in satellite communications for many years and had done contract work linked to Bell Northern Research in the 1970s. As such, he was well aware of CRC and its capabilities. The firm took advantage of the CRC Innovation Centre as its initial location after being formed in 1997. Being located at CRC, the firm was able to develop a relationship with the Advanced Antenna Technology Research Group and determined that they could play an important role in the development of the terminal. The Advanced Antenna Technology Research Group developed and tested several prototypes before settling on a final design. The CRC model shop also played an important role in efficient prototyping of the various antenna designs. The Advanced Antenna Technology Research Group paid for a student to participate in the project.

The location of the firm at the Innovation Centre contributed to a close and effective working relationship with CRC groups.

Attribution

The antenna design provided by the Advanced Antenna Technology Research Group was a critical element in the overall terminal design. It met demanding electronic and physical specifications, including compact size and ease of construction. The firm benefited from the credibility of working with CRC and having CRC involved in the product design and testing. The resulting terminal has been successful both technically and commercially, selling several thousands of units annually, and making the firm the leader in this field.

Impacts

There were several levels of impact.

First, the terminal was very successful technically, meeting all design parameters. As an indicator of excellence, the military version received an award from the U.S. Department of Defence for excellence in design.

The project also resulted in significant commercial impact, including sales and revenues. Based on the successful design of the terminal, the firm is selling several thousand devices annually, at a cost of about $1K each, resulting in annual sales of several million dollars. This terminal is the main product of the firm at this stage. Efforts are being made to expand the application areas in which this product is being used.

The success of this product has led to a major increase in employment and economic growth for SkyWave. In 1997 the firm had 4 employees, increasing to 30 by early 2001. Firm revenues are about $5 million at this time.

Licences/Royalties/Revenues

SkyWave Mobile Communications Inc. had several contracts with the Advanced Antenna Technology Research Group, totalling about $60K over the two year period 1998-1999. Because the project was partially collaborative and a learning experience for the Advanced Antenna Technology Research Group, SkyWave was charged for 50% of total project costs.

Individuals Interviewed

Mr. Peter Rossiter	President, SkyWave Mobile Communications Inc.
Mr. Michel Cuhaci	Research Program Manager, Advanced Antenna Technology Research, Radio Science Branch, CRC

Antenna Developement for SkyWave Mobile Communications Inc.

Project Incrementality (influence)	Direct User Impacts	Industry Sector / Supply Community Impacts	Economy / Societal Impacts
Involvement x performed R&D, product development and testing essential to project success ? responsible for technical management of project x helped do some useful R&D that otherwise would not have been done	Technical results x new or improved product x new or improved process x advancement of knowledge x increased technical capabilities ? improved quality control x new skills internally ? increased efficiency / improved productivity x technology transfer Policy/legislative results ? policy behavioral changes ? agreement / accord ? legislative / regulation ? acceptance of standards Commercial results x increased sales x increased market share x increased profitability ? cost savings Organizational effects x increase in jobs ? diversification x expansions ? strategic alliances / partnerships x achievement awards / recognition	x production process efficiencies x increased science and technology information ? increased sales ? cost savings ? changes to industry structure (e.g., concentration, competitiveness internationally) ? spin-off companies ? technology infrastructure (e.g., standard scientific and engineering data, industry standards, test protocols, and instrumentation) ? training of technological problem-solvers whose talents can be applied in many areas ? establishment of quality standards	? reduced consumer costs ? protection of environment ? improved energy efficiency savings ? improved public health and safety ? education/ communication/ awareness ? public service efficiency gains x increased employment ? reduction in subsidies

? has not occurred
x has occurred
p potential in future

Case Study – Electromagnetic field probe array

This case involves support by the Radio Science Branch for the development of an improved two-dimensional probe array to measure electromagnetic fields associated with printed circuit boards and high frequency electronic equipment. The probe provides measurement information for electromagnetic compatibility and interference testing.

Project Overview

In 1989, EMSCAN purchased the rights to an electromagnetic field probe measurement system from BNR (which became Nortel). During the early 1990s, BNR continued the development of the system under contract to EMSCAN. However, there was little documentation provided to EMSCAN, and there was much that wasn't known about the probe's performance, including how well it measured actual fields in various configurations.

In 1997, a scientist from the Electromagnetic Compatibility Research Group, with expertise in the area of electric and magnetic field probe arrays, learned about their product and contacted EMSCAN. He identified their common interest and offered to collaborate with EMSCAN on further refinements and improvements in the probe array. Following consultations and discussions, including visits by EMSCAN management to CRC and the scientist to EMSCAN in Calgary in 1998, the firm contracted with the Radio Science Branch to conduct tests and analyses on their field probe array system.

During the course of contract work, which was renewed in March of 2001, the Radio Science Branch scientist characterized the probe grid array and was able to provide an improved understanding of how the array was performing. As a result, the scientist was able to identify and offer solutions to a number of performance-related problems. The results of the research led to an increased confidence by EMSCAN in the performance specifications of the original probe array and improvements to the original design, including an increase in the upper frequency limit for measurements from 1.2 GHz to 1.7 GHz. In addition, the increased knowledge provided by the Radio Science Branch has made a major contribution to the development of a new, improved probe array and data acquisition system which samples data at a higher rate and can be used at frequencies up to 3 GHz. An early prototype of the new product has been tested, and the system is in the advanced testing stage before commercial production.

The contribution from the Radio Science Branch has had a number of benefits for EMSCAN. Technically the research results have led to improvements in design and performance and provided confidence in the firm and their clients that the probe array is a high quality instrument that meets product specifications. From a business perspective, these improvements have enabled EMSCAN to maintain sales levels of the main product. The new improved scanner measurement system under development with the assistance of CRC is expected to attract interest from electronics firms worldwide and result in a significant increase in sales for EMSCAN. The firm's improved business prospects have attracted the interest of a potential major partner.

Radio Science Branch staff continue to work with EMSCAN on developing next generation products and exploring new directions for the firm.

Profile of the Firm

EMSCAN is a small electronics firm in Calgary formed in the 1980s, with a unique product, a two-dimensional electromagnetic field scanner. The probe array is used to measure electromagnetic fields emanating from electrical equipment to assist designers and compliance engineering in determining the source of these emissions prior to submitting these devices for compliance testing. No other firm has a similar product. At the present time, EMSCAN has about 10 employees (4 of whom are technical professionals), and sales of about $1 million/year.

Roles and Relationships

Radio Science Branch staff have been performing research on electric and magnetic field probes and arrays since the early 1980s, and have developed considerable expertise in this area. This knowledge has contributed to Branch capabilities in measurement of electrical and magnetic fields related to electromagnetic compatibility and interference effects on electronic equipment.

As mentioned previously, in 1997, EMSCAN was contacted with an offer to assist in improving their product, and after discussions which identified a common interest and the potential value of Radio Science Branch expertise to EMSCAN, in 1998 the firm contracted with the Branch for measurements on their probe array. Branch staff provided measurements and analyses that served to characterize the device, and identify problems and potential modifications and improvements. The relationship has continued and the Radio Science Branch is supporting new product development.

Attribution

The Radio Science Branch has played a vital role in the recent technical and commercial success of EMSCAN. The technical expertise and measurement capability provided by the Branch have both been critical factors in improving the present scanning device, the development of the improved scanning device and research into possible next generation scanners for the firm.

Impacts

Technical support from Radio Science Branch staff in testing, scanner improvement and new scanner development has had a number of technical and commercial impacts. Before the Branch became involved, EMSCAN had only minimal knowledge of how the probe behaved and was not able to demonstrate that it met published specifications. Following characterization of the device by the Branch, a number of problems were identified and solved. The result was an improved scanning device. Radio Science Branch staff have also helped address customer inquiries regarding specialized applications for the array. The improvements and technical support have provided increased credibility and visibility for the firm and its scanning device among electronic equipment manufacturers and resulted in additional sales.

A new electromagnetic scanner measurement system, designed to assist designers of electronic circuitry in meeting worldwide standards for electromagnetic field compatibility and product

integrity, is being developed with the assistance of the Radio Science Branch. The new product is expected to attract interest from Japan, Europe and North America, and lead to an estimated 50% increase in firm sales.

The Radio Science Branch is also working with EMSCAN on the development of a next generation scanner. While at the very early stage, based on past performance, there is reason to believe that this initiative will also be successful, and EMSCAN will continue to be at the forefront of electromagnetic scanner technology. In addition, there is now a possibility of a strategic alliance with a major firm, based on the high quality and technical sophistication of the new EMSCAN product.

Licences/Royalties/Revenues

The Radio Science Branch has performed work under contract for EMSCAN over the past four years with an estimated total value of $74K. There have been no royalties or licensing agreements arising from this relationship.

Individuals Interviewed

Mr. Gordon Ramsay	President, EMSCAN
Dr. Adrian Alden	Research Scientist, Electromagnetic Compatibility Research, Radio Science Branch

EMSCAN – Development of Improved Electromagnetic Scanners

Project Incrementality (influence)	Direct User Impacts	Industry Sector / Supply Community Impacts	Economy / Societal Impacts
Involvement x performed R&D, product development and testing essential to project success ? responsible for technical management of project x helped do some useful R&D that otherwise would not have been done	Technical results x new or improved product ? new or improved process x advancement of knowledge x increased technical capabilities x improved quality control x new skills internally ? increased efficiency / improved productivity x technology transfer Policy/legislative results ? policy behavioral changes ? agreement / accord ? legislative / regulation ? acceptance of standards Commercial results x increased sales x increased market share x increased profitability x cost savings Organizational effects x maintenance/oincrease of jobs p diversification p expansions p strategic alliances / partnerships ? achievement awards / recognition	x production process efficiencies x increased science and technology information x increased sales ? cost savings ? changes to industry structure (e.g., concentration, competitiveness internationally) ? spin-off companies x technology infrastructure (e.g., standard scientific and engineering data, industry standards, test protocols, and instrumentation) ? training of technological problem-solvers whose talents can be applied in many areas x establishment of quality standards	? reduced consumer costs ? protection of environment ? improved energy efficiency savings ? improved public health and safety ? education/ communication/ awareness ? public service efficiency gains x increased employment ? reduction in subsidies

? has not occurred
x has occurred
p potential in future