Making Government Science Work for Canada and the World[1]

A Legacy of Excellence at the Canada Centre for Remote Sensing (CCRS)

The authors and contributors to this document and the editor are named on the following Author's Page as well as in their respective sections or Subsections.

Executive Summary and Lessons Learned

The Table of Contents follows the Executive Summary and Lessons Learned

June 20, 2019

Ottawa, Canada

---

[1] The original title of this work referred only to Canada. In a telephone conversation on January 7, 2019 Dr. Ade Abiodun - one-time CCRS Postdoctoral Fellow and later a senior official in the United Nations remote sensing and space program suggested that the word "World" be added to recognize the contributions CCRS made beyond the borders of Canada. As ever, Ade was convincing and the title has been changed! His story is in Section 3.6.2.

Page left blank on purpose

Author's Page

This document that details how to do science in Government for the benefit of the country and its citizens is the result of a volunteer effort. Authors listed below are those who have written material for this work. Except for Dr. Morley, names are listed alphabetically. This work was initiated by Dr. Morley and is a tribute to him.

A note on the use of the term "Dr." Many of the people referred to and many of the authors have earned PhDs. That is the nature of a research-based organization. We have tried to use the term "Dr." the first time someone's name is mentioned or in a list of those named as seemed appropriate. To use it throughout the document everywhere someone's name is mentioned seems to be distracting to the flow for the reader. Our apologies in advance if someone with a PhD believes that they are not accorded appropriate respect with this approach. Those marked * are deceased.

Authors and Editors: Chapters and Sections

Dr. Lawrence "Larry" Morley*
Dr. Frank Ahern
Ralph Baker
Dr. Josef Cihlar
Dr. Ian Crain
Roy Dixon
Howard Edel
Tom Feehan
Carolyn Goodfellow
Dr. Laurence Gray
Dr. Alan F. Gregory
Florian Guertin*
Dr. Bob Hawkins
Michael Kirby
Keith Langley
Dr. C.E."Chuck" Livingstone
Tom Lukowski
Wally McColl
Dr. Heather McNairn
Jennifer "Jenny" Murphy
Dr. Bob O'Neil
Peter Paul
Dr. R. Keith Raney
Dr. Dianne Richardson
Dr. Bob Ryerson
Dr. Vern Singhroy
Dr. Karl Staenz
Dr. Murray Strome
Dr. Philippe Teillet
Dr. Thierry Toutin
Dr. Ridha Touzi
Lori White
John Wightman

Contributors

Contributors are those who have provided a limited amount of material including anecdotes, papers and material written some time ago and "re-purposed" for this. Names are listed alphabetically. Those whose work is cited but who did not prepare material used directly here are not listed as contributors.

Tom Alföldi   Bill Bruce*   E.A. "Lee" Godby   .Paul Hession   Shannon Kaya   Les Whitney

Editor-in-Chief

Dr. Bob Ryerson
Box 1125, Manotick, Ontario
K4M 1A9
bryerson@kimgeomatics.com

Editor's NOTE: Each author is responsible for his or her contributions and any opinions expressed therein. As editor I have only sought authors, organized the material and performed an edit for clarity and consistency in grammar and format.

Executive Summary and Lessons Learned

Bob Ryerson

ES1. Executive Summary

We the authors of this history and "how-to" guide freely contributed our time and knowledge to its creation. Why? Because we appreciate that what we accomplished together was something special: something that no other group anywhere in the world accomplished no matter their size or budget. We want to explain not only what we did, but how we did it to provide some guidance for others in government who seek to apply science to meet the future needs of Canada and Canadians. This short summary is intended to whet the reader's appetite and provide an overview of what the Canada Centre for Remote Sensing accomplished – and why. The summary ends with the lessons learned – lessons that are as relevant today as they were when first applied by CCRS.

One of the best explanations of how so much was accomplished comes in Section 5.5 – the conclusion of the Section on RADARSAT by Dr. Keith Raney, a former Chief Scientist at CCRS and arguably the world's leading radar scientist in the period this history covers. His explanation:

> "Long-term enterprises become successful only to the extent enabled by the steadfast leadership of their management, sustained by enthusiastic quality staff, and high level support. Leadership and senior management need to be willing to accept risks, when the road ahead is well prepared, and the benefits of success are clear. RADARSAT-1 is a good example. The all-important user advisory groups set up by management (inspired by Larry Morley) in the early 1970s became essential resources leading to a remarkably responsive satellite SAR launched two decades later. The CCRS SAR-580 program that provided radar data products and user-oriented analysis techniques were an essential component in developing and expanding a knowledgeable user base, both in Canada and world-wide."

Former Scientist and Director Dr. Bob O'Neil elaborated on the conditions for success in Section 6.5.3 when he stated that "CCRS hired people with a range of backgrounds with two common attributes: pride in what they did and the drive to meet what sometimes seemed like unattainable goals."

This history of the Canada Centre for Remote Sensing (CCRS) was written at the suggestion of the late Dr. Lawrence "Larry" Morley, who has rightfully earned recognition as one of Canada's all-time leading scientists and engineers. In 2014 Dr. Morley was inducted posthumously into Canada's National Science and Engineering Hall of Fame: he was one of but sixty members. He was the founding Director General and led CCRS from its inception until the 1980s. Dr. Morley always said "Canada was made for remote sensing" given the limited budget of CCRS and the enormous size of the country we were setting out to monitor and help map. While this document has been written as a history, along the way it also outlines how to do effective science in government. This is as Larry intended: as with most work done by CCRS two objectives have been met with one output.

CCRS was known world-wide as a world-class organization that consistently punched well above its weight in the important area of earth observation. It served as the model for a number of countries and how they approached remote sensing and the geospatial sciences. We the authors believe that the CCRS organization "model" is more widely applicable than to just remote sensing and related fields. The organization – from management structures to the library – was built to foster innovation. As is explained in Section 6.4, innovation was not something that was just hoped for, or that we relied on luck to achieve. Innovation was built into our organization's DNA.

This is the story of CCRS – both what it did, how it did it and, most importantly, the lessons learned that might be usefully applied by Government in other areas of science and technology. There is a great deal of focus on supporting and international activities inasmuch as they were, in retrospect, critical to the long term success of CCRS and the growth of the industry that CCRS nurtured. It is believed that it is particularly important to emphasize these supporting activities since most scientists and science advisors tend not to give them the attention that they deserve if the goal is to create a successful and sustainable science-based activity to support the national interests of a country.

This history is not just about CCRS. It recognizes the important roles of industry, academe, other levels of government and other government departments with which CCRS worked as a truly national centre of excellence. At the same time we also agree with the point of view on the important role of government in innovation espoused by Dr. Mariana Mazzucato in her *TED Talk* filmed in June of 2013 that was titled "Government – Investor, Risk-taker, Innovator." We recommend viewing her presentation as a point of departure before reading this work:
http://www.ted.com/talks/mariana_mazzucato_government_investor_risk_taker_innovator

The accomplishments of CCRS and its staff are truly amazing in both their scope and importance. Almost every page identified yet another leading edge development or a first in the field: there are far too many to list them in this summary. For this executive summary we have extracted some of the most significant achievements and activities in the following table. For each we have identified the section where further details can be found.

The reader will find that some topics are covered more than once from different perspectives. For example a specific technology may be described by the scientist or engineer who invented the technology as well as by the applications scientist who used the technology. We believe that these different perspectives give a more rounded and complete view.

Following the table are the more than sixty lessons learned that have been extracted from this work. We hope that the Lessons Learned over the next pages will be widely and wisely shared across government.

Some of the Significant Achievements and Activities of CCRS and Its People[2]

Awards and Accolades

- In 2011 CCRS was the first organization outside of the US to win the prestigious William T. Pecora Award, the highest honour in the field of remote sensing for an organization. Over 35 accomplishments are cited in Section 8.2.3.[3] The nomination letter begins with the following paragraph: "I am nominating the Canada Centre for Remote Sensing (CCRS) for the 2011 Pecora Award. CCRS has contributed in a major way to the understanding of the Earth over a period of forty years through the development of important technologies, innovative applications and policies, as well as major contributions to the international community. It has worked successfully with the USGS and NASA as well as other agencies and industry in the USA and elsewhere. Cooperation has been its hallmark."
- CCRS employees have won hundreds of awards for contributions in the field. Section 8.2 documents some of the most important.

Advisory Structure

- To truly understand the organizational genius of Larry Morley, Lee Godby and University of Waterloo professor and management consultant Don Clough, one need only look to the Canadian Advisory

[2] Editor's Note: Text boxes are used throughout this document to provide additional information. Some of them are longer than one page and many are split between two pages. This may not be ideal in terms of format, but it does mean that fewer pages are wasted.
[3] Several of these are repeated in this table.

Committee on Remote Sensing - CACRS. The Committee and how it functioned as an inclusive truly national advisory body was responsible for much of the success Canada enjoyed in the field. Section 2.2.

- CACRS provides a useful model for guiding science in government. Section 2.2.
- There are two significant new programs that came out of CACRS Recommendations: the development of the airborne radar program; and RADARSAT. Sections 6.7.2 and 5 respectively.

Active on the World Stage

- Larry Morley was the individual who did more than anyone to make the world's remote sensing community a global village based on cooperation and sharing. Section 2.1 and Appendix F.
- The CCRS Library provided world-wide access to the first searchable data base of English and French publications in remote sensing and by so doing became the world's go-to source for information in the field. Section 6.3.
- Canada's first cooperative agreement with the European Space Agency was initiated by CCRS for ESA to gain access to the Convair-580 SAR. In a 1985 assessment of the relationship with ESA, Canadian participation in the ESA ERS program was viewed as "a major asset" primarily because of the role of the Canada Centre for Remote Sensing. CCRS was described as "the leading body in remote sensing. It had a good team, the necessary resources and long experience". "The same report noted that MDA, which had been awarded the prime contract for providing the SAR data processing technology at the two ERS satellite stations in Europe, had become a leader in the field. Section 7.8.
- The Convair-580 aircraft and the systems on board were used to provide SAR imagery, share our experience, and demonstrate our excellence in Asia, Africa, the Middle East, Latin and South America, and, of course, Europe. Sections 6.5.6 and 6.7.2.
- CCRS was a founding member of the Committee for Earth Observation Satellites (CEOS) and played a pivotal role in data calibration, standards, and the like – helping Canadian industry (such as MDA, PCI and others) along the way. Section 3.6.3.4.
- As a result of the award-winning GlobeSAR program additional sources of groundwater were found in Jordon. The Syrian refugee camps in eastern Jordan currently rely on this water. Section 6.6.6.
- CCRS had both bilateral and multi-lateral relationships around the world. Section 3.6.

Responsive to National Priorities

- Key issues faced by the government of the day were always kept top-of-mind by CCRS management – and scientists. For example the thread of protecting sovereignty has run through CCRS and remote sensing from their beginning in Canada. There was also an early focus on thermal imagery for assessing heat loss in buildings in response to the energy crisis in the early 1970s, while climate change became top of mind in the 1990s. Sections 6.5.3 and 6.6.10.
- CCRS worked with a wide range of other federal departments and agencies as well as the provinces and academe. Sections 3.1, 3.2 and 3.4.
- In the massive budget cuts of 1994-95 the only program in all of Government to obtain substantial new funding was the space program which obtained some $800M over the next decade or so and most of that was earmarked for remote sensing or earth observation (EO). CCRS wrote much of the EO justification and the industry CCRS worked with provided support. Sections 2.3.4.2, 3.3.2.6, 4.3 and 6.6.1.

Relationships with Industry

- Dr. John MacDonald, founder of high tech success story MDA, was quoted as saying "it was from Larry Morley that we learned how to build a high tech company in Canada." MDA got its start working with CCRS. Section 3.3.4.5.
- CCRS was considered so effective in its development of industry that it was studied to gain insights into how science could lead to commercial success. Section 3.3.1.
- CCRS contracting and related policies led to international success for several companies including PCI Geomatics and Intera. Sections 3.3.4 and 3.3.3.
- MDA has sold the Geometric Image Correction System (GICS) technology derived from MOSAICS for CCRS to many satellite ground stations around the world for satellite missions such as Landsat, SPOT,

ERS-1&2, MOS, NOAA AVHRR, JERS, RADARSAT, Envisat and others. The GICS technology became the de facto world standard, and MDA the leading provider of Earth observation satellite ground systems with market share estimated as high as 90%. Section 7.5.

High Impact

- The CCRS Convair-580 Synthetic Aperture Radar research aircraft and work by CCRS scientists on polarimetry provided the proof-of-concept and scientific backing for an **estimated $10 billion investment by Japan, Europe and Canada in radar remote sensing satellite systems.** Unlike most other countries, we in Canada used aircraft to prove and develop concepts before launching spaceborne systems – a cautious but effective Canadian approach. The CCRS Convair-580 Synthetic Aperture Radar research aircraft flying laboratory is a symbol of how we approached scientific research: cautiously and in support of our economic, environmental, and foreign policy goals. Sections 6.5.6 and 6.7.2.
- During the 1990s the GeoAccess Division's Atlas of Canada web site routinely ranked among the top Government of Canada sites in terms of yearly visits by users. Section 6.10.
- In 2006, as part of the centenary celebrations of the Atlas of Canada, the Royal Canadian Geographical Society recognized the Atlas with its Gold Medal award. The Canadian $100 banknote was produced to celebrate the same centenary. Section 6.10.2.

National Leadership

- CACRS was originally set up as a national advisory body including all sectors and regions of Canada. Section 2.2.
- The Canadian Remote Sensing Society led by Larry Morley was the first national society anywhere with remote sensing in its name. Section 3.5.2.
- "The ground breaking work by CCRS supported many a graduate thesis and advanced many a career…and has most certainly yielded dividends." Section 6.6.3.9.4.

Efficient and Well Managed

- The Auditor General could find nothing to criticize! The ultimate stamp of approval on how CCRS was managed and the results obtained came from a study involving the Auditor General and a report of the Auditor General of Canada. Section 2.3.2 and 3.3.1.
- The GeoAccess Division was a part of CCRS for just twelve years. Over those twelve years what began as a collection of orphans that no-one other than CCRS seemed to know what to do with became an award winning unit that everyone coveted. This is largely as a result of the solid management team that was assembled and the belief of the staff that what they were doing was important for Canada. And it was important. Section 6.10.
- While CCRS developed a wide range of new technology, CCRS used generic off-the-shelf computer hardware and software where possible to avoid designing costly special purpose systems, and by so doing reduced the on-going operation and maintenance costs. Section 7.2.

Technology Developments

- CCRS did a significant amount of the world's basic research in civilian radar remote sensing. Section 5 and 6.7.2.
- Working with CCRS MDA developed the first digital SAR image – forever revolutionizing the use of SAR data. MDA became the world's largest producer of SAR processors. Sections 3.3.2.6, 3.3.3.6, 5.1.2, and 7.6.In the 1976-1979 time frame CCRS developed the Digital Image Correction System (DICS), the first operational facility to produce geocoded imagery from Landsat MSS data. Section 7.4.
- The CCRS Colour Image Recorder was the world's first high-resolution digital film recorder system. Section 7.7.
- The Polarimetric Work Station developed by Dr. Touzi of CCRS has been adopted in Canada and in many countries around the world (India, Brazil, China, France, Russia, and Argentina, among others) as a user-friendly tool for efficient exploitation of polarimetric satellite SAR information provided by various

satellite and airborne SARs. Section 6.7.2.4.3.
- CCRS developed methods to use SAR data for individual ship detection. Section 6.7.2.4.3.
- The pioneering research into image analysis algorithms by CCRS and the rest of the RS community in the 70s and 80s formed the basis for today's practical applications from point-and-click photography to the "vision" capabilities of autonomous vehicles. In particular the CCRS work led to a successful export industry. Section 6.8.2.2.
- Data from the US's flagship Landsat Thematic Mapper sensor had serious problems (striping in the data) that the US could not solve. It was CCRS scientists Frank Ahern and Jenny Murphy who developed a solution to the problem. Their approach was subsequently adopted world-wide – including by the US. Section 6.8.2.5.1.
- CCRS successfully received and processed the first Landsat-1 image and made it available to the U.S. The image was rushed to Ottawa from Prince Albert in time to be shown at the 12th ISPRS Congress held from July 24 - August 04, 1972. Section 6.9.2.

Leading Edge Applications

- CCRS led the Great Lakes Land Use Mapping Project – the world's first large area project where information derived from existing map data, satellite data, airborne data, and census data were incorporated together in a GIS. Section 6.6.3.3.2.
- CCRS worked with Statistics Canada to produce the first real-time pre-harvest operational crop area estimation done anywhere. Section 6.6.3.6.
- An operational crop monitoring system was developed with and for the Canadian Wheat Board. It was later taken over by Statistics Canada which received a government-wide award. (See Section 6.6.3.5.)
- The unique CCRS approach to monitor rangeland condition won an award for Drs. Ron Brown and Frank Ahern for the English speaking world's most outstanding paper in remote sensing in 1983. (Section 6.6.3.7 and 6.6.3.1.2.
- CCRS was a major contributor to the BOREAS Program. Canadians have benefited from improved weather forecasts resulting from a better understanding of the energy exchange over the vast boreal ecosystem. Section 6.6.10.4.
- CCRS was an early player in the area of climate change and national monitoring. Section 6.6.10.
- CCRS's contribution to Canadian agriculture is measurable and remarkable." Section 6.6.3.9.4.

Technology Transfer, Education and Visibility

- CCRS was active in technology transfer and the development of training materials used at home and abroad. Sections 3.1.7 and 3.2.4.
- CCRS had an active marketing and public awareness program. Section 6.2.

ES2. Lessons Learned

ES2.1 Introduction

This is believed to be the most important section of this work. The lessons learned over the history of CCRS provide both positive advice and some advice on how not to do things with regard to science policy and implementation of that policy in government. The lessons learned are identified in the next nine Subsections. The topics considered are:

- Management and leadership (not the same thing!);
- Advisory bodies;
- Working with industry, academe and government agencies;
- Identifying opportunities;
- Innovation and problem solving;

- Building research capacity;
- Putting innovation into operation;
- Understanding politics and politicians: and
- International relations.

One of the interesting aspects of re-reading hundreds of papers, advisory reports and meeting minutes concerning CCRS was the realization that the early leaders of CCRS knew that they were forging a new way of doing science in government – and that other organizations might learn from studying CCRS. This was clearly stated in Canadian Advisory Committee on Remote Sensing (CACRS)[4] reports, for example. And while many did learn from CCRS, we hope that this document will lead to many more gaining insights from what amazing things CCRS accomplished and how it did so.

ES2.2. Management and Leadership

- To ensure knowledgeable management and leadership, all levels of management and the leadership should have experience relevant to the discipline.

- Leaders should be expected to lead, not just manage.

- To ensure succession planning in both management and leadership, efforts should be made to identify potential managers and leaders among the engineers and scientists involved in the program. (At CCRS many people identified as having management and/or leadership potential went on to become Directors, Directors General, and Assistant Deputy Ministers in organizations in governments across Canada. A number of others became leaders in industry.)

- Secondments, participation on interdepartmental committees, mentoring and formal training can be used to further staff development and expand the impact of the organization.

- All projects and programs must be on time, on budget and there will be no surprises.[5]

- There should be no fear of failure…such fear limits the potential for success.

- While failure can be tolerated, both project managers and senior management should know when to cut losses – and not be afraid to do so. A project selection and review committee of senior scientists and their managers chaired by a member of the leadership team will help in this regard.

- Management should have plans in place to rapidly absorb extra budget should funds become available. At the same time, it is wise to know what projects or programs might be sacrificed should there be calls for budget reductions.

- Everyone in the organization is important and should believe that their role is important.

- Management by walking about is important. Leaders and senior managers should be seen and should be available on an informal as well as formal basis.

- Management should keep in mind that Research Scientists are promoted based largely on publications and related metrics. Technology transfer and operational applications of science are sometimes best left to those not in the Research Scientist category.

[4] Pronounced KACK-ers.
[5] Editor's Note: These are the words of the late Florian Guertin who gave so much to CCRS – and this document.

- Constant reorganization and changing linkages and mandates tend to result in reluctance to embrace changes – even beneficial changes.

ES2.3. Advisory Bodies

- To ensure that widely-based and appropriate advice is received, a broadly based advisory body should be established at the outset to provide advice to government.
- To avoid hearing only limited advice, the main advisory body should meet annually with its constituent working groups that cover the key areas within the discipline including technical areas, potential users, industry, researchers, and appropriate levels of government. (This may be done at a relevant national symposium.)
- In that some science and industry policy may be related to national security and industrial development, some elements of the advisory body's deliberations may have to be held in secret.
- If the research involves natural resources or other areas that fall mainly within the jurisdiction of the provinces, as CCRS work did, then the provinces and territories must be fully engaged in the advisory structure.
- As science and research lead to new ideas, evolution and change in advisory bodies and their working groups should be both expected and accepted as the norm.
- Advisory bodies that advise the scientific level as well as the political level are more effective than those that advise the political level alone.

ES2.4. Working with Industry, Other Government Agencies and Academe

ES2.4.1. Introduction

How CCRS worked with those in industry, other government agencies and academe is one of the keys to its success. Words like collaboration, partnership and technology transfer were all part of the vocabulary at CCRS. By and large CCRS listened to its stakeholders both through advisory structures and bilaterally. Furthermore CCRS was generous in sharing success, and paid strict attention to its mandate and those of its partners to ensure cooperation. Here industry, other government agencies and academe are grouped together inasmuch as certain elements of working with others cross these sectoral boundaries.

- The organization should actively build and maintain links with partners and stakeholders in industry, government, and academe as well as with key international partners.
- By partnering with outside organizations, including those engaged in R&D, one can leverage work for broader application to a much wider community. CCRS was able to exert an influence far out of proportion to its small size.
- Words like collaboration, partnership and technology transfer should be part of the essential vocabulary of everyone in the organization.

ES2.4.2. Industry

- Government can be an effective beta client for industry's commercialization activities.

- Do not compete with industry: allow industry and the advisory body to decide what is or is not competition.[6]

- Industry should be fully engaged in advisory bodies.

- Recognizing that industry will, in the end, likely be the agent to make the science operationally useful, mechanisms to involve industry in technology transfer should be in place from the start. These may involve industry employees being embedded in or seconded to government, government staff seconded to industry, incubators, or other mechanisms including Public Private Partnerships.

- In that governments should not be involved in selecting winners and losers, mechanisms to engage industry should be open and transparent and involve independent evaluations of proposals.

- Project reports, not just scientific papers, should be readily available to Canadian industry to lead to commercialization for the benefit of Canada (and the taxpayers who paid for the research).

- To obtain the best result for the dollar expended and to avoid "low-ball" bidding all requests for proposals should indicate the dollar amount set aside for the contract and proponents should be encouraged to make innovative use of the funds available to maximize the return on the expenditure. Such an approach leads to innovation and reduces the potential for less competent "low-ball" bidders winning contracts that they cannot complete or which yield results that they are unable or unwilling to commercialize.

- If industry or other governments have benefited from the R&D done, benefits should be quantified and brought to the attention of the political and senior bureaucratic levels – preferably by industry or the other levels of government most involved.

ES2.4.3. Working with Other Government Agencies

- If the research involves natural resources or other areas that fall mainly within the jurisdiction of the provinces, attention should be paid to cooperation and the development of mechanisms to transfer technology to the lower or other levels of government.

- If the research will serve, or can be expected to serve, another government ministry or agency, the nature of relationships and responsibilities should be formalized to maximize the potential benefits. These agreements may include cost-sharing, secondments, how credit is shared, and how results and benefits are calculated.

- Joint projects with other levels of government and other government agencies or ministries tend to amplify expertise.

ES2.4.4. Working with Academe

- Education is a provincial/territorial responsibility – a Federal agency must be mindful of that fact.

- Academics from universities and colleges should be fully engaged in advisory structures.

[6] This was a bone of some contention. The Ontario Centre for Remote Sensing was accused of unfairly competing with industry, as were some of the other provincial centres.

- Researchers in academe should have access to data and the necessary information for both research and education.

- Beneficial working relationships with academe can take many forms including hiring summer or co-op students, secondments during professorial sabbaticals, or government scientists serving as adjunct professors, thesis examiners, visiting faculty members, or advisors on program structure and/or content.

- Agencies may find it useful to contract research to academics (e.g. funding graduate student research), or contract education and training associated with international activities of the government agency.

- Government scientists participating in research teams involving academics can be an important way to share and further research.

ES2.5. Identifying Opportunities

- To ensure success, work must contribute to the needs and priorities of the government (See Section ES2.9 below.) and, ideally, other levels of government, industry and the international market.

- New government or other funding programs (including international opportunities to which Canada has access) should be evaluated as to their relevance to the organization's activities.

- Creating positive relationships with the media and publicizing successes should be a key activity supported at the highest levels. While perhaps once seen as unusual in a science-based organization in Government, public awareness and marketing should be part of any science program. Such activities will lead to the widest possible understanding of the science and/or technology to ensure that serendipitous applications have a greater chance of being identified.

- There may well be opportunities to contribute to foreign policy, trade and/or international development: these opportunities should be explored.

- All of the above imply that a broadly-focused and technically and scientifically aware marketing activity is required.

ES2.6. Innovation and Problem Solving

- A research and development organization must be a safe place for new ideas: calculated risk is to be encouraged.

- Do more with less – every time. One way to accomplish this is to ensure that every project or activity has more than one potential beneficiary and more than one purpose – i.e. projects should be planned to produce multiple outputs to meet multiple objectives with the same input.

- Build on the verifiable research of others – but do not do "me-too" research (research that simply proves that someone else was right in their conclusions).

ES2.7. Building Research Capacity

- Not every area of needed expertise can be covered by a Canadian – you may have to hire some people from other countries to put you "over the top."

- If the research involves natural resources or other areas that fall mainly within the jurisdiction of the provinces, consideration should be given to how or if research capacity should be built up[7] to meet provincial and territorial needs.

- A diversity of scientific backgrounds of staff can lead to a broader range of potential solutions to research problems.

- A diversity of cultural and linguistic backgrounds of staff can lead to a broader range of potential international markets, as well as a wider range of approaches to scientific questions.
- Budgets must be predictable from year to year to allow for multi-year projects.

- Capital budgets are easy to cut, but such cuts may lead to failing infrastructure in the future.

ES2.8. Putting Innovation into Operation

- **The value of a new technology comes not from its creation, but rather from its use.**

- Recognizing that there is no one appropriate approach to operationalize an innovation, various ways may be used including allowing industry access to scientists through some form of collaborative mechanism (such as an incubator), licensing, transfer mechanism to address other levels of government, etc.

- Ensure that the required suite of technology development tools and relationships are available when and as needed. For example, CCRS had sensor development expertise (scientific, engineering, and technological), test and demonstration capability, applications development expertise and wide connectivity with government and private sectors within Canada and abroad to keep its work relevant and cutting edge.

- To ensure that appropriate companies are engaged to further operationalization of the science governments should try to work with companies that have had success in commercializing R&D.

- Researchers often want a perfect or near-perfect solution. Even the near-perfect solution is often too expensive to implement: industry (or users) should be engaged early in the process (ideally at the beginning) to allow earlier commercialization and early use of the resulting technology and by so doing, be first to market.

ES2.9. Understanding Politics and Politicians

- Obtaining or maintaining financial support for a government program requires the support and interest of the political level. Linkages must be shown between the program and the important

[7] Built up here implies the full range of activities that might be envisioned – how research capacity is organized, strengthened, structured, or enhanced.

issues of the day as outlined in Minister's letters, Speech from the Throne, or policy announcements. These issues may be creating a clean and sustainable environment, job creation, increased exports, etc.

- Members of industry and academe including those active in broadly-based advisory bodies and working groups can contribute to increased visibility, awareness and understanding by the political level through outreach activities, pro-active media coverage, meeting with parliamentarians, etc.

ES2.10. International Relations

- A world-class organization must be both outward-looking and highly competitive.

- International activities must benefit international partners as well as Canada.

- Recognizing that science and the markets to apply innovation from science are international, identifying sufficient funding for international activities is critically important.

- To stake out an interest in a new or developing market for a new area of innovation, it is important to establish a leadership position in the international community. This may be done by volunteering to chair and host a new international committee or working group, lead a technical standards body, or serve as a host repository for information. This may be done through the UN, a development bank or independently. On a much grander scale, one might develop an international training institute or facility – much like the International Space University or the former ITC in the Netherlands.

- Virtually every new technology and its application must be considered in the international context in terms of the science, its application, and the market, including the potential for development assistance through Canadian and international mechanisms.