Supporting Canada's Leadership Role in Astronomy: Untangling the Web of Public Financing

A Report from:

The Coalition for Canadian Astronomy

and

The Working Group for Astronomy

An Examination of the Funding Support for Canadian Astronomy and Astrophysics

October 2006

"*Babbage secured the backing* [1822] *of the Royal Society, which in turn aroused the interest of the Treasury. Babbage had a meeting with the Chancellor of the Exchequer, who was so impressed that he offered £1,000 of government backing there and then. It was not just a generous offer, but an unusual one, demonstrating that the government was beginning to recognize a need to take a role in industrial development. In the following years, Babbage was to discover that working with the government would not be easy. On a number of occasions he would have to draw on his own resources to keep the project from collapsing, as he would not get a proper flow of funding until the early 1830s, when the Duke of Wellington, now Prime Minister, gave it his backing. On, off, fast, slow, hot, cold, Babbage found himself working with a government machine apparently gone haywire. Charles Dickens satirized the process in* Little Dorrit *with the How Not To Do It Office, which specialized in making a meal of 'mechanicians' and 'natural philosophers' like Babbage.*"

from *The Bride of Science* (pp 154-155) by Benjamin Woolley, the story of Ada Lovelace, 19th Century mathematician and partner with Charles Babbage, inventor of the Differencing machine

Background and Objectives

In May 2000, the NRC-NSERC Long Range Planning Panel released its report: *The Origins of Structure in the Universe (LRP)*[1]. Within a few months, the Coalition for Canadian Astronomy was formed with the mandate to engage the resources of the Canadian Astronomical Society (CASCA), the Canadian research community, and Canadian industry to ensure that the goals of the LRP would be achieved.

In 2004, CASCA established a panel to carry out a Mid-Term Review (MTR) of the LRP; their report was completed in November 2004 and released in 2005[2]. In its report, the Review Panel noted the difficulties in funding and managing key elements of the LRP; it recommended that the Association of Canadian Universities for Research in Astronomy (ACURA) and CASCA "…develop and review models for establishing a new structure for developing and managing large facilities for Canadian astronomy". In addition, Dr. Arthur Carty, National Science Advisor, suggested that the Coalition considers examining national funding for astronomy in Canada in light of the experience gained over the previous five years. In the fall of 2004, our *Working Group* (WG) was formed to consider options for a coherent funding system that would ensure that Canadian astronomy and astrophysics remains at the cutting edge of the field and sustains its remarkable past record of scientific achievement in the years to come. This report summarizes our discussions and presents our conclusions[3]. In the interest of succinctness, we refer to information in other documents but generally do not discuss them in detail. Although this document is based on discussions and advice from those who participated in the process, its contents are the responsibility of the members.

Current Status of the LRP

The LRP is an ambitious but realistic plan to ensure the continued excellence and worldwide impact of Canadian astronomy. The plan and its recommendations are motivated by scientific questions astronomers around the world are trying to answer. It does not focus on a single project or facility, but is a broad decadal plan for Canadian astronomy and astrophysics as a whole. The LRP priorities

[1] Commonly referred to as the Long Range Plan or LRP (www.casca.ca/lrp/front-back/en-index.html)
[2] (www.casca.ca/lrp/mtr-approved.pdf).
[3] The Working Group Terms of Reference and Work Plan can be found at www.casca.ca/what/TermsofReference.pdf ; WG membership and participants are given in Appendix 1.

for the development of new facilities and for the training of highly qualified scientists and engineers to design and use those facilities are defined by the goal of understanding the *Origins of Structure in the Universe*. It is supported by the entire Canadian astronomical community as represented by the Canadian Astronomical Society, the Association of Canadian Universities for Research in Astronomy, and by Canadian industries who benefit from the challenges of designing and building the innovative facilities and instruments required. The LRP has also been endorsed by various Federal Members of Parliament from all political parties. That political support is a major reason the LRP received its initial federal funding and contributed significantly to the successes of the plan. But we are only part of the way to our goal. In working to secure funding for the LRP, the Coalition and those it represents have struggled with the maze of funding agencies and Federal Government Departments whose support is needed for such a broad, discipline-wide plan. The WG was formed out of the difficulties the Coalition faced and with the aim of defining a coherent and robust funding structure or process which would be more satisfactory than the current funding system.

The WG began by reviewing the progress of the LRP, its successes, its failures, and by identifying the funding needed to complete the Plan. Results from this process are summarized in the *Phase 1 and 2 Report*[4] which was completed in November 2005. Among the successes noted were:

- partnership in the James Webb Space Telescope (JWST) and the Atacama Large Millimetre Array (ALMA) through NAPRA (North American Partnership in Radio Astronomy);
- partnership in the early design phases of the Thirty-Metre Telescope (TMT); continuing involvement in planning for a Square Kilometre Array (SKA); and
- significant growth in the number of faculty and graduate students engaged in astronomical research at Canadian universities.

The report also highlighted two major difficulties encountered in achieving the goals of the LRP:

1) the fragmented and overly complex system that had to be navigated in order to secure funding from the various agencies which each had different criteria, timelines, and internal management processes; and
2) the practice of the Federal Government and its Agencies of not providing specific funding beyond five years.

The WG concluded that "the present lack of a policy for large science projects and of a long-term vision for funding them is at the core of the problem." We should note here that, while *large science projects* are often discussed in terms of building a major facility, the scientific goals are what provide the motivation. Funding the scientific research is a key part of funding the LRP.

During our process of developing a report, the National Science Advisor, Dr. Arthur Carty, and his office (ONSA) completed their review of science, releasing the *Framework for Major Science Investments*[5] which explores the need for Canada to set both priorities and a process for review, funding, and oversight of major science projects. While this report has elements in common with our work, we believe that the fundamental context of the WG is significantly different. As

[4] Attached to the Report are tables (some from the MTR) which identify funding needs; the report can be found at www.casca.ca/what/WGPhase12Reportglhh.pdf

[5] (http://science.pco-bcp.gc.ca/default.asp?Language=E&Page=discussion)

previously mentioned, the LRP is a unified discipline-wide framework requiring Canadian participation in a range of facilities and directions. This coherent plan defines a small number of crucial scientific investments which, in total, will allow Canadian astronomers and astrophysicists to play a major role in answering important scientific questions. The NSA report does not deal with this type of approach. Instead it focuses on evaluating and funding single, large projects. In addition, though many of the major LRP priorities are "Big Science", not every priority requires "Big Science" funding level for Canadian participation. The eventual structure for funding major science initiatives may well provide options for funding a future LRP, but no such structure is in place at present and the need to fund the LRP is ongoing and even urgent at times.

Test Cases and Funding Models

The Working Group then proceeded to consider how the current funding situation might be remedied, or at least improved, by looking at specific projects as test cases. Those chosen were:

- JWST: the LRP's top priority for new space facilities; already funded by the CSA;
- TMT: the top priority for new optical, ground-based facility; Canada is a 25% partner through ACURA and the project is currently in the Detailed Design and Development phase, Canadian researchers and industries playing an active role.
- SKA: the top priority in ground-based radio astronomy; Canada is a member of the Steering Committee but funding for this early-stage participation is not ensured; and
- Canadian High Performance Computing Consortium (HPC): an enabling technology that supports much research in astronomy as well as many other fields. A proposal has been submitted to the Canada Foundation for Innovation (CFI) but HPC will also need operational support from NSERC and other sources.

These four projects have markedly different timelines and different primary funding routes. They also have different, but complementary, science goals, different technical challenges and different costs for Canadian partnership. And, although only one or two funding agencies are named, to ensure the full scientific benefit of any of these projects will normally require support from at least one additional agency (see Appendices 2 and 3 for more detail). In our discussions, it quickly became clear that success for every test case would be limited by a lack of coordination among the multiplicity of agencies even if, in principle, the necessary funds were available.

For instance:

- Canada's participation in JWST has been funded by the Canadian Space Agency (CSA), but gaining the opportunity to develop and build key instrumentation has involved astronomers from both the NRC Herzberg Institute for Astrophysics (HIA) and the university communities – funded by the NRC, NSERC and Canadian universities.
- Funds for Canadian participation in the TMT design phase received from CFI represent less than 20% of our financial commitment. NRC/HIA and NSERC have also provided support to this point. But, even if the CFI provides funds to support Canadian participation in the construction, operation, and the scientific discoveries of the TMT, it is not clear that it will be able to fully fund the required capital cost. Securing the remaining capital would then be problematic.

- Canadian participation in the SKA Steering Group has been supported by funds from NRC and NSERC, but our continued involvement in the planning is being compromised by the lack of policy and appropriate programs that can be used to support such activities, particularly when this may involve transfer payments.
- The HPC consortium is national and multidisciplinary, making it very different from the other three which are international and astronomy alone. Its structure is more that of an *enabling platform* for a broad range of disciplines, but one of particular importance to Canadian astronomers and astrophysicists. HPC supporters and ultimate users, however, will also come from both government laboratories and universities. While the funding will come from the same group of agencies, the multidisciplinary component will likely alter the way in which resources are applied for and allocated.

Again, details on these and other issues for three of the projects (TMT, HPC, JWST) are summarized in the Tables in Appendix 2; no Table is included for the SKA since it is both at a much earlier stage and potentially has elements in common with the TMT.

Agency Roles, Mandates, Barriers

With its membership representing astronomers at universities and government laboratories, university administrators and industry, and enhanced by the active participation of Vice Presidents of the CSA, NRC, and NSERC, the WG was able to address a range of issues. Moreover, it was clear that the participants were all committed to addressing the issues at hand. This led to genuinely open and frank discussion and ultimately strong consensus.

As the WG examined funding complexities for the four major facility priorities described above, its discussion continually spiralled back to the same issues, most of which were related to the resources and mandates of the major federal science funding agencies in Canada: CFI, CSA, NRC, and NSERC. While other funding sources, especially the provinces are also relevant, our group focussed solely on federal funding. In our discussions, we explored the mandate, structure, skills, processes, strengths and weaknesses which result. A brief summary of the four agencies in this context can be found in Appendix 3 of this report. Common topics for any of the projects being discussed were:

- What is the possible role of each agency?
- What expertise does the agency bring to support that project?
- What is the effect of an agency's mandate on possible participation and/or leadership?
- How is each agency accountable to the public and the scientific community when it becomes involved in a major science initiative?
- What are the barriers to participation at any level?, and
- What can the agencies do by working together to improve the situation?

Conclusions

Our unavoidable conclusions are that:

1) Agency cooperation and coordination can make a difference. But this is limited and, no matter how successful that coordination and cooperation, it cannot compensate for fundamental weaknesses in the current funding system of the Federal Government.

2) Ultimately, what is needed is a stronger and more consistent Government commitment that is flexible, peer reviewed, rigorous, responsive, accountable, and provides "end-to-end" funding support for major projects.

Recommendations

Based on this analysis, the WG proposes two major recommendations for consideration by the Government of Canada:

The Working Group of the Coalition for Canadian astronomy recommends:

1) ***That the relevant agencies work together when possible to support strong science initiatives, in any discipline; and this should be facilitated by regular interagency communication***.

One model currently employed in the United States is the Astronomy and Astrophysics Advisory Committee (AAAC) which advises the National Science Foundation (NSF), the National Aeronautics and Space Administration (NASA) and the U.S. Department of Energy (DOE) on selected issues within the fields of astronomy and astrophysics that are of mutual interest and concern to the agencies[6]. Any interagency coordination that is developed will also be able to deal with gaps that are present in both process and structure, leading to efficiencies within the agencies as well as more effective science priority setting.

Moving to a stronger, more visionary and more consistent government policy on Canadian science will require substantive changes that we cannot address here. But we recommend:

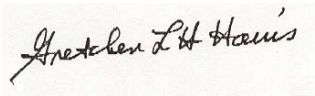
2) ***That the Government of Canada adopt, as a major priority, a stronger, more visionary and more consistent government policy on Canadian science and establishes a dedicated and integrated process and structure for the long-term funding and management of astronomy and astrophysics***.

This is a challenge being faced by many of the countries which are both partners and direct competitors of Canada in astronomy; and it is one which must be met in order to adapt to the rapidly changing needs for future major observatories, computational resources, effective planning and operation. The Canada-made solution will have substantial impact on our astronomical research community and its ability to maintain the strong international presence we have worked so successfully to achieve. Both in the United States and in the United

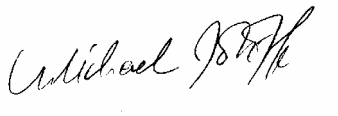
[6] (www.nsf.gov/mps/ast/aaac.jsp)

Kingdom (Canada's major peers in astronomical research), the funding structures and mechanisms to engage astronomers in priority setting and long-range planning are different from those of the Canadian environment. Hence, they provide a reference which will be useful when implementing this recommendation. One option, currently being put into operation in the UK, is a single agency which coordinates and funds large research facilities. This has clear advantages with regard to coordination of funding and long-term planning. However, care will have to be exercised in ensuring that this structure provides the strong connections between the research community and government policy and decision-making. The picture is rather different in the U.S. where astronomy is funded by several government agencies (primarily NSF, DOE, and NASA) and private foundations. Planning and priority setting are carried out through a decadal review process that has deep engagement with the research community. Recommendations of each review are then used by the funding agencies to guide their priority setting and long-range funding plans for astronomy.

Signed:



Gretchen Harris (Présidente)



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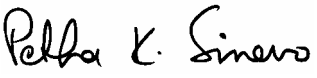

Pekka Sinervo

Greg Fahlman

Appendix 1: Working Group Participants

Working Group Members:

- Coalition Co-Chair/CASCA
  - Gretchen Harris, Past President of CASCA – WG Chair
- Coalition Co-Chair/Industry
  - Michael Jolliffe, Vice-President, Government Relations and Communications, Americas, AMEC
- Coalition Co-Chair/ACURA
  - Pekka Sinervo, Dean of Arts and Sciences, University of Toronto
- ACURA
  - René Racine, Executive Director
- NRC/HIA
  - Greg Fahlman, Director General

Invited Participants:

- Canadian Foundation for Innovation
  - Carmen Charette, Senior Vice-President (now with Industry Canada)
  - Kate Wilson, Coordinator, International Relations
    (CFI did not participate in 2006 meetings and were not involved in the preparation of this document.)
- Canadian Space Agency
  - Alain Berinstain, Director, Planetary Exploration and Space Astronomy
  - Denis Laurin, Senior Program Scientist
- National Research Council
  - Richard Normandin, Vice-President, Research
  - Carl Caron, A/Director, Physical Sciences
- Natural Sciences and Engineering Research Council
  - Isabelle Blain, Vice-President, Research Grants and Scholarships
  - Kate Wilson, Manager, Physics and Astronomy (now with the CFI)
- Office of the National Science Advisor
  - Kevin Fitzgibbons, Executive Director

Other Participants and Observers:

The WG also benefited from the presence and participation of many others over the past two years. These included: Ralph Pudritz (Chair of the Long Range Planning Panel), Ernie Seaquist (Chair of the MidTerm Review Panel), Feyrouz Kurji (Director, Knowledge Infrastructure, Industry Canada), Joshua Bowie (Policy Analyst, Knowledge Infrastructure, Industry Canada), Jim Hesser (Director, Dominion Astrophysical Observatory; immediate Past President of CASCA), and Peter Martin (current CASCA President and Coalition Co-Chair).

We are most grateful to all of those who participated and provided the WG with such a broad, thoughtful, and honest perspective in this genuinely difficult task.

Appendix 2: The Role of Funding Agencies and Test Case Projects

Funding Agencies							
Oversight	**Government**					**Non-Government**	
Role	Operating		Granting			Nlanning…	
Agency	**CSA**	**NRC**	**CFI**	**NSERC**	**Provinces**	**CASCA**	**ACURA**
Annual Budget for Astronomy	~$3M/yr in operating funds for Space Astronomy within Space Science Division, plus capital funds for specific projects (see astronomy Agency Table)	• ~$30M • Annual budget of HIA, including LRP (~$10M) and Telescope Transfer payments (~$10M)	• no specific budget line: average: $4M/yr for all Astronomy awards	• GSC 17: $5M • Other Programs not discipline specific: ~$3M/yr to Astronomy	• not discipline specific: university support; CFI matching awards	• N/A: Professional Society	• ~$100k (internal ops)
Governance and Accountability	• Industry Canada • GoC Appointed President • GoC appointed Advisory Board • Direct report to Minister • Space Astronomy has an Advisory Board jointly appointed with CASCA (JCSA) and SSE Thrust has a Thrust Advisory Group	• Industry Canada • GoC appointed President • IC/GoC appointed Council • President reports to IC Minister • HIA has an Advisory Board appointed by NRC Management	• Foundation owned by the GoC and endowed by direct transfer of GoC funds • GoC appointed Members • GoC + Member appointed Board	• Industry Canada • IC/GoC appointed Council • President reports to IC Minister	• No national mandate • Relevant provincial agencies typically have Advisory groups • Provincial Governments and Legislatures	• Elected Board • AGM of membership • Committee structure to provide advice to the CACSA Board	• Member appointed Institutional Council • Elected Management Board • Executive Director

Case 1: The Thirty-Metre Telescope: TMT

	TMT SPECIFIC						
Agency	**CSA**	**NRC**	**CFI**	**NSERC**	**Provinces**	**CASCA**	**ACURA**
Current TMT Role	• No direct role	• Pre-DDP work with LRP funds • Support of ACURA-led effort in the DDP of TMT Project through staff work and project management roles • CFI in-kind matching • NSERC SRO support • Expected to have a continuing role	• Interim funding of $4M • Required $6M of matching funds • Future role is uncertain	• Initial grant to explore International Opportunities for VLOT project • Has accepted SRO LOI for additional funds needed to complete DDP	• Ontario: $2M for CFI match • BC has agreed to provide $2M but details still not finalized • Future roles are uncertain	• Oversight role as part of Coalition for Canadian Astronomy	• Adhering organization in the TMT Project • Appoints TMT Board members • Provides oversight of TMT Project in Canada.
Past/Current Funding	N/A	• LRP: $4.2M for FY2002-05 (3 years) • Supplemented by HIA internal resources to end of FY2006-07 • Total TMT-specific to date: $4.5M	▪ $4M direct to U of Toronto	• IOF (2000-01): $260k – not TMT specific.	• Ont: $2M • BC: $2M	N/A	• ~$50k on operations for TMT Oversight

Case 2: High Performance Computing: HPC

	HPC SPECIFIC						
Agency	**CSA**	**NRC**	**CFI**	**NSERC**	**Provinces**	**CASCA**	**ACURA**

Current HPC Role	• No specific role, (other than possible user?)	• No specific role, (other than possible user?)	• Provided larger part of the equipment and infrastructure
			• Has launched the New Platform Fund with
			  ○ Up to $60M in capital funds
			  ○ Up to $18M in operating funds
				• Funding partner to CFI, for operating funds
				• Funds the research carried out using HPC
				• Currently, the HPC consortium receive $1M in operating funds;
				• Total research activities funding estimated at over $50M, in 2005-06 (GSC17 accounts for ~1.5% of this)
					• Match CFI grants
					• Major operating (e.g., electricity) expenses
						• No specific role	• No specific role.

Past/Current Funding	N/A	N/A	• Contributed to infrastructure in 7 HPC centres across the country	• Funding has increased 5-fold since 2000 • In2005, has contributed to the preparation of an HPC LRP	• As above	N/A	N/A
Future Funding/Roles	• Possible user	• Possible user	• Uncertain, beyond current NPF contribution	• Funding of operating and research costs	• Funding of operating costs	N/A	N/A

Case 3: The James Webb Space Telescope: JWST

	JWST Specific						
Agency	**CSA**	**NRC**	**CFI**	**NSERC**	**Provinces**	**CASCA**	**ACURA**
Current JWST Role	• Responsible for the construction and delivery to NASA of: Tunable Filter and Fine Guidance Sensor • Project management interface between Canadian industry and NASA. • Support of Science Team • CSA/NASA Letter of Agreement, eventual MOU.	• Optical concept development of FGS. Contributed in expertise in optical design and detectors. • Canadian Principal Investigator is HIA scientist.				• Oversight of LRP, in which JWST is an element	• No specific role.
Past/Current Funding	• Average $6M/yr for 9 years; peak spending $18M/yr. • $450K/yr science team support.	• Direct costs covered through OGD agreement with CSA				N/A	N/A
Future Funding/Roles	• Fund to completion and delivery. • $600K/science team during operations.	• Construction activities as above • Marginal data management costs covered through CADC.		• Possibility for support of instrument development and data analysis through various NSERC programs		N/A	N/A

Appendix 3: Astronomy Agency Table – Comparison of Mandates, Structures, Funding Processes

	NRC	CSA	NSERC	CFI	ACURA
Type	Schedule 2 (Council) Operating Agency:	Operating Agency: effectively a Government Department	Schedule 2 (Council) Granting Agency	Independent granting agency; direct endowment from Government	University-member corporation
Mandate (informal relevant to astronomy)	To fund and develop Canada's Ground-based Astronomical Observatories	To fund , manage and operate Canadian space astronomy missions	To support university and industrial based research through peer reviewed grant programs	To fund infrastructure that will advance the capabilities of Canadian Universities.	To ensure that Canada's university community has access to top-flight research facilities in Astronomy
Unit (most directly relevant: other parts of the organization may play roles)	Herzberg Institute of Astrophysics HIA: an Institute currently within the Physical Sciences Portfolio of NRC	Space Science Division: Astronomy program; Once a mission completes Phase A it is passed to Space Programs division for implementation.	Grant Selection Committee 17 : includes Space Physics and research in General Relativity; other programs are used by the community	Competitions as announced; Canada Research Chair start-up support (New Opportunities).	Institutional Council top-level body; Board of Management acts as an executive council; Executive Director
Governance and Accountability	The Council governs NRC as specified in the NRC Act. Members are appointed by the Government. HIA has an Advisory Board that reports to the Portfolio VP. The HIA-AB mandate is defined solely by the NRC Executive. The reports are not made public. In practice, HIA takes advice from a very broad array of Boards and Committees populated with established members of the community.	President reports directly to Industry Minister. CSA advised on astronomy from Joint Committee on Space Astronomy (JCSA): JCSA strictly advisory, joint with CASCA, and shared mandate. Reports are made public through CSA and CASCA. Space Science and Exploration Advisory Group advises on overall thrust; CSA Advisory Council advises on overall space program	Like NRC, NSERC is accountable upward to Parliament, through the Minister of Industry. Accountability to the community is through Council, appointed by the Government. The Peer review committee decisions are made public by NSERC.	The CFI is governed by a Board of Trustees, appointed by Government. Decisions are made public by the CFI.	ACURA Institutional Council members are appointed by their respective Universities. Public accountability is through the Universities.

	NRC	CSA	NSERC	CFI	ACURA
Modus Operandi	HIA executes the specific mandate in the NRC Act, following NRC operating policies. HIA supports and interacts with the community in a variety of ways and operates peer review committees for telescope access. HIA has a largely unique in-house capability to engage in long-term development and construction projects. It acts much like a "national laboratory" for astronomy.	Space Science, headed by a DG; supports several disciplines; Astronomy has small number of specific staff assigned. Primarily a management organization with a wide range of programs/procedures to support projects in academia, government and industry. Several CSA projects are being developed in conjunction with NRC-HIA.	GSC 17 is guided by a senior NSERC staff member but is a peer review body that recommends specific allocations of funds to NSERC management. All relevant NSERC programs work in a similar way. Primarily supports self-directed research; awards based primarily on merit. Funds are granted directly to researchers	Convenes multi-layered peer review bodies that take strategic goals into consideration. Funds are allocated to Universities, not individual researchers; Provincial matching funds usually required, as are additional matching funds from University sources.	Provides strategic guidance and oversight; is the lead for Canada in the TMT project; acts through the Executive Director, the BOM and Institutional Council;
Priorities and Planning	The HIA strategic plan is based on implementing the Astronomy LRP. The LRP is implemented through specific projects and staff allocations that are internally determined but are subject to scrutiny by external bodies (CASCA; HIA AB; external project panels)	Primarily through the Joint Committee for Space Astronomy (JCSA) and the Space Science and Exploration Advisory Group. Activities are based on an internally generated space astronomy plan but this is generally consistent with the LRP.	Internally driven via Council and Government priorities; has some internal mechanisms to rationalize support across disciplines. The GSC is an independent group. Supported the development of the LRP but has no internal mechanisms for implementation.	Board of Trustees sets policy; generally seems to react to Government priorities defined by earmarked endowment funds. Has no particular commitment to the Astronomy LRP (now).	Through decisions of Institutional Council. The relevant planning document is the Astronomy LRP
International Activities	Signed agreements covering CFHT, JCMT, Gemini and ALMA; other national funding agencies recognize NRC as Canada's Astronomy "funding agency".	The CSA has numerous international agreements related to space astronomy. Typically interacts with like-organizations in other nations or blocs (e.g., NASA, ESA).	NSERC, to my knowledge, is not directly involved in International facilities as a managing or administering agency.	Not directly involved in International ventures as a managing or administrative partner.	Charter allows for participation in international ventures. ACURA is the adhering partner to TMT.

	NRC	CSA	NSERC	CFI	ACURA
Current Funding Levels (not definitive)	The current HIA budget is about $30M/yr for everything. This number is typical of the post-2003 levels of funding: LRP + EVLA + A-base + "contributions". The A-base is about $10M, including salaries (70%), operations and capital. Contributions to off-shore facilities are around $10M/yr and increasing.	Current CSA budget for all programs is ~$300M/yr; annual $$ to astronomy related activities depends on capital expenditures for building of hardware. Projects being supported include: JWST, MOST, ODIN, FUSE, HIFI, Planck, SPIRE, BLAST, and UVIT. Concept development for future missions supported. Ongoing, non capital, space astronomy budget ~$3M/yr.	GSC17 dispenses about $5M/yr as grants. Scholarships add another $1M/yr (according to NSERC report generator. The CITA grant, equipment and SRO's must add another $1.5M or maybe $2M to the total. We can put NSERC at about $8M/yr.	Over 8 years, the total for Astronomy and Astrophysics awards is $31M including New Opportunities and so on. This works out to about $4M/yr over the lifetime of the CFI. (The numbers are current as of Jan 2006)	N/A to ACURA. BC+ON = $4M match to CFI for TMT. Most Provinces have competitive programs that provide some benefits for university astronomers. This is likely very small relative to the Federal Agencies' support.
Capital	NRC has provided most (not all) of the capital funding for the existing facilities. NRC provides capital for HIA internal use (equipment, buildings, project components, computers and the like).	CSA funding must include capital for the construction phase (Phases B/C/D) of a mission. Example capital budgets: JWST: ~$6M/yr x 9years. MOST: ~1.8M/yr x 5 years HIFI: ~1.9M/yr x 5 years UVIT: ~1.5M/yr x 3 years	NSERC made a capital contribution to Gemini; has supported some instrumentation development associated with CFHT and JCMT (relatively small amounts). NSERC provides capital for researcher-specific equipment. This is included in the $8M estimated above.	CFI has funded the direct Canadian contribution to SCUBA-2 ($12.3M) and provided $7.9M for ALMA, $4M to TMT. Overall, the CFI has provided about $26M to facilities (including Obs Mt. Mégantic), with the rest (about $5M) to individuals over an 8 year period.	N/A. ACURA will likely rely on the Federal funding agencies for capital funds (or a direct grant from Government). Funds may come from the Provinces or from private sources.
Operating	NRC provides contributions to offshore observatories for their operations (about $10M/yr and increasing) as well as operating funds to HIA (about $20M, about 1/2 of which is soft LRP funding). Approximately 1/2 of the total operational money is for salaries.	CSA provides operating funding at the project level (e.g., FUSE, MOST, HIFI, JWST) and at the researcher level (e.g., the IC at LAE in Montreal) to interpret raw results.	Most of the $8M noted earlier is for operating (research specific) and mainly goes to student and PDF salaries. I estimate the breakdown is about 75% salary and 25% travel and minor equipment	CFI provides some limited operational funding for the SCUBA-2 project – for infrastructure support.	N/A ACURA will likely rely on the Federal Government funding agencies for operational support of major national infrastructure.

	NRC	CSA	NSERC	CFI	ACURA
Strengths	HIA has a unique technical capability: can do the "heavy lifting" in getting large projects completed NRC has other Corporate and Institute-level resources that can be tapped by HIA to help move projects forward NRC has relatively deep pockets that can buffer HIA project-level activities against government pay-as-you-go rules.	Project management expertise engaging government, industry and academia in international projects. Links with international space agencies required for partnership in space projects. Can engage in long-term and large-scale projects. Has an Agreement with the TBS that permits active engagement (grant funding) to help develop the apace astronomy community in the universities.	Peer-review, merit-based competitive funding. Directly finds researchers with minimal strings attached Flexibility in tailoring programs to meet needs of community (stronservice ethic). Committed to development of HQP (graduate student and PDF support)	Huge pots of money that are allocated through a rigorous peer-review system. Can engage in long-term and large-scale projects.	Provides a new platform on which national-scale projects in Astronomy can be managed on behalf of the primary user community. Ensures that Government and Federal Agency national astronomy priorities are consistent with University and community goals
Weaknesses	Priority setting at the Corporate level: a Council responsibility Accountability to the community Lack of flexibility in working with University-based researchers	CSA strategy is to increase its capability by partnering with other international agencies to increase benefits to Canadians. By doing so, the CSA is not always in control of the mission selection process or timing.	Limited ability to go beyond historical precedents for discipline level funding Inability (unwillingness) to make long-term commitments	Irregular funding opportunities Lack of operational support Matching funds required for most projects	Limited internal funds Novelty
System	• Lack of coordination between Agencies: leads to whipsaw effects of project funding requiring operational or scientific support (e.g., CFI capital funding → NSERC or NRC for operational funding). • Federal Finance Administration inhibits inter-agency cooperation (exchange of funds is severely limited). • Federal-Provincial jurisdictional issues arise for National projects (LRP) funded through CFI. • No mechanisms to support large scale projects with all Agencies properly in-phase and on-board.				