A Comprehensive Plan for Development and Maintenance of a Flourishing Space Physical Science Community in Countries with Modest Population Base

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Abstract

Space agencies of countries such as Canada experience particular challenges with respect to the establishment and maintenance of a flourishing space physical sciences community. The Canadian Space Agency has developed a long-term plan that will allow a relatively large number of Canadian scientists and industry partners to contribute to space physical science, and that will also provide a continual flow of flight experiments. This plan has inherent flexibility, allowing it to be adapted and used by space agencies of countries with a similar population base and resource capability as Canada. The plan can be visualized as a pyramid, with conceptual studies forming the base, and flight experiments the peak. Conceptual studies are solicited through a yearly Announcement of Opportunity (AO) that supplies grants to top-ranked proposals. Feasibility studies, which follow naturally from successfully completed conceptual studies, are solicited in the same AO. Depending on the maturity and complexity of the scientific and technical requirements for a flight experiment, a research team can submit proposals for flight experiment AOs *de novo* (i.e. without previous CSA funding) or after a successful feasibility study. Announcements of Opportunity for flight experiment will be offered every two years, depending on the number of successful proposals undergoing implementation. Applicants to these AOs will be able to tailor proposals to appropriate categories; i.e. proposals that have low resource (e.g. upmass, crewtime) requirements will be assessed separately from proposals that have significant resource requirements. It is expected that this AO scheme, combined with strategic support of workshops and a strong network of collaboration among international partner agencies, will allow CSA to develop and sustain a vigorous space physical science community.

1. Introduction

The Canadian Space Agency (CSA) was established in 1989, and has the following mandate: "To promote the peaceful use and development of space, to advance the knowledge of space through science and to ensure that space science and technology provide social and economic benefits for Canadians[1)]". The Space Science division of the CSA has the responsibility of providing Canadian scientists access to the unique environment of space. The Life and Physical Sciences group within Space Science has developed a comprehensive program that provides a rational route for development and nurture of the Canadian microgravity research community. The objective here is to explain the elements of this program in the context of a space agency in a country with a relatively modest population base (32,000,000). The constraints and opportunities associated with Canadian space research are in many ways similar to other countries with a similar population base, but there also exist certain unique features of the Canadian space research context. Consequently, much, but not all of the CSA Physical Science program elements may be exportable to other nations.

2. The Canadian Research Context

The Canadian population is mainly distributed across a narrow region of southern Canada, spanning a distance of 4500 km from east to west. Within this belt, 62% of the Canadian population is found within two provinces, Ontario and Québec. This geographical reality imposes certain restrictions on the ease with which the CSA can communicate its program elements to scientific constituents; most communication to this end is done electronically. Countries that lack this geographical constraint have options (e.g. regular information sessions at research institutions) that are unwieldy in Canada.

Within Canada, public sector-funded fundamental and applied physical sciences research is administered by the Natural Sciences and Engineering Research Council (NSERC). Grant Selection Committees (GRC) assess proposals submitted to NSERC research competitions. However, NSERC does not have a GSC for microgravity research. Consequently, the CSA is the sole provider of public sector funds to physical science researchers interested in expanding their research programs to microgravity research, regardless of whether access to space is required for such research.

3. The Canadian Space Context

The Canadian Space Agency currently supports research on the following reduced gravity platforms: parabolic aircraft; recoverable satellites; and the International Space Station (ISS). The CSA, through an agreement with the National Research Council of Canada, has direct access to an aircraft capable of parabolic flight. For the other platforms, access to the

platforms is gained through collaboration with CSA's International Partner (IP) agencies.

The CSA is one of the ISS partners, and, because of the contribution of the CANADARM 2 on ISS, the CSA has allocations to certain ISS resources (e.g. crewtime on the non-Russian side of ISS). However, there are important differences between the CSA and the other ISS partners, notably with respect to the nature of the contribution to ISS, and to the size of the population base underlying the CSA constituency (**Table 1**). Notwithstanding the essential nature of the Canadarm 2 to ISS construction, the relative allocation of ISS resources to Canada is significantly less than the allocation of resources to the other ISS partners, all of whom will contribute at least one pressurized module to ISS. Thus the CSA has the opportunity to utilize ISS resources for physical sciences experimentation, but must do so within the constraints of the CSA ISS allocation and the budget realities driven in part by the relatively small tax-base of Canada.

With regards to other research platforms in the reduced gravity, near free-fall environment, the

CSA does not support a domestic sounding rocket program, lacks a domestic drop tower, and does not have launch capacity for recoverable satellites. However, access to these platforms is possible through the CSA's membership in the European Life and Physical Sciences program (ELIPS-2).

4. Elements of the Physical Sciences Program

The responsibility of the CSA to the microgravity community does not begin and end with the provision of access to reduced gravity environments. Additional responsibilities include:

Development of hardware to meet the requirements of Canadian microgravity

Table 1 Salient characteristics of the International Space Station partners.

Partner	Population Base (millions)	Contribution to ISS
CSA	32	Canadarm 2
European Space Agency	459*	Columbus module
Japanese Aerospace and Exploration Agency	126	Kibo module
National Aeronautics and Space Administration	281	Destiny Laboratory Module, other modules
Russia	141	Zvezda, other modules

*Population of Europe, thus the potential population base

- researchers. In many cases, it may be possible to negotiate the use of an IP's equipment for flight experiments, but the CSA anticipates that there will always be a need for CSA to develop its own hardware, be it experiment-specific equipment or facilities that can host more than one experiment or types of experiments.
- Development of a healthy microgravity research community. In this context, 'healthy' means that a body of researchers develops a strong core of experience with microgravity research, and collectively achieves a significant measure of respect within the global microgravity research community.
- Development of mechanisms for researchers to gradually proceed from initial ideas for microgravity research to fully-fledged, mature proposals for flight experiments. It is also necessary to have a mechanism for a scientist to directly submit a proposal for a flight experiment, in the case where the quality of idea supersedes the need for gradual development of microgravity research experience.
- Encourage Canadian microgravity researchers to join forces with scientists from other countries when appropriate. This is best done if there is a mechanism for Canadians to submit proposals to the CSA for the ground-based research required for the Canadian scientist's function within the international team.

In order to meet these responsibilities, the Life and Physical Sciences (LPS) division, as well as LPS's umbrella group within CSA (Space Science), have developed a suite of Announcements of Opportunity (**Table 2**).

Of these AOs, two are aimed at the development and maturation of new ideas for microgravity research (Space Science Enhancement Program) or missions (Mission Concepts), and two solicit proposals for new flight experiments (Low Resource and Small Missions AOs). The principal difference between the Low Resource and Small Missions AO is that the Small Missions AO is less constrained with respect to resource requirements (e.g. mass and volume of hardware), and Small Missions proposals can include requests for funds for hardware development. For successful proposals in the Low Resource AO, hardware development occurs through separate processes internal to CSA. The main platforms targeted for microgravity research in these flight experiment AOs are the International Space Station and recoverable satellites.

The Low Resource (LR) AO has an additional objective of allowing Canadian researchers to submit proposals for the components of their ground-based research that is required for full participation in international teams of microgravity researchers working towards international flight experiments.

Table 2 Announcement of Opportunities (AOs) within CSA Space Science that are relevant to microgravity research.

AO	Purpose	Typical Applicants
Space Science Enhancement Program (SSEP)	Development of concepts, and testing of feasibility of experimental approaches	Scientists from academia, government, or industry
Low Resource (LR)	Flight experiments with low requirements for mass, volume, and crewtime	Scientists from academia, government, or industry
Small Missions (SM)	Flight experiments that can be executed within a three year period	Teams consisting of academic scientists and industry personnel
Mission Concepts (MC)	Development of novel concepts for flight experiments (typically these have a hardware component)	Teams consisting of academic scientists and industry personnel

The AO suite can be visualized as a pyramid with concept and feasibility studies forming the base of the pyramid, and flight experiments forming the apex of the pyramid.

CSA Space Science also periodically issues *ad hoc* AOs that are aimed at specific flight opportunities (e.g. a recoverable satellite).

5. Essential Aspects of Announcements of Opportunity

Timing and frequency of recurrence of each AO is important, and must balance the following demands: **a)** provide timely opportunities for researchers to advance from concept research to flight experiments; **b)** allow applicants sufficient time to develop ideas, plans, and team memberships to the level where they will be competitive at an international level; **c)** permit CSA staff to administer and co-ordinate review processes in an efficient and timely manner. This last aspect of the program is perhaps the most difficult, because of the AO development and administration requires significant human resources.

Each agency must also determine a plan for review of AOs. It is essential that scientific peer-review be a component of all AO reviews, and for all AOs, with the exception of SSEP, an additional technical review is also required. The best practice for such AOs is to first conduct a fair and sound scientific peer review, which culminates in the establishment of a ranked list of proposals. The technical review can then develop an implementation plan based on the scientific ranking, feasibility of execution, and availability of suitable flight opportunities.

6. Development of Equipment (Hardware) for Flight Experiments

In many cases, the need for hardware development springs directly from successful proposals for flight experiments. If hardware is required for a flight experiment, the space agency has the choice of developing the hardware itself, or, if appropriate, negotiating use of an IP's hardware. Evidently, considering the costs and constraints associated with flight experiments, it is highly desirable to use existing hardware, if appropriate, and if an appropriate arrangement can be made with the owner of the hardware.

A space agency also needs to have mechanisms that lead to the design and construction of new space-based hardware for flight experiments. The role of the agency is to co-ordinate and integrate inputs from several sources (**Fig. 1**) in order to develop plans for new hardware.

In this overall scheme, CSA can solicit input through the organization of workshops that aim to identify needs of the research community. CSA can also receive similar inputs through consultation, which can involve CSA personnel as well as industry and academia. Workshops can use reports from these consultations as a 'seed' for discussion, and consultation groups can also be involved in the preparation and analysis of reports from workshops. Advisory groups play an important role in helping CSA to assess and integrate the inputs received from consultation and workshops. Each of the three inputs (workshops, consultation, advisory groups) could potentially be used independently to provide direction for hardware development, but it is more likely (and preferable) that hardware development plans will arise from an integrative approach that uses all three inputs. IP agencies are also an important input into this process, through discussion in bilateral or multilateral fora aimed at identification of future hardware needs.

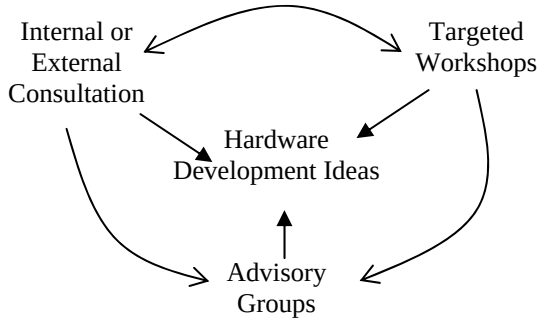

Fig. 1 Inputs leading to development of new ideas for space-based hardware.

7. Conclusion

All space agencies face budgetary and human resource constraints that limit their ability to fulfill all of the needs of the microgravity research community. For this reason, it is essential that each space agency develop a program that allows scientists to compete fairly, allowing nurturing of new ideas into high quality flight experiments. The program described here provides the basis for such a program, yet has inherent flexibility to suit the specific requirements of each space agency.

Reference

1) Canadian Space Agency Act, SC. 1990, c. 13