IACPES Policy Project

The Importance of Collaboration between Universities, Industry and Government: A Canadian Space Exploration Perspective

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Preface

The motivation to pursue this policy topic stems directly from my graduate research project which has involved developing laser-based techniques for detecting different forms of water and minerals at the surface of Mars. This research has naturally led to the desire to learn more about the steps involved in making space-bound instruments a reality.

During my studies, I've been fortunate to work under the supervision of Dr. Jim Whiteway who was the Principal Investigator of the Canadian developed Lidar instrument on board the NASA Phoenix Mars lander. This has led to several opportunities for exposure and involvement in the decision-making processes which ultimately make planetary missions a reality. These activities have included personal conversations with senior scientists, members of industry, and members of government, which have taken place through several avenues including policy conferences, science conferences, and university visits. Further, I have been involved in contributions to Canadian Space Agency (CSA) proposals and funded projects, including participating from inception through to completion on a two-year science definition study for an ultraviolet Raman spectrometer on Mars. Lastly, I'm currently a participating member of the CSA's Planetary Exploration Topical Team in Planetary Atmospheres which has been tasked with setting Canada's priorities for future space missions. This has allowed me the opportunity to gain first-hand insight into how the prioritization of mission objectives is set, both during topical team meetings which have included both university researchers and industry members, as well as through participation at the Canadian Space Exploration Workshop organized and run by the CSA.

1. Introduction

As the complexity of scientific activities increases, collaboration is increasingly viewed as a necessary component. Within the setting of space exploration missions, university research scientists are at the forefront of conceptual laboratory work and basic research and technology, while scientists and engineers within industry provide highly specialized instrument development and spaceflight applications. These pursuits are only made possible with the funding and international collaboration agreements established by government institutions such as the Canadian Space Agency.

The aim of this paper is to first provide a general overview of what is meant by collaboration and to explore what makes it beneficial, secondly to offer a description of each of the three sectors involved in Canadian space mission collaboration, thirdly to describe the important process of setting Canada's space exploration priorities, and finally to provide insight into the nature of these collaborations within the specific context of recent Canadian space exploration missions. These final two sections include knowledge gained through participation in prioritization meetings and workshops as well as through interviews with space exploration community members who have been leaders at the forefront of Canadian space missions.

2. The Need for Collaboration: Challenges of Space Exploration Missions

Space missions are among the most challenging scientific endeavours, making the need for collaboration crucial for their success. Cost is perhaps the largest factor, with modest planetary missions such as the Phoenix Mars lander costing just short of US $400 million [1], and more complex projects such as the Mars Curiosity rover approaching a cost of US $2.5 billion [2]. A large chunk of this expenditure comes from launch vehicle/services alone (US $243 million for the upcoming Mars 2020 rover mission) [3], making full-scale missions an unrealistic option for smaller countries which lack their own launch capabilities. As a non-launching nation, Canada's recent strategy has largely been focused on contributing individual instruments to larger space exploration missions which have been led by more sizeable space organizations such as NASA or the European Space Agency (ESA). This requires that Canadian university researchers and industry members are proactive leaders in their fields and ready to contribute their scientific and engineering expertise when such opportunities for international collaboration arise.

Major challenges to space missions also lie in the development of space-ready instruments. The technology used in these missions is often cutting-edge and previously

untested, as space instrumentation must be optimized for minimal size, weight, and energy consumption while also being able to withstand the harsh conditions of space. Additionally, the time window between the announcement of a mission and the subsequent launch is generally just a few years, making timely development, testing, and implementation a key factor. Thus, highly specialized experience, knowledge, and facilities are required, which only a select number of industry members and university researchers can provide.

Thus it is clear that a strong path to collaboration between government, industry, and university researchers is necessary to overcome the various challenges confronted when making space exploration missions a reality.

3. Overview of Collaboration and Resulting Benefits

The roles of government, industry, and universities have long been intimately connected, however recent years have seen the nature of these linkages evolve into that of increased cooperation and collaboration. Etzkowitz and Leydesdorff (2000) [4] describe three distinct models of government-industry-university collaboration in order to provide a historical and regional overview. The traditional model of collaboration used in North America and Western Europe, termed the laissez-faire regime, features a limited role for government in the economy. This model sees industry as the driving force of innovation, with universities taking on the distinct role of providing skilled personnel and government taking on purely administrative duties. This contrasts with a statist regime (seen in Russia, China, and some South American countries), in which government plays the main role of leading academic and industry activities, while limiting their individual ability to innovate. Modern societies have been progressively moving away from these traditional models to a more balanced regime which seeks to maximize innovation through increased cooperation. The Triple Helix model describes overlapping collaborative efforts in which universities take on an increasing role, forming partnerships with government and industry, and taking the lead role in joint endeavours when it is advantageous.

Strong collaborative efforts between government, industry, and universities offer several key advantages. Most important among these benefits is the efficient sharing of resources which include knowledge, funding, skilled personnel, equipment and facilities. Additionally, providing university and government support to industry initiatives helps to stimulate economic growth. Active university involvement also exposes students to industry and government experience and contacts, allowing for a smoother transition into the

workforce. Lastly, this type of collaboration builds healthy relationships for future projects, increasing the likelihood of successful cooperation in subsequent joint efforts.

4. Overview of the Three Sectors: Government (CSA), Industry, and Universities

4.1 Government: The Canadian Space Agency

Canada's involvement in space activities dates to the 1962 launch of the Alouette-I scientific satellite. This achievement made Canada just the third country to successfully enter space with an artificial satellite [5]. Since that time, Canada has built up a strong history of space mission success with has included important advances in space robotics (including the Canadarm and Dextre), satellite communications, Earth observation, and space science and exploration (including major contributions to the Phoenix Mars lander and the James Webb Space Telescope) [6].

The Canadian Space Agency (CSA) was established in 1990 as the government agency responsible for overseeing the implementation of Canadian space policies. The CSA reports to the federal Ministry of Innovation, Science, and Economic Development (formerly known as known as the Ministry of Industry) under 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*". Canada's base annual budget for space related activities is typically set at approximately $300 million by the federal government, however reached $483 million in 2015-16. In recent years, the bulk of this budget has gone to earth observation and satellite communications program, leaving approximately $100 million for the science and space exploration program.[7]

The Canadian Space Agency has developed a Space Policy Framework [8] which includes 5 guiding principles:

i) Canadian Interests First

ii) Positioning the Private Sector at the Forefront of Space Activities

iii) Progress Through Partnerships

iv) Excellence in Key Capabilities

v) Inspiring Canadians

4.2 Canadian Space Industry

Canada has a mature space industry which includes over 200 private sector companies employing over 8200 employees, 53% of whom are classified as highly qualified personnel (HQP). The Canadian space industry generates over $3.5 billion in revenues annually, with over 50% originating from export sales. While the total number of companies is considered somewhat large for a country the size of Canada, the majority are small and highly specialized with the top 10 organizations accounting for 83% of space revenues and 61% of the workforce [9]. Successful industry contributions to recent space exploration missions include Macdonald Dettwiler and Associates and Teledyne Optech helping to design and build laser-based instruments for the Phoenix Mars and OSIRIS-REx asteroid missions and Neptec developing navigation cameras for the European ExoMars rover.

Despite remaining an active sector, there is some concern that Canada's space industry is beginning to shrink. In January of 2016 Com Dev, the second largest space company in Canada, was sold to US company Honeywell for $455 million. This followed an attempted purchase of Canada's largest space company, Macdonald Dettwiler and Associates (MDA), in 2008 by US based Alliant Techsystems. The federal government blocked the sale of MDA under the Investment Canada Act, claiming that it was not of net benefit to the country [10].

4.3 Canadian University Researchers

Canadian university researchers have been very active in leading major scientific instruments on space exploration missions. Recent contributions include the light detection and ranging (Lidar) instrument on the Phoenix Mars lander led by Professor James Whiteway from York University, the laser altimeter (OLA) on the OSIRIS REx asteroid mission led by Professor Michael Daly from York University, the Alpha Particle X-ray Spectrometer (APXS) on the Mars Curiosity rover led by Professor Ralf Gellert from the University of Guelph, and the Near-InfraRed Imager and Slitless Spectrograph (NIRISS) on the James Webb Space Telescope led by Professor René Doyon from the the Université de Montréal.

5. Setting Canadian Space Mission Priorities

One the more important collaborative space exploration exercises is the formation of future space mission priorities. Given the limited funding resources available in Canada and the large number of both competing scientific objectives being pursued by university researchers and technological developments being pushed by industry members, coming to a

consensus on which tasks are deemed most important requires serious consideration and the input of many interested parties.

To accomplish this task, the Canadian Space Agency first sends out invitations for the creation of several topical teams which cover a number of space-related fields including astrobiology, planetary atmospheres, planetary geology, space astronomy, and space health. These teams typically include active community members from both universities and industry. Once these teams have been set, topical team chairs will ask team members to submit possible space exploration objectives. These objectives are intended to be broad and focused on addressing the most important scientific goals and targets. A vote is then held among team members to score the submitted scientific objectives in terms of scientific merit, importance to community, and benefit to Canada. The CSA provides a weighted scoring rubric to help aid in this exercise. Once the objectives have been ranked, team members are urged to submit specific investigations (including preparatory activities, scientific instruments for space missions, and facilities for space missions) for each of the broader objectives. This exercise is then opened to the broader scientific community by holding a Space Exploration Workshop, where non-topical team community members are invited to offer new ideas for possible investigations or to provide input on existing investigations. Another aim of this workshop is to identify possible cross-cutting investigations which are deemed to be important by multiple topical teams. The final tasks are then to rank the specific investigations within each objective and ultimately to combine the objectives and investigations of all the topical teams in order to compile an overall prioritization of goals.

6. Insights from Canadian Space Missions

The goal of this section is to gain first-hand insight into the nature of these government-industry-university collaborations through interviews conducted with major contributors to Canadian space exploration missions. The questions posed aim to identify the key roles of each sector within space missions and to reveal challenges and lessons learned from previous collaborations.

6.1 Overview of Interviewees

Interviews were conducted with the following key contributors to Canadian space exploration missions:

Dr. James Whiteway: Professor at York University. Lead scientist for the Lidar instrument on the Phoenix Mars lander.

Dr. Michael Daly: Professor at York University, formerly lead engineer at MDA. Lead scientist for the laser altimeter (OLA) on the OSIRIS-REx asteroid mission, lead engineer for the Lidar instrument on the Phoenix Mars lander.
Dr. Cameron Dickinson: Space Scientist, MDA. Systems lead for the laser altimeter (OLA) on the OSIRIS-REx asteroid mission.

6.2 The Importance of Government

The main role of the Canadian Space Agency is to provide funding for space missions. This includes their part in deciding which missions to approve, a task which heavily depends on the prioritization exercise described in section 5. The CSA also manages industry and government contracts and other administrative aspects, allowing scientists and engineers to focus on their areas expertise. Additionally, the CSA acts as a liaison between university researchers and industry, helping to manage the flow of information between the two sectors and to resolve any conflicts. Lastly, the CSA provides inter-agency connections (e.g. with NASA and ESA), allowing Canada to be a part of larger space missions.

6.3 The Importance of Universities

The main role of university researchers comes in providing the science background and the questions and objectives to be addressed by a specific mission. Beyond the theoretical science, university members also often bring intimate technical expertise and experience using a particular scientific instrument or method. This specialization is a key factor when it comes to Canadian teams being selected for participation in larger space missions. In the ideal case, university researchers are also able to provide the proof of concept for the chosen instrument, giving industry a base model from which to work from.

6.4 The Importance of Industry

Industry plays a vital role in providing highly specialized expertise in building space flight ready instruments. Space mission components must be optimized to be light weight, consume minimal power, and to be able to withstand a range of low temperatures and pressures which are rarely encountered on Earth. Further, industry has the workforce and resources necessary to produce an operational space-ready instrument on the short time scale required of planetary missions, a task which would be impossible to complete within a university environment. Lastly, industry provides a quality assurance and management structure which ensures that proper testing is carried out and potential errors are minimized.

6.5 Challenges and Lessons from Space Mission Collaboration

(i) Poor communication between sectors leads to undesired results.

The consensus between the interviewees was that the largest challenge to collaboration comes from general communication difficulties between the 3 individual sectors. A striking example of this came during the design and development stage of the Mars Phoenix Lidar. The mission structure called for distinct science and industry teams with communication between the two groups first requiring approval from the CSA. This led to a scenario in which the instrument was originally designed with an inappropriate excitation laser wavelength, which ultimately resulted in near-critical delays in development and testing.

It was felt that this type of situation could avoided by ensuring that a direct flow of ideas and communication exists between the three sectors at all times. This could be accomplished by directly installing members from one sector into the other during key stages of the project or by appointing one central representative from each sector who is accountable for relaying information for the duration of the entire mission. The importance of having pre-existing relationships between university researchers and industry members was also emphasized. This could be accomplished either formally through conferences and workshops, or perhaps even informally through non-professional social events.

(ii) Delays in CSA funding approval result in missions being delayed or canceled.

One of the main challenges faced by university researchers and industry members in Canada comes during the proposal stage of planetary missions. Due to the limited resources that are available to the Canadian Space Agency, any major spending decisions require heavy scrutiny and review prior to approval. Because of the dynamic nature of space missions, this delay in the approval process has previously led to proposed Canadian instruments being canceled or delayed, as the agency leading the main space exploration mission (typically NASA or the ESA) must look to other research teams.

A proposed solution to this problem would be to provide the CSA with the autonomy and long-term budget to make time sensitive decisions. At the Canadian Space Exploration Workshop in November 2016, the CSA emphasized that they are aware that this is a problem and were working on new policy to overcome this barrier. A Canadian Space Advisory Board has recently been assembled to examine these issues, and a new Canadian Space Strategy is expected in mid-2017 [11].

(iii) Emphasis on previous prioritization documents doesn't always capture the importance of recent developments.

The nature of planetary exploration is one of constant discovery, leading to the frequent need to investigate new research paths. While Canadian space prioritization documents are typically updated every 4 to 6 years, the relative importance of certain objectives can change dramatically on much shorter time scales. If these new objectives are not explicitly outlined in prioritization documents, receiving Canadian Space Agency approval for a mission based around them becomes a difficult challenge.

While more frequent updates would be beneficial, the cost and effort of organizing and motivating a large and diverse community of university and industry members to participate in prioritization tasks is a daunting exercise. A proposed solution is to continue holding large scale prioritization exercises once every 5 years, but to assemble smaller teams which would ensure that documents are updated during annual reviews.

7. Conclusions

Space exploration activities are complex scientific endeavours requiring large budgets, innovative scientific research, a sizeable workforce, rapid instrument development and testing, and strict adherence to policy. Successful participation in these missions therefore requires a great deal of cooperation and collaboration between government, industry, and university members who each play a critical role. This collaboration begins at the earliest possible stage, with the three sectors coming together every 4 to 6 years to set Canada's future space mission priorities. As this exercise motivates all future space exploration activity, special efforts should be made to ensure that prioritization documents are frequently updated to reflect any changes in scientific and technological priorities.

At the mission proposal stage, the role of Canadian university researchers and industry members is to clearly illustrate how their expertise and experience meets the requirements of scientific objectives identified by the larger space agencies (e.g. NASA and the ESA) who are typically in charge of the main space missions. The government also plays a critical role by providing inter-agency connections and by ensuring that funding approval is provided rapidly enough for Canadian contributions to be included on the mission. Efforts are currently being made to speed up this funding process which has previously posed a barrier for Canadian space missions.

Once a space mission has been approved, the main collaborative efforts shift to that of instrument development. This requires a clear path to communication between all three sectors, particularly university researchers and industry members who must combine their scientific knowledge, instrumental experience, and technological abilities to build a space-hardy, efficient instrument which is also capable of achieving the required scientific objectives. Fostering healthy, pre-existing relationships between industry and university members is necessary to ensure that this process runs as smoothly as possible and to avoid potential mission-critical delays.

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