Microsatellite Science and Technology Center: Canada's Center for Microspace Innovation

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Abstract

"Microspace" refers to an integrated, small-team approach to space missions that is beneficial since it can save up to 90% in costs and scheduling. Canada has shown that it can lead microspace missions for significant purposes, based on the on orbit successes of MOST, CanX-2 and NTS. However, in spite of its successes, Canada has yet to reach its full potential. More can be done to cultivate new microspace missions and technologies to create great value for Canadians. Through a recent award from the Canada Foundation for Innovation (CFI) and the Ontario Ministry of Research and Innovation (MRI), a new Microsatellite Science and Technology Center (MSTC) is scheduled for construction starting in 2010 to address this opportunity. The MSTC will be a networking hub for space science and technology researchers across Canada, will have facilities for developing new miniature satellite technology, and will bring new nanosatellite and microsatellite space mission concepts to sufficient maturity for implementation. The Space Flight Laboratory (SFL) at the University of Toronto Institute for Aerospace Studies is an international leader in nanosatellite and microsatellite missions (satellites under 10kg and 100kg respectively). The new Center will provide an ideal opportunity to engage in early technology development and mission conceptualization with Canada's leading researchers. This will complement and provide an evolutionary path for current SFL activities that include the development of complete nanosatellite and microsatellite missions for in-situ space research. Within the framework of the microspace philosophy, the MSTC will enable vigorous research into raising the technology readiness level (TRL) of promising new technologies through levels 0 through 5, and the completion of Phase 0 and Phase A feasibility studies that are essential in generating new mission concepts. This will synergize and leverage SFL's capabilities and expertise to promote technologies from TRL 6 through TRL 9, and implement experimental space missions from Phase B (Preliminary Design) to Phase E (Operations). The new Center will strive to define and establish feasibility, and champion new technology development in support of new microspace missions that could be implemented by SFL. The Center will be a unifying force that will allow researchers and collaborators to boost Canadian activity in creating new microspace mission opportunities. This will build and strengthen Canada's capacity for low cost missions in the future. This paper summarizes the background, objectives and plan for the MSTC.

Introduction

The Canada Foundation for Innovation and the Ontario Ministry of Research and Innovation have awarded the University of Toronto funds to establish the Microsatellite Science and Technology Center (MSTC), based on the pioneering achievements and success of the Space Flight Laboratory at the University of Toronto Institute for Aerospace Studies in developing high performance, yet low cost nanosatellite and microsatellite missions for the international community. The MSTC will be a national center. It will be a networking hub for space science and technology researchers, will have facilities for developing new miniature satellite technology, and will bring new nanosatellite and microsatellite space mission concepts to sufficient maturity for implementation. In essence, the MSTC's primary function is to build and strengthen Canada's capacity for microspace missions and associated technology development.

The Space Flight Laboratory (SFL) at the University of Toronto Institute for Aerospace Studies is an international leader in nanosatellite and microsatellite missions (satellites under 10kg and 100kg respectively). At present, the absence of a dedicated Canadian program to cultivate new opportunities (new mission, payload, technology ideas) and act as a network hub among internationally recognized researchers is limiting the possibility for Canada to advance the state of the art in satellite research and technology development. The MSTC provides an ideal opportunity to alleviate the problem by complementing and building upon the strengths of current activity at SFL and elsewhere in the country.

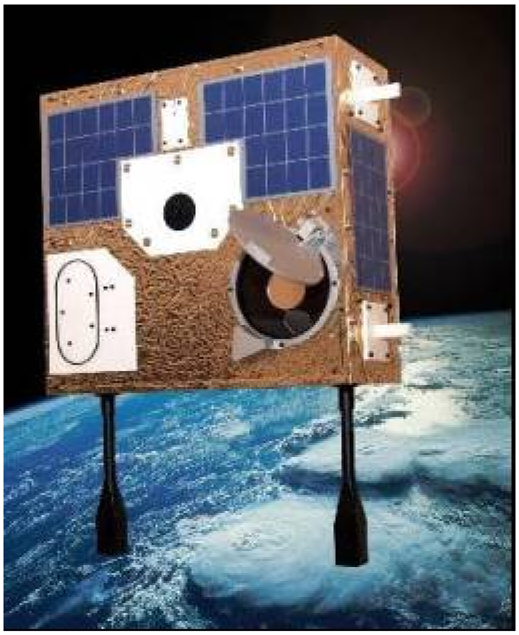

Figure 1: The MOST Microsatellite

SFL is delivering low-cost satellites, launches and ground control to international users. Having played an integral role in the design, construction, test and operation of Canada's space telescope, MOST (Figure 1), and having helped to bring microspace to Canada in the process, SFL has been developing low cost missions for over a decade. In April 2008, SFL launched two highly successful nanosatellites, CanX-2 and NTS (CanX-6) for atmospheric science and ship tracking respectively (Figure 2). SFL will launch AISSat-1, a 7-kilogram ship tracking satellite for the government of Norway in early 2010 (Figure 3). Two satellites for the BRITE space astronomy constellation are about to be completed for Austria (Figure 3), with additional BRITE satellite development for Poland and Canada on the horizon in 2010. The CanX-4&5 formation flying demonstration mission, involving two 7-kilogram satellites using carrier phase differential GPS and custom propulsion technology will launch in 2011. SFL has recently been awarded the NEMO-AM mission to monitor aerosols for the Indian government using a 15-kilogram satellite. This activity at SFL is largely based on established technologies – the Generic Nanosatellite Bus (GNB) and the Nanosatellite for Earth Monitoring and Observation (NEMO) platform. However, something must be done to advance the state-of-the-art to keep Canada at the forefront of microspace mission development on the world stage.

Without directly and concretely addressing the need for new technologies, new instruments and new missions, Canada would be left behind in its ability to advance the state-of-the-art through new technology development or grow new mission concepts to sufficient maturity for actual implementation. To address this issue, the MSTC will focus on early technology development and mission conceptualization. SFL will continue to focus on mature projects, such as producing satellites, pursuing launch opportunities, and conducting on-orbit operations. Specifically, the MSTC and its users will champion and develop technologies at readiness levels (TRL) 0 through 5, and work on Phase 0 and Phase A feasibility studies. SFL will promote technologies from TRL 6 through TRL 9, and implement space missions from Phase B

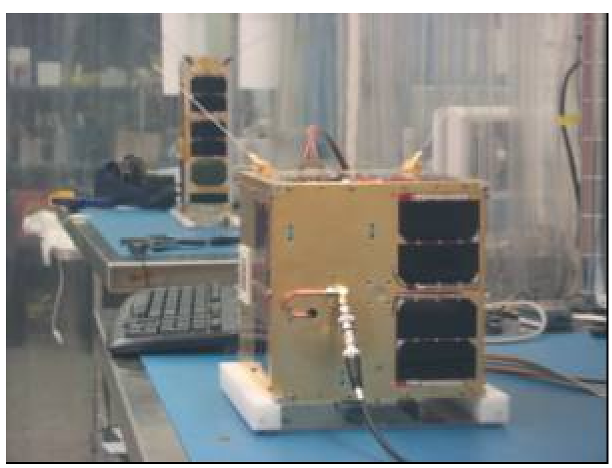

Figure 2: CanX-2 (back) and NTS (front).

(Preliminary Design) to Phase E (Operations). MSTC activities are intended to be collaborations among various universities from across Canada, including the University of Calgary, York University, the University of Waterloo, the University of Winnipeg, the University of Lethbridge, the University of New Brunswick, and the University of Toronto, who are the principal users (or collaborators) of the MSTC. Other users of the MSTC provide domestic and international networking opportunities and include government agencies (including the Canadian Space Agency, Defence R&D Canada), Canadian companies, foreign companies, universities, and governments from Japan, Denmark, India, England, and Austria. Expansion of the community served by the MSTC is anticipated with time.

Activities at the MSTC

Activities of the MSTC will be multidisciplinary. Relevant scientific disciplines include geophysics, astronomy, atmospheric science, solar-terrestrial physics, and planetary science. Relevant technological disciplines include novel propulsion systems, high efficiency communication systems, next generation power systems, attitude control technologies, and high-performance computing technologies for space. In addition, payload technologies will be investigated with application to communications (e.g. broadband, Internet, search and rescue) and remote sensing (e.g. Earth observation for natural resource monitoring, safety and security, and national defence.) These payloads may be optical, RF (including SAR), thermal, or multi- or hyperspectral imagers.

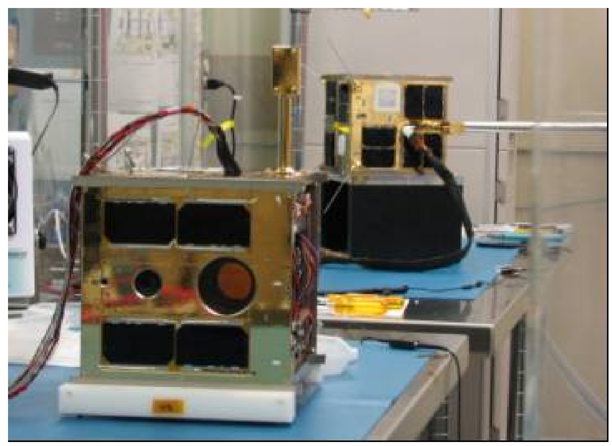

Figure 3: UniBRITE (front) and AISSat-1 (back).

The MSTC will build upon past CFI investments that have been made to the principal users. Most of the principal users, who are experts in related fields, have CFI-funded facilities of their own that will complement and synergize with the Center. These users will develop instruments, devices, and parts that will contribute to next generation missions. The new Center will take the outputs of the existing facilities and use the new infrastructure to aid the principal users to design, prototype, and test new devices for space following the design approach used for nanosatellites and microsatellites. The users will be able to study the possibility of miniaturization or efficiency improvement, define mission concepts based on having achieved a minimum level of technology readiness, and propose and champion those missions for implementation.

The technologies that the MSTC will develop may include, but are not limited to:

1. Instruments for nano/microsatellite missions – miniaturization of spectrometers, IR detectors, cryogenics, CMOS detectors, CCD detectors, lidar, multi-static radar, multispectral or hyperspectral imagers.
2. Satellite technologies (platform technologies) – high efficiency solar cells, MEMS and high-temperature super conductor devices for radios, sensors and actuators, GPS-based positioning and formation flying strategies, new power systems, on-board computers, radios, attitude control hardware (sensors and actuators), deployment mechanisms, electric propulsion systems.

These new technologies are important to Canada because they enable:

1. Canada to stay at the forefront of low-cost space missions, namely, nanosatellite and microsatellite missions on the international stage. This will give the country an advantage in executing its own small missions under national control with state-of-the-art capabilities. Canada

would not have to outsource to another country, but could develop the satellites at home with capabilities that enable the most challenging missions in this class.

2. Potential economic benefits through commercialization – technologies that can be sold at home and exported abroad.
3. Greater scientific return to Canadian researchers for social benefit at home and internationally. They allow researchers to develop strong connections with the international science community by virtue of tangible space missions and real science return in the near term.
4. Training of highly qualified personnel both in payload or instrument development and in the development of the satellites themselves. The MSTC will create practical hands-on opportunities for students to develop or integrate new instruments and devices and be involved in conceiving missions. The activities of the MSTC will also enable SFL to expand the number of satellites under development thereby creating more opportunities for graduate students to receive practical hands-on training in satellite engineering.

Delivering "Microspace" Expertise to Canadians

The microspace approach to building spacecraft involves small, tightly integrated teams working with the severe cost and schedule constraints. It is a development philosophy that focuses attention on what has, based on experience, directly contributed to actual on-orbit reliability. Following the microspace approach enables up to a 90% savings in cost and a 5 to 10 fold reduction in schedule when compared to traditional space development approaches.

The MSTC will enable SFL to help Canadians by applying its expertise in microspace development approaches and boost its mission development capabilities to proactively define and develop new technologies and missions with principal users, many of whom have their own CFI facilities to develop component technologies or scientific instruments. The close collaboration of the MSTC with SFL will facilitate breakthroughs in achieving desired scientific returns at substantial cost savings. This is due to the combination of microspace expertise and mission capabilities with the expertise of principal users in developing next generation devices and instruments for new space missions. The cost savings will arise from the following fundamentals at the MSTC:

- Applying the enhanced microspace approach developed at SFL to adapt the latest commercial technologies for use in space and follow a focused quality assurance program that has been tuned or tailored to the specific environment, requirements and design problem at hand.
- Collaborating with MSTC users to identify requirements and then negotiate those requirements into a set that can be achieved with available commercial technologies while still meeting the scientific or technological objectives of the principal users.
- Collaborating with users to define development strategies and plans to minimize cost and create compatibility with nanosatellites and microsatellites (i.e. microspace missions).
- Collaborating with users to define assembly, integration and test plans to minimize cost and create compatibility with microspace missions.
- Collaborating with users to define new applications for the technologies of the users, allowing multiple applications to share development costs.
- Networking among users to cross-fertilize and share technologies and approaches to capitalize on each other's advances.
- Developing mission concepts with users to enable the users to achieve their objectives in space, but through microspace missions instead of more costly and time consuming traditional missions.

The cost savings will have the effect of:

- Increasing the likelihood of technology and mission funding by virtue of a lower price point for the scientific or technological return.
- Accelerating development and/or scientific return resulting from reduced funding requirements.
- Increasing overall value of the scientific and technological endeavors to Canadians.
- Allowing Canada to do more missions and technology development within constrained budgets.

Let's Collaborate and Strengthen Canada's Capabilities in Microspace Missions

The MSTC will encourage collaboration across Canada. The goal is to establish symbiotic relationships that leverage existing capacity at SFL and SFL's international connections, while boosting the ability of scientific and engineering researchers to advance their work and achieve at an accelerated rate. An annual workshop will be organized by the MSTC for its users, where new ideas will be presented and discussed for collaborative technology development or mission conceptualization. These discussions will produce teams of mixed composition that will champion the new ideas on the national or international stage to realize an innovative space mission, or begin next generation technology development. A primary objective of the MSTC is to quickly raise the TRL of immature technologies and to establish the feasibility of new mission concepts. By focusing Canadian efforts through the MSTC, more technology development, more missions, and more capacity will be facilitated.

MSTC and the Canadian Space Industry

Through the MSTC, industry will benefit through low cost access to space for rapid on-orbit demonstration of new technologies that would otherwise have to wait many years before being marketable. Also, both the MSTC and SFL are available to help Canadian industry to develop larger satellite missions while minimizing cost, enabling industry to be globally competitive and enabling industry to maintain and grow job opportunities.

The benefits of the MSTC include:

- Low-cost access to space for Canadian researchers. The MSTC will foster new partnerships between SFL and scientists and engineering researchers who would not otherwise have as timely or inexpensive access to space through microspace missions. The MSTC will reduce the entry threshold for researchers in space.
- Greater return for Canadian space scientists, including publications and contributions to human understanding of Earth and space.
- Accelerated development, accelerated advancement of technology readiness levels, allowing new technologies to be adopted in space missions much more quickly and enabling commercialization.
- Increased competitiveness and product sales for Canadian companies – the MSTC and SFL will help companies on the international stage and provide a low-cost means to access/utilize space and develop immature concepts into technologies that can be commercialized. Companies can also claim heritage from SFL mission experience that in turn boosts their international sales.
- More missions for Canada and Ontario within tight budgets. Greater return on investment in space.
- More missions under provincial or national control. Timely access to global information.
- Opportunities for Canadian researchers to network with colleagues within Canada and internationally on space technology development or missions.
- Opportunities for cross-fertilization and sharing of technologies among MSTC researchers for different or emerging applications.
- Technology commercialization for Canadian business, leveraging SFL's experience in this area.

- More satellites for Canada to construct, helping to sustain capacity and capability within Canada and helping to maintain and create high-tech jobs.
- Training of Highly Qualified Personnel (HQP) across Canada through the development new mission concepts, instruments, enabling technologies.
- Less duplication of expertise, less waste by leveraging the existing capabilities of SFL in microspace and the facilities of the principal users for technology and instrument development.
- Ultimate beneficiaries: scientists (low cost access to space experiments), industry (technologies sold or used to gain performance/cost advantage), public (lower cost communication technologies, climate monitoring, asset tracking, solar power, disaster monitoring/prediction).

Conclusion

The Microsatellite Science and Technology Center (MSTC) will be a one-of-a-kind national center for accelerated microspace technology and mission development. The MSTC will leverage the extensive microspace expertise of the Space Flight Laboratory, and make this expertise of benefit to Canadian researchers in general. New technologies and instruments for microspace missions will be elevated in readiness, and new mission concepts will be conceived and championed through the focused efforts of the MSTC and its users. Through the MSTC, Canada will have a strong ability to advance the state-of-the-art, and both build and maintain internationally recognized capacity and capabilities in microspace development.

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