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SPACE FACILITIES FOR ASTRONOMICAL RESEARCH: PREPARING FOR THE NEXT GENERATION

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ABSTRACT

This white paper is written in the context of the CASCA Long Range Plan (LRP) and CSA's Long Term Space Plan (LTSP) 2010. Canada has contributed to several space astronomy missions, from small and relatively fast balloon borne projects, to a commitment to deliver two important instruments for the James Webb Space Telescope. This has given Canadian astronomers and engineers international recognitions of their expertise. The community is engaged in generating new ideas to maintain this excellence. CSA has started a road mapping exercise with considerable community input. Planning an efficient mission roadmap requires recognition of the level of expertise and excellence in academia as well as industrial capacity together with an understanding of government funding programs and objectives. This paper presents a summary of what has been accomplished and the way forward in terms of government objectives.
Subject headings: space astronomy: missions, organizations: Canadian Space Agency

1. LAUNCHING THE NEW DECADE

There are currently close to 30 astronomical satellites from various nations operating in orbit. They observe the universe from far infrared to gamma rays and are providing an unprecedented wealth of data that have and continue to enrich our understanding of the universe, its composition and structure and our place in it.

In the previous two decades Canada embarked very successfully in the exploits of space astronomy. With technological developments in universities and industry, Canada became an important player in several missions: VSOP, ODIN, FUSE, BLAST, MOST, Herschel and Planck. Our contributions to these missions have provided international recognition of both scientific and technical capabilities in Canada. MOST is exceptional in being the first all-Canadian space telescope. Launched in 2003, this micro-satellite continues to operate and has received world-wide attention for its impressive performance and unique scientific output. Following the success of MOST is Canadas next micro-satellite NEOSSat, the first space telescope dedicated to near-Earth object surveys starting in 2011.

Canada is currently committed to provide instruments to EBEX, Astrosat and JWST. Providing detector readout electronics and calibration of UV detectors for the Astrosat will provide Canadian astronomers access to a unique UV imaging telescope. Canadas largest contribution to date to any space science mission is certainly the Fine Guidance Sensor, a vital component of the worlds next largest observatory, the James Webb Space Telescope (JWST); Canada will also provide a unique science instrument the Tunable Filter Instrument (TFI). These state of the art instruments have demonstrated our capabilities in technological development, but not without serious challenges. An active science team to each project has been critical in the instrument development and to maintain the scientific focus. The scientific exploitation of all the missions, as perhaps well exemplified with Herschel, is made possible by strong and well prepared Canadian teams and with support by the granting Agencies.

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The VSOP, ODIN, FUSE, BLAST missions have ended. MOST has greatly passed its life expectancy. The JWST and Astrosat instruments are in their final phases for delivery in the next year. Given the 5 to 10 year development for a space mission, it is critical to commit now for the next generation. There are currently no new missions approved. However some are being studied at a mission concept level or Phase 0.

CSA supported initial participation in the ESA Cosmic Vision program. ESA has retained the SPICA mission for the next phase of Cosmic Vision; it is a JAXA lead mission, similar to Herschel in size but operating at much colder temperatures and higher sensitivity. Canadas contributions in Herschel have allowed a logical progression of our scientific and technical expertise to a SPICA instrument (SAFARI).

Generating ideas for future missions has been supported recently by the issue of two CSA mission concept studies AOs (CSA 2007, 2009). The 2007 AO for Concepts in Space Science and Technology included two studies in space astronomy: an Oort Cloud Occultation Telescope and a Lunar Liquid Mirror Telescope). With the 2009 AO, CSA is currently evaluating the possibility of participations to the JAXA Astro-H X-ray observatory and a future (international) dark energy survey telescope. The proposed contribution to Astro-H is not a scientific instrument per se, but rather a metrology system to monitor the precise position of the focal plane, to enhance the performance of the observatory. Not only a science instrument, but any (Canadian) technology, software or expertise of benefit to the mission is a means of establishing partnerships. In the case of Astro-H, metrology is a technology derived from non-astronomical application.

Another example of a non-astronomical technology are robotics, a Canadian signature technology that could introduce a new paradigm for large space observatory missions. Hubble was given a life, and many extensions, as a result of servicing missions (with humans in the loop these were necessarily very expensive). Some concepts for future large observatories (ATLAST is one example) include capabilities for servicing by automated or remotely controlled robotic systems (Renewing the Partnership between Astronomy and the Human Space Flight Program: A National Strategy, NRCs Committee on Science Enabled by NASAs Constellation System Request for Information Response from Frank Cepollina, et al., May 5, 2008) (NASA RFI http://servicingstudy.gsfc.nasa.gov/). Elements of on-orbit servicing have been demonstrated by such missions as XSS-11 in 2005. The ISS, with Canadarm-2 and Dextre, can also be considered as an example of highly serviceable spacecraft. Given the investments in large observatories there are incentives to include designs for modular instruments so they can be upgraded as new technology becomes available as well as for repair and replace components; not to mention possible re-fueling and de-orbiting tasks. Canadas strong robotics program is continuing in the context of exploration, and other applications can benefit. MDA is currently completing a study for on-orbit servicing, using observatory concepts of the 2020 decade as test cases.

In collaboration with other agencies, the CSA will continue to support solar system exploration missions (Global Exploration Strategy 2007); in that context, astronomical research in exo-planet search and characterization and solar system formation studies could have synergy with the exploration program, but participation on planet finding missions have not been voiced strongly so far.

2. ADVANCED KNOWLEDGE

Astronomical research in Canada has been active for many decades. In 1971 the Canadian Astronomical Society (CASCA) was officially formed and holds today about 500 members. The Association for Canadian Universities in Astronomy (ACURA) includes 23 universities in Canada. NSERC supports about 20 Canada Research Chairs in astrophysics. Scientific output in astronomy and astrophysics measured by the citation rate of publication was highest in the world (per capita) in 2006. Space astronomy so far has included the participation of several Canadian universities: British Columbia, Calgary, Toronto, Laval, Lethbridge, McGill, Montral, St-Marys, Victoria and Waterloo.

To clearly assess the strengths and future directions of research in astronomy requiring access to space, the CSA issued an AO for the creation of specific Discipline Working Groups (2007-2009). This resulted in the creation of five groups (CMB, HEA, UV Spec, Wide Field, FIR), with the participation of a total of 85 university researchers. The resulting final reports from each DWG (summaries are available on CSA website) (CSA Discipline Working Group Exec summary reports (weblink: http://www.asc-csa.gc.ca/eng/sciences/committees-dwg.asp#astronomy) provide an excellent compte-rendu of the level of research activities and commitments in each discipline, and scientific objectives with strategies to achieve them. The reports provide recommendations for space and sub-orbital platforms matching the disciplines near to long-term goals. A well attended space astronomy workshop was held at CSA in 2006 to support planning and community input (CSA 2006).

3. EXPANDING CAPACITY

Having participated on a dozen missions and delivered sophisticated hardware and software from balloon payloads to major space observatories, Canadian expertise has already reached a level of international recognition. However, in order to address new scientific goals and increasing measurement challenges, technology must evolve and overall expertise must be maintained. This requires a sustained infrastructure of both knowledge and technology. University laboratories (for example Laval COPL, Université de Montréal Laboratoire d'astrophysique experimentale (LAE), University of Lethbridge Physics and Astronomy, University of Toronto Astronomy and Astrophysics, CITA, UTIAS Space Flight Lab (SFL), UBC Physics & Astronomy, Centre de recherche en astrophysique du Québec (CRAQ), and government laboratories (for example NRC Herzberg Institute of Astrophysics (HIA), CSA David Florida Labs (DFL), Institut National d'Optique (INO)), contribute programs of development in optical design, opto-mechanical, detector electronics, space qualification and testing in extreme environments all relevant to space astronomy. Capacity in space industries is also critical to deliver complex space instrumentation. In order to maintain and expand on capacity to deliver competitive technologies, the CSA issues regular Request for Information (RFI) to assess the technology needs and Requests for Proposals (RFP) to advance them. Priorities must be frequently updated to follow the international program of new concepts and progress on selected missions.

Balloon missions are included in the CSA space astronomy program for several reasons. Not only because instruments on high altitudes balloons must contend with near space environment (low pressure, temperature) instruments are needed for pointing, communication and power source, not unlike a spacecraft. The relatively low cost and short schedule of a balloon project (compared to a satellite) allows the project to be developed by a team of graduate students, often entirely managed by the PI or professor. Many new graduates gain direct and valuable experience in space related project and thus expand the capacity in Canada for new professionals in space research. Small spacecraft, nano-satellites and perhaps micro-satellites, can be considered in the same category as balloon mission for contribution in capacity building.

4. ROADMAPPING

To strategically and efficiently develop new technologies and expertise it is important to establish what future missions offer the best advantages to Canada (Canada 2007). Missions must be identified with sufficient lead time for the technology to be developed and ready for the mission schedule. This is the purpose of a roadmap; CSA has prepared a (draft) roadmap contributing to the long term plans of the CSA. Input to the roadmap was obtained from the DWG and other consultations with the community (mainly with the Joint Committee on Space Astronomy or JCSA with members recommended by CASCA forming the advisory committee to CSA on space astronomy) and with other space agencies. The roadmap does not commit to any new missions, but identifies mission opportunities that will provide benefits to Canada, not excluding the possibility of a (larger than microsat) Canadian lead mission. With limited resources it is important to judiciously identify priorities and select missions that produce returns that can be quantified, and scientific performance that can be measured according to the Government funding program objectives. For a transparent selection process, evaluation criteria must be devised that can estimate the returns on these broad objectives. The LRP process and its community discussions should address these issues and identify the most important and beneficial missions, especially those requiring significant resources.

5. SUSTAINING LEADERSHIP

Fundamental investigations needed to address the astronomical questions of today drives space missions to larger and more powerful observatories, with costs that become difficult to bear by a single nation. Thus most countries have become very open to international partnerships, often as equal partners. Although it is not difficult to identify a goal or priorities for a mission (be it dark energy or exo-planets), it is sometimes more difficult for international teams to agree on mission approach and requirements. However, such challenges are usually overcome. International missions are great opportunities to create sustainable partnerships. The resulting international relations go beyond the devices or instruments that get delivered; they can provide long term benefits in terms of technology and scientific and expertise exchanges. Scientifically, we have often obtained returns that outweigh our contributions.

In order to maintain a capacity to provide competitive technology or expertise to a world-class mission it is necessary to support national infrastructure (facilities, programs) that are geared to develop such technology and expertise. Such facilities already exist in university and other institutions (as listed above). Increased collaboration and partnership among these centers will promote a greater sharing of ideas, solutions and development, both in technology, corporate expertise and personnel.

Government can play a key role in promoting partnership and maintaining long term programs. Funding agencies should be able to provide commitment to projects that span long periods, from concepts to build, launch and operate, as well as provide means to exploit and preserve the data. It is beyond the scope of this paper to recommend specific strategic partnerships. It is planned with the CSA new Grants & Contribution program to provide several mechanisms to produce such results.

Preparing for the next generations must not neglect the importance of public outreach and education. What often sparks the interest of young people in astronomy and related fields are opportune presentations, talks or activities by educators and professional researchers. This interest can lead to career in the scientific field or at least a found appreciation of it. General public outreach (which can take many forms as greatly exemplified in 2009 by International Year of Astronomy) is necessary to inform the public of the significance and impact of current discoveries and theories, and indirectly provide an appreciation of the efforts and investments needed to carry out the research. Being knowledgeable about our universe, our place in it and our origin is a fundamental advantage.

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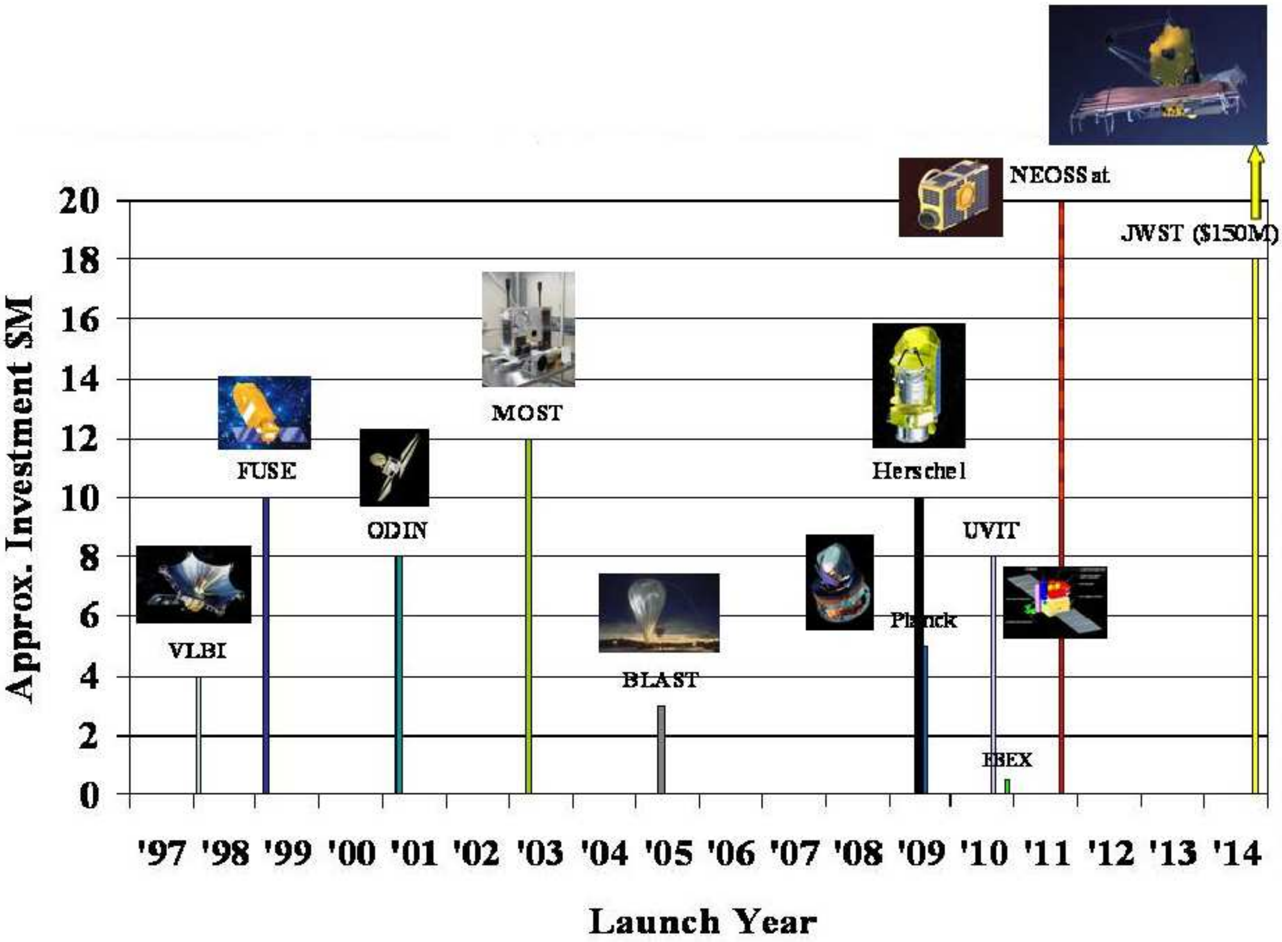

FIG. 1.— Approximate Government of Canada Investments in Space Astronomy Missions (NEOSSat is jointly funded with DRDC). Note that the investment figures prior to 2005 shown are very approximate as they do not include full-cost accounting. See also investment figures shown in CCA Report (Canadian Coalition for Astronomy 2006).