CANADIAN SPACE AGENCY

SPACE SCIENCE BRANCH

BACKGROUND DOCUMENT

for a

SMALL PAYLOADS PROGRAM

VERSION 01

July 10, 1996

EXECUTIVE SUMMARY

CSA Space Science Program (SSP) management recognizes that smaller projects play an important role in the overall health and future of the Program. It was decided that a strategy that incorporates such projects into the overall framework of the Program was needed. This document presents a plan for the implementation of a Small Payloads Program (SPP) and has been prepared as background for an accompanying Announcement of Opportunity (AO). This is not a new program within the SSP but a formalization of the current small payload projects initiative into a cohesive and continuing program with stated long-term objectives, coherent strategies and a clear evaluation method.

The plan discusses lessons learned and limitations evident in recent small payloads projects, primarily sounding rocket projects, and incorporates them into the implementation strategy.

The Small Payloads Program will produce benefits including routine and quick-response access to space, training of new researchers and engineers, flight qualification of new instruments, technologies and support hardware, support for Canadian industry, and a "made in Canada" program.

The SPP will provide for a series of scientific missions of limited size and cost on platforms including sounding rockets, balloons, and microsatellites. Missions would be selected based on a series of science and engineering competitions involving combined research/university/industry teams. Selected projects will be managed by the Space Science Program and will include cooperation with the Engineering, and Operations branches of the CSA.

Investigator teams will provide proposals in response to Announcements of Opportunities (AOs) which are planned to be issued every two years. A nominal schedule will see a balloon launch every two years, a rocket every one to two years and a microsat every three years. The number of projects receiving support at any one time will depend on several factors including the overall budget and platform type and will vary from year to year. Overall, however, the selection will be set by the best science return for the

dollars spent. The level of funding which has been budgeted for small payloads is $2.5M/yr. Instrument development will be supported partly through the Concept Studies initiative, partly through this program and partly through other available sources. Maintenance of an industrial capability is considered an essential part of the program.

Training is considered to be another essential component of the Program. Universities are encouraged to utilized their laboratory capabilities and that of other institutions and industry for the development of scientific instruments. This will provide excellent training opportunities and it will also be a source of prototype space instruments with the potential to evolve into international-class payloads with known heritage.

The goals of the Program are:

- to ensure a healthy, and technically capable, space science community,
- to enable an on-going source of prototype space instruments with the opportunity to develop, through an evolutionary process, the necessary heritage for larger international class projects, and
- to provide industry with a low-level but stable workload by which socio-economic benefits can accrue.

The Small Payloads Program will produce "cutting edge" scientific exploration, but just as importantly, it will ensure an enhancement of the science community and a Canadian industrial capability to build and fly innovative space hardware.

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1.0 INTRODUCTION

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1.1 Background

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The Churchill launch range for sounding rockets (CRR) and the Gimli launch facility for large balloons were officially closed in November, 1984. Since then the CSA/Space Science Program (SSP) has carried on an ad hoc program of rocket and balloon launches at a level much reduced from that prior to this date.

Over the years, since the first rocket launches in Canada, small projects have provided a number of benefits to the country. They have given young researchers a means of establishing themselves, permitted the development of new instruments and techniques, sparked interest in space research in undergraduate as well as graduate students, and provided a start for new engineering enterprises. The enthusiasm and new ideas which are generated by people and companies starting out in the field can be best fostered by small projects since they are of short duration, and relatively low cost and thus can afford to accept higher risk and therefore make use of new technologies.

In recent years, since the shutdown of the CRR and the Gimili facility, the launches have been too few in number and too irregular in frequency to maintain the interest of the majority of the science community. Another result is the weakening of the industrial infrastructure. In order to maintain an industrial capability and to obtain the most from the overall Space Sciences Program it must have a continuing small projects program with a well-defined launch schedule which provides for a sufficient number of launches to attract a new generation of space scientists as well as to keep today's established scientists at the cutting edge of research activities.

The current budget of the SSP includes funds for a continuing Small Payloads Program over the next ten years. In this paper the program is called the Small Payloads Program (SPP). The term "small payloads" includes sounding rocket and balloon payloads. Recently, the idea of an orbiting payload type called

"microsats" has become an item of interest and discussion in the community and payloads for this platform will also be considered as a candidates in this plan.

1.2 Purpose

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CSA Space Science management has recognized that smaller projects play an important role in the overall health and future of the CSA and the Space Science Program. It has therefore been decided to implement a strategy that encourages such projects into the overall framework of the Program. This document outlines the concept of how this is to be accomplished. To this end, a Small Payloads Workshop was held January 22 and 23, 1996, in Montreal to discuss a draft version of the document and invite comments. Comments received at the Workshop and written input into the plan have been incorporated as much as possible in this current version.

2.0 RATIONALE, RELEVANCY AND BENEFITS

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The rationale for any program within the SSP must be that it meets the overall objectives of the CSA and SSP, or that it complements other parts of the program in meeting the objectives.

To meet the objective of providing access to space for Canada's space science community, the SSP must consider the total number of scientists in the community, the level of flight preparedness of the experiment, the particular science to be accomplished, and the available budget. Since both the level of development of space science experiments and their platform needs vary, a range of platforms should be made available. A Small Payloads Program should complement the other activities of the Space Science Program, by providing access to space on a reasonably routine basis, at lower cost, in a shorter time frame, and with fewer requirements.

The lower cost and therefore higher acceptable risk of small payloads, make them ideal vehicles for training new scientists and engineers. Small payloads can provide experience in the fundamentals of space system development which are common to all space missions. A number of the small payloads developed under this program are expected to evolve into international-class proposals for future projects. The Small Payloads Program will provide the opportunity for younger scientists to develop the experience required in order to provide the techniques and capabilities appropriate for larger mission activities. It is also expected, however, that many scientific studies will require only a small payload platform to make the desired measurements, in which case evolution to the international-class is not necessary or desirable.

2.1 Candidate Systems

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Each platform has its own benefits which are outlined in the following paragraphs. The number of projects of each platform type receiving funding will vary from year to year and will be determined by the best science return for the dollars spent. Science return will consider the novelty of the science, expected impact of the scientific results, number of scientists involved, and the expected level of publishable information. All proposals will undergo a peer review by a panel of scientists knowledgeable in the pertinent field. An attempt will be made to ensure the viability of necessary industrial infrastructure covering all platform types.

2.1.1 Sounding Rockets

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The workhorse of the early days of space exploration, this vehicle provided the capability to probe the lower levels of space. Since then payload systems and vehicle technologies have become increasingly more sophisticated. Current sounding rocket vehicles are now capable of reaching altitudes in excess of 1000 kilometres with payloads of over 500 kilograms. With these capabilities, they are able to support cutting edge scientific experiments for most space disciplines. Systems exist for in situ measurements probing both temporal and spatial regimes, for supporting space plasma physics and for solar, stellar and Earth pointing for astronomy and atmospheric sciences.

Some advantages of a sounding rocket platform include the capability to reach almost any location of interest (where satellites cannot), flexibility and relative simplicity. The major disadvantage is the very short flight duration - in the tens of minutes - and the sometimes relatively high cost when complex payloads are required.

2.1.2 Balloons

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Balloons have been in existence for well over a century and are very effective lifting vehicles for atmospheric and other research. Balloon technologies have advanced to the point where they are now capable of lifting payloads of several tonnes to altitudes above 40 km for in situ atmospheric chemistry and physics research, and for astronomical observations through the very thin atmosphere at high altitudes. The advantages of such systems include the capability to reach locations on a routine basis that are unobtainable by satellites, as well as providing relatively long duration flights (usually days but up to weeks are possible) at low cost. A significant disadvantage is the dependence on the prevailing winds for trajectory control, although at times, this can be used as an advantage (circumpolar flights at high latitudes).

2.1.3 Microsats

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At the present time, there is a considerable interest in the microsat concept within the space science community, both national and international. This is not a new idea, but has evolved from earlier minisat studies of the 1980s. The FOCUS study is an example. This latter concept started off as a low-cost extension of the sounding rocket program but with an orbital capability. The projected launch vehicle was the Shuttle with a HitchHiker carrier. Present day technologies have advanced to such an extent that very small satellites, such as the microsat concept, have the potential to be a very powerful research tool. The mass of a microsat is expected to be in the 25 to 75 kg range with approximately 25% of this mass available for instruments. Microsat missions chosen to be implemented under the SPP will need to be small, low cost, and simple, to conform with the management style and QA environment common to SPP projects.

An obvious advantage is the longer duration flight time (orbital) but a definite drawback is cost - the need is for *low cost* launches with satisfactory orbit selection. Additional disadvantages are the need for more complex subsystems, GSE and operations. Microsat size limitations will also compel the need for micro-instruments and if microsats prove to be practical scientific systems, then one could assume that the same technologies would be applicable to sounding rocket and balloon systems with a commensurately lower launch cost. The use of microsats also will require the development of relatively higher reliability instruments.

As a final comment, future programs, including the planned SciSat and other international programs, may require investigators to have the capability to design and build flight hardware, at least to the prototype level. Experience gained building small payloads will help qualify both the scientists and their team in the development of instruments which will be necessary if they are to participate in the larger programs.

2.2 General Advantages

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The advantages of a small payloads program can be summarized as follows:

- A "made in Canada" program
- Routine access to space
- Relatively low cost
- Quick response to new or unexpected scientific phenomena
- Training of new investigators and students, both science and engineering, for all space programs
- Short development time, commensurate with graduate student programs
- Recoverability for calibration and reflight (not microsats)
- Flight qualification of new technologies/hardware
- Highly desirable vehicles for many scientific studies.

3.0 LESSONS LEARNED

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Many lessons have been learned as a result of recent small payloads projects. These are discussed below and have been incorporated into the plan implementation strategy, outlined in Section 4.

3.1 Number and Regularity of Opportunities

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The low number of opportunities and irregular AOs discourages research institutes from getting involved in space projects.

It is proposed that AOs be published regularly (every two years) to permit researchers to plan their research program around regular small space payload opportunities. This will assist in attracting young scientists and engineers into the field thus providing continuous rejuvenation of the programme, both in the scientific and technological areas.

3.2 Low Payload Activity

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The low level of payload development activity decreases the level of technical preparedness of industry which leads to inefficiency and cost increases.

The plan proposes to provide a minimum level of activity to satisfy the science community and provide the stability to sustain Canadian industry, albeit at a low level.

3.3 Hands-on Instrument Development

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Lack of hands-on instrument development capability within the university environment results in the need to have instruments built outside the research institutes often resulting in lost training opportunity and higher project costs.

This problem is related to the lack of opportunities in that research institutes cannot draw interested students into the field unless research projects are guaranteed. It is felt that a SPP which provides regular launch opportunities will encourage more graduate and undergraduate students to become involved in instrument development. The experience gained in small payloads instrument development could be applied to international-class projects and/or to industry.

3.4 Space Science Community

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The present Canadian space science community in the domains of solar-terrestrial physics, atmospheric studies and space astronomy comprises a majority of mature scientists whose needs and interests are focused on sophisticated instruments such as those used on large international projects. Many of their career paths, primarily in the first two of the domains noted above, started in the rocket program and their instrument development skills (and indeed the advanced instruments in use today) have evolved by this route. This career path is no longer available to the community and has been lacking for several years. This inconsistency has led to the requirement for very complex payloads as described in the next paragraph.

3.5 Payload Complexity

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Recent payloads have been very complex leading to high costs and risks.

The SPP proposes a balanced program encompassing a range of project complexities which will permit all the program objectives to be met. The least complex projects will be less costly and will be expected to contain a large training component. The most complex will necessarily need to have a high scientific potential. Recoverability and reusability will be encouraged to reduce long term costs.

In order to be able to address the full range of scientific questions, the program must accept a wide range of proposals with varying but limited project costs. The desire, however, is to have a degree of complexity lower than that of the most recent rocket projects (e.g. GEMINI and OEDIPUS-C).

3.6 Costs

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The costs of most recent rocket payloads has been excessively high. Analysis reveals several causes for this situation. One of the primary reasons is the high complexity of the payloads. The high costs in the case of OEDIPUS C were to a large extent caused by both its complexity and the high cost of the primary science instruments which were built in industry. This is partly because opportunities are so infrequent that it is felt that the scientific and technical envelope must be pushed as far as possible since each flight is considered to be a "one-shot" affair. In conjunction with this is the fact that only one payload is developed at a time which limits the efficiency of the process. Overlapping projects would help ensure that all activity areas are fully occupied.

Payload development and instrument integration requires a minimum size industrial team available on a permanent basis. The SPP proposes to have two or more developments taking place simultaneously which will require only incremental support. The program has never been sufficiently large to support a competitive environment between industries. Nor will it be able to benefit in cost terms from economies of size, however, individual project costs can be reduced if better (longer term) plans can be put in place. Recent experience with a balloon project, BAM, clearly demonstrates the low costs that can be achieved with a complex development on the cutting edge of scientific exploration. This was because an experienced university group did a large amount of the work in the university with the help of many students, both graduate and undergraduate.

Overall program costs can be minimized by reflying recovered payloads, encouraging the proposal of simpler payloads, and using prototype instruments supplied by the scientific team. Benefits will be lower project costs, increased number of projects, greater training potential, and a larger number of prototype instruments available for advancement to the more complex, ie., Orbital Programs. Other cost-reduction methods are suggested in this plan, e.g., standard subsystems and interfaces. Input from the science community and supporting industry will help to define further which methods are most appropriate for cost reductions, however, inadequate volume appears to be the primary cost driver. Cooperative programs with international partners will also be helpful in reducing the high costs of launches which have to take place outside Canada. Cooperation with the provinces, other government departments and space-interested organizations in Canada, such as centres of excellence, could lead to further efficiencies.

3.7 Competition in Industry

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Lack of competition in industry has been given as a cause of increased project costs.

At this time, Bristol Aerospace Ltd. is the only company providing sounding rocket payload services in Canada. The inability to compare proposal costs leads to some uncertainty in establishing an equitable price for payload development work; however, considerable effort has been made in recent projects to compare development costs with historical costs. Taking into account inflation and the increasing level of complexity of recent projects, an obvious cost inflation due to lack of competition has not been present. Increased costs in payload contracts have been seen, however, and are attributable to factors already covered in the Costs section.

To help keep costs in check, the SPP proposes changes to the way payload development projects are managed, including more PI involvement and a stricter adherence to agreed-to requirements. Fixed price contracts will be utilized where requirements are well-defined and where the procurement can be competitive.

3.8 Rise of Project Costs due to PI Requirements

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Both an initial incomplete definition of science requirements at the proposal phase and the addition of new science requirements during a project have led to cost increases to the payload development contracts of recent rocket projects.

Since this is a research-driven program, it must provide some flexibility to accommodate the unexpected, however, it is foreseen that the SPP will not provide the level of flexibility that has been seen in the past. The SPP proposes to minimize the cost effects of changing PI requirements by the following procedures.

During the science proposal phase the PI will be required to provide requirements in sufficient detail to enable an accurate accounting of costs. Involvement of industry in this phase will be mandatory in order to define costs more accurately. Once a project cost has been established in the proposal and the proposal selected, the PI will be awarded a Phase A contract in order to establish the costs to a degree where the follow-on development phases can be costed within more rigid bounds. In order to ensure that costs are not inflated during this phase and that every effort is made to accurately estimate the total program costs in the proposal phase, the total cost established at the end of the Phase A work will be required to be within 20% of the initial proposed cost. Non compliance with this guideline could lead to termination of support for the project.

At the conclusion of a successful Phase A, a formal agreement between the CSA/SSP and the PI will specify the support that CSA will provide to the project. During the course of the project, the PI, together with his/her team, will play a significant role in balancing payload development costs and science requirements to ensure that total costs remain within the approved envelope. An additional 10% contingency, on the original proposed cost, will be held by the project manager for use, at his/her discretion, during the remainder of the project. Any increases beyond this 10% level will require a formal review by a CSA Project Review Committee. It is envisioned that a project could be terminated if costs exceeded a certain overrun threshold.

3.9 International Launches

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In most cases we must rely on international ranges to launch sounding rockets and orbital vehicles, and range costs are high. The cost of a commercial sounding rocket launch at White Sands Missile Range is about $300K and it costs a similar amount at Andoya Rocket Range, Norway. Shared orbital launches are expected to be somewhat more, while international balloon launches are somewhat less.

Fortunately, there is often an opportunity to have international cooperation whereby Canada supplies the vehicle, both Canadian and the international partners develop the scientific instruments, and the international partner supplies the launch. Both GEMINI and OEDIPUS C were cooperative projects - NASA provided the launch in return for flying U.S. instruments and sharing the data.

3.10 Reliability/Success Ratio

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Small payloads projects are usually described as low cost, high risk. The latter description is the result of the use of current and state-of-the-art technologies which generally are well-proven systems by the time they are used on orbiting spacecraft.

Performance speaks for itself in the NASA sounding rocket program which boasts a 97% success rate with its launch vehicles and 85% success rate with its payloads, a performance that exceeds that of high cost satellite projects. This performance is matched in their scientific balloon program.

All projects are hampered with multiple single-point failures, any one of which can affect the outcome catastrophically, regardless of the performance of the majority of systems. As an example, a vehicle failure usually results in total loss of data and payload. In the case of GEMINI, the failure of one crucial subsystem resulted in the failure to achieve most of the mission scientific objectives even though all other sub-systems functioned nominally.

Risk mitigation is handled by good design practice and rigorous testing, if this is possible, before acceptance for flight, but reliability is often a matter of statistics in which luck also plays an important part.

3.11 Funding

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Stable long term funding is required to permit a coherent plan to be implemented and objectives to be met.

It is estimated that a sounding rocket and balloon program will cost $1.5M per year and that a microsat component will cost an additional $1M per year. This assumes that payloads will be much simpler than in recent years. This level of funding has been budgeted for small payloads.

4.0 SMALL PAYLOADS PROGRAM

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4.1 Program Description

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The Small Payloads Program (SPP) will provide for a series of scientific missions of limited size and cost on platforms that include sounding rockets, balloons and microsatellites. Missions will be selected based on a regular series of competitions involving combined research/university/industry teams. Due to the variety of platforms which this program will support, the SSP will follow a flexible program management scheme; however, all proposals will be weighed against SPP objectives (listed below).

In general, the SPP suggests that respondents to an Announcement of Opportunity (AO) construct a team led by a Principal Investigator that includes both a university and an industrial partner. The university partnership should normally include graduate students from engineering, mathematics and science departments as integral members of both the mission definition and concept design team, and the instrument manufacture and test team. The industry partnership will allow technical expertise and guidance to be brought by one (or more) industrial partners to the early concept development and design stages. It is expected that the industrial partner will subsequently be the prime contractor for the payload design, manufacture and test, and will be expected to include the university graduate students and perhaps university technical staff as members of the team during this effort.

The SPP is part of a four point Space Science Program strategy to meet Canadian space science community needs in the fields of solar-terrestrial relations, atmospheric science and astronomy. The first element is a new initiative to provide support for concept studies related to the development of hardware

for future flight. The second element is the SPP. The third element is the proposed SciSat Program and the fourth element is the continuing international-class program which provides access for Canadian instruments on international missions. All elements of the four point strategy contribute to meeting the objectives of the SSP and of the science community. The SPP will contribute substantially to meeting the overall objectives of the SSP.

In addition to increased cooperation outside the agency, the SPP is expected to provide an opportunity for increased synergy within the agency. The Engineering Branch is viewed as a key player in this program and it is proposed that they be asked to provide technology oversight in areas which the SSP project manager cannot handle alone. In this role, they would be expected to contribute expertise in small payload technologies, aid in the preparation of AOs, supervise microsatellite design competitions, coordinate technology development by the industrial partners, assist in project and program evaluations, and act as technical adviser to the SSP Project Manager. Furthermore, development of a microsatellite ground system could be undertaken by this Branch.

The SPP will expect to utilize other facilities and capabilities of the CSA as in past rocket project developments. Possibilities exist for the utilization of DFL facilities for environmental testing, Radarsat's mission/satellite control centre for microsat mission operations, and the Space Science Saint-Hubert laboratories for specific subsystem integration and test.

The following is a proposed methodology for carrying out the Small Payloads Program. Implementation procedures will be detailed in the Small Payloads Program Implementation Plan.

4.2 Definitions

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For purposes of the Small Payloads Program, the following definitions will be applicable:

Platform:
: The mode of doing small payload science in space. The three primary modes are: balloons, sounding rockets and microsatellites. This list is not exclusive. Other modes will be considered if sufficient justification is given.

Instrument:
: Scientific apparatus including sensor(s) and optionally, internal power and control.

Bus:
: Structure, fairings/bays, support systems such as power, telemetry, data acquisition, sequencing and control, subsystems such as attitude control, attitude determination, position determination and booms.

Payload:
: Bus and instruments. This definition is traditional in sounding rocket and balloon projects and will be used in the SPP. Note that payload design refers to the design of the bus plus design of accommodations for the instruments, but not design of the instruments themselves.

Microsat:
: A microsat will be considered to comprise the bus and instruments. Although the term payload is synonymous with satellite or microsat, by SPP definition, it will be avoided where possible, when discussing microsats, due to the possible confusion arising from the different definition of payload

normally used in satellite projects.

4.3 Objectives

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The following are the guiding objectives of the Small Payloads Program of the CSA Space Science Program:

- Provide low cost, regular and rapid access to space for Canadian space scientists for cutting edge scientific experiments (primary objective)
- Provide training opportunities for students in the areas of system design, instrument fabrication and test, and software development by encouraging research institutes to develop and maintain an in-house capability to design and fabricate space-qualified instruments (secondary objective)
- Provide a level of activity sufficient to maintain an industrial capability to support the manufacture and launch of sounding rockets, balloons and other small payloads in Canada (secondary objective)
- Create a forum for increased synergy among university disciplines and between universities and industry (tertiary objective)
- Develop an expertise in microsat and smallsat technologies in Canadian universities and industry (tertiary objective)
- Support innovation in emerging technologies and transfer of that technology between universities and industry (tertiary objective)
- Advance intra-agency cooperation consistent with the new vision for the agency as represented by its new organization and mandate (tertiary objective)
- Provide opportunities to communicate the excitement and benefits of space science to the Canadian public (tertiary objective)
- Increase involvement with the international community (tertiary objective).

4.4 Program Goals

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The goals of the program are to:

1. Ensure a healthy, technically capable space science community
2. Enable an on-going source of prototype space instruments for later evolutionary development for the larger international-class projects
3. Provide industry with a low-level though stable workload by which socio-economic benefits can accrue.

The first and second will be achieved by encouraging the universities to utilize their in-house laboratory capability for the development of scientific instruments and to facilitate an environment for the

involvement of students at the graduate level. The third goal will be achieved by the training of technical personnel, and the development of tried and tested space products.

4.5 Scope

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The program will support projects in the disciplines of solar-terrestrial physics, astronomy and atmospheric studies.

The program will provide launch opportunities on the following primary platforms: sounding rockets, balloons, and microsats although other small payload opportunities will not be excluded.

4.6 Stakeholders

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CSA:

The CSA/SSP will provide program and project management and science oversight to the program. It will be responsible for project selection; supporting the development of instruments, the selection and possible development of payload buses, the integration of instruments, and the provision of launch; and negotiation of international participation. The CSA/SSP has introduced an initiative to provide funds to investigator teams for the development of new instrument concepts. Some of these are expected to be directly applicable to the SPP.

The CSA/Engineering(ENG) will be requested to provide technical oversight to the program. Under the guidance of the SPP project manager they will conduct design competitions and evaluate design alternatives. ENG will handle issues of commercialization and technology transfer. The establishment of a ground segment capability to support the integration, test and launch of the various small payloads is needed and could be coordinated by ENG. Collaboration between SSP and ENG could yield interesting technology spin-offs similar to the spinning space tether, developed by ENG in conjunction with SSP's prime contractor Bristol Aerospace, for the OEDIPUS-C mission.

The CSA Operations Sector/Branch will participate by providing operations engineering input to the design teams and contributing operations facilities and equipment, on a non-interference basis. DFL will provide testing support for SPP projects.

NSERC:

NSERC is expected to support the science analysis, dissemination of results, graduate student support and associated ground based studies through research grants and other granting programs.

Investigator Organizations (IO):

Canadian Universities, Centres of Excellence and Government Science Organizations have always been, and will continue to be, the primary source for Research Principal Investigators and Science Team members. For this program, cooperation with Universities will be extended to include the engineering, mathematics and computer science faculties, as appropriate. The PI will propose multi-disciplinary teams in response to Announcements of Opportunity; such teams are expected to include industrial partners. Due to the variety of platforms supported by this program, and the

varying level of experience in the proposing organizations, the management methodologies will differ. PIs will be free to propose a management scheme which provides the optimum cost, technical and risk benefits.

Industry:

Industry will be expected to maintain a team capable of designing, building and integrating payloads, as required, and supporting launch operations for small payload projects . They must have sufficient personnel resources to meet normal small project schedules but not so large that inefficiency, excessive overhead and Q.A. will be a burden on the financial envelope.

Although the SPP cannot solely support industry participants, the SPP should provide the opportunity for industry to develop technology, create spin-off products, and develop new customers for space related products. Industry participants in past small payload projects have benefitted in such a way.

International Participants:

International participation is encouraged, since cooperative programs will help reduce costs and add scientific capability not available in Canada.

4.7 Strategies

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The following strategies will be adopted to implement a program which meets the stated objectives, and permits good control of costs and schedules.

4.7.1 AO Frequency

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An AO should be issued by the Space Science Program every two years requesting proposals for small payload missions.

4.7.2 Launch Frequency

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Assuming that the program will comprise projects of varying difficulties and platforms, the launch frequency is expected to be a minimum of one launch every one to two years.

4.7.3 Project Management

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The CSA/SSP will assign a Project Manager. He/she will be responsible for day to day management of the program and ensuring that costs and schedules approved at the start of each project are adhered to.

A Project Review Committee will be formed, consisting of the Head of SOrb, Head of SSP Program Planning, the Program Scientist, the Project Manager and an external representative who is a CSA/ENG member. The responsibility of this committee is to review each project on a regular basis and to consider

requested changes in schedule and/or costs above an approved contingency level for the Project Manager.

The Project Manager will normally act as contract manager for all contracts. CSA/ENG will be involved in the management of specific technology development contracts related to the mission. In certain cases, such as a balloon payload development which is to be carried out in-house, an umbrella development contract could be awarded to the scientific institution carrying out the work. The SPP will be open to consider alternative working relationships between the CSA, the PI and industry; however, it will be the decision of the CSA/SSP to determine whether the proposed management arrangement meets the CSA/SSP objectives.

4.7.4 Mission development philosophy

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The project schedule will vary considerably with the complexity of each project. Project Reviews, material selection, documentation and other PA-related requirements will follow the CSA/SSP Performance Assurance Requirements (PAR) document or an approved organizational equivalent.

A Requirements Review(RR) will be held early in the project to clarify and finalize all requirements. Trade-offs between scientific requirements, availability of standard subsystems, cost and schedule will be made. All experimenters will be present and will be required to accept the stated requirements. Concept designs in areas of greatest concern will be provided during this Review.

A Preliminary Design Review(PDR) will finalize requirements and review the preliminary design of the payload. Areas of highest risk must be advanced to a point where they are well understood. A Phase A contract will be let, encompassing the RR and the PDR.

Where schedules permit, contractors will follow a more rigid design philosophy, whereby instrument and payload designs are completed and signed off before any manufacture is started. Ideally, instrument manufacture should be well underway before payload manufacture starts. A Critical Design Review will be held at the completion of all design work. All experimenters must be present and must agree to the final design.

4.7.5 Mission Profile

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The Mission Profile defines the phases of each project and the responsibilities of project participants. Project timelines will vary depending on the type of platform. Typical timelines for balloon, sounding rocket and microsatellite missions are given in the Implementation Plan.

Mission Definition and Concept Design:

Each AO process will normally result in the selection of more than one mission utilizing different vehicles. It is also possible that multiple proposals for a given vehicle type may be chosen for development to the concept design stage. Once a mission is selected, the mission definition, design concept and performance requirements will be frozen and the launch vehicle/platform identified. At this stage, the principal investigator/university will be prime with industry advisors as subcontractors. The proposer will be free to suggest other management methodologies.

Instrument Design, Manufacture, Integration & Test:

This element includes the design, build, integration, test and verification of the scientific instrument. The IO will be responsible for this activity and function as prime contractor for the science instrument development, test and integration support activities. University graduate students and/or other university technical staff would be expected to be employed from the earlier stage as members of the team, with supported from industry as required.

The development of the science instruments by the Investigator Organization is an essential element of the program. Giving students direct responsibility for instrument development is the most effective method of training. Provision of science instruments at a cost affordable to the program is also essential. It is expected that the IO will require the assistance of SMEs during instrument development. It is also expected that a small investment in prototype instruments will lead to many industrial spinoffs.

Payload Design, Manufacture, Integration & Test:

This element includes the design, build, integrate, test and verification of the payload. The industry partner will normally function as prime on the payload development, integration and operations activities, with university graduate students and/or other university technical staff from the earlier stages working as integral, but part-time, members of the industry team. The IO will be required to be present for instrument integration and payload sequence testing. Balloon missions could have the IO perform both the instrument and bus development functions, e.g. BAM.

Launch:

The majority of the launches for the SPP will either be purchased from international suppliers or will be provided by an international partner as part of its contribution to a cooperative program. Primary rocket launch sites are White Sands Missile Range, Poker Flat Rocket Range and Andoya Rocket Range. Akjuit, Churchill, Manitoba is also a possible rocket launch site. SIL of Saskatoon and NSBF, Texas are the primary balloon launch facilities.

There is an increasing supply of low-cost minisat and microsat launch vehicles such as the START2 becoming available, and these, along with launch opportunities where the microsat would constitute a secondary payload, constitute the options presently being considered.

Mission Operations:

This element is intended to cover small payload launch and operations. Rocket and balloon launch and operations costs include payload build-up and test plus waiting time for scientific conditions. Once the payload is launched, operations are short and straightforward. For microsats it is envisioned that existing/planned agency satellite command, control and support facilities will be employed for satellite operations -- the Radarsat mission operations facilities could be employed, for example. It is also envisioned that a low-cost data receiving station will be developed to support science data collection from the Principal Investigator's facility.

4.7.6 Involvement of Investigators in Instrument and Payload Development

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The PI will be expected to accept greater responsibility in the decision making affecting total project costs. Proposals will be required to be accurate in their requirements. Proposals must also be complete in every was, i.e., all aspects of the mission must be included and costed in the budget and included in the

schedule. An industrial partner will be needed to obtain the information pertaining to the payload.

Use of standard subsystems and interfaces will help to increase the costing accuracy. It is the responsibility of the proposer to become aware of the standard subsystems available and what standard interfaces are in use. Technical documentation defining standard subsystems and interfaces will be prepared for each type of platform. As these documents are completed copies will be provided.

Once a proposal has been accepted and a project cost has been agreed to by the CSA and the PI, the PI will be expected to make decisions on technical capability in order to keep costs within limits. It is possible that scientific requirements will have to be reduced in order to keep costs within budget. It is therefore important that the original project costs are credible and that they are agreed to by all participants.

4.7.7 Student Involvement

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Every mission should demonstrate that it is meeting the training objective by employing at least one graduate student. Use of undergraduate students in the project will be considered positively. Support for undergraduate students may be included in the budget. Students in both science and engineering disciplines are expected to be part of the project team.

Involvement of PDFs and RAs will also be considered a positive element.

4.7.8 Evaluation

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At the end of each project, an evaluation will be carried out by the SSP to determine how well the project met scientific, training, cost, schedule and international objectives. A program evaluation will be carried out every two years to assess progress against overall program objectives and to make any needed modifications to the program.

4.8 Guidelines

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In order to meet the objectives of high scientific return while at the same time training new scientists and engineers, it will be necessary to have a diverse program with missions of varying levels of sophistication. In addition, measures must be taken to control project costs. The guidelines given below will help maximize the number of projects which the SPP can undertake within its limited budget and provide the maximum opportunity for student involvement.

4.8.1 Payload Complexity

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Different levels of mission complexity will be acceptable; however, proposers will be encouraged to make use of standard subsystems and to avoid the use of project-unique hardware. Although science has to be a determining criteria, project cost will be an important evaluation factor.

4.8.2 Use of Standard Subsystems and Interfaces

Proposers are encouraged to use available standard subsystems and to meet the standard interface specification, defined in the relevant IDD. Designs not meeting these standards must be justified and will be judged on the basis of science return and cost.

The development and testing of new subsystems and hardware required to meet new scientific requirements will be supported by the program and test flights will be carried out as part of regular flights on a non-interference basis.

4.8.3 Payload Recovery/Reflight Hardware

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Recovery and reflight of all small project payloads (excluding microsats) is encouraged since this will both lower costs and reduce program risk. Applications for reflight may be given special consideration depending on the reasons for the reflight and on available funding. Requests for reflight resulting from a vehicle or payload anomaly may be considered more favourably than a request due to instrument failure.

4.8.4 Instrument Development

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Instruments are expected to be designed and built by the research organization. This guideline is to encourage investigator groups to develop or maintain a capability to design and manufacture flight instruments, which, in turn, will help to minimize costs and provide training opportunities. This does not mean that all work must be done on campus. The use of small to medium enterprises (SMEs) has been shown to be very cost effective.

The development of instruments within the Investigator Organization will utilize a small portion of the total SPP funds (approximately 20%). The instruments will be protoflight developments and frequently will require industry input especially at the subsystem level. The provision of a small amount of funding by the program is expected to result in the development of a large number of new instruments many of which will evolve into international-class proposals. The development of international-class instruments within the Orbital Program will continue to be performed in industry.

4.9 Success Criteria

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Program output will be compared against program objectives. Projects will also be evaluated against the initial project goals.

The program success criteria will include the following:

- Peer-reviewed scientific results in the form of papers in refereed journals;
- Papers presented at scientific symposia;
- Positions created for PDFs, Doctoral and Masters students;
- Student involvement;

- Instruments and new technologies qualified for space flight;
- Demonstrated industrial proficiency in a new area of space systems development;
- Collaboration between Industry, University, and Government;
- International involvement/exposure of Canadian scientific/industrial capabilities; and
- Enhancement of the visibility of the CSA and space science in general in Canada.

A more detailed performance measurement framework has been completed for the Space Science Program for each of the disciplines. One more specific to the Small Payloads Program will be prepared and incorporated into the main framework.

4.10 RESOURCES

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The CSA/SSP hopes to provide resources for the SPP at a fixed annual level of $2.5M until the year 2004. This will permit the SPP to plan and manage its cash flow and to support a continuing program.

A minimum level of activity is required to sustain industry capability. The cost of one rocket project every one to two years and a balloon every two years, which is considered to be a minimum sustainable level, is estimated to be about $1.5M/yr. The extra cost of one microsat project running concurrently, will be about $1 M/yr over a total project lifetime of 3 yr.

Although a rigid division of funds between industry and universities will not be set, past history of small payloads projects has shown the division to be approximately 70% to 80% to industry and this division is expected to be maintained in the SPP.

The program will be supported by 2.5 Full Time Employees (FTEs).

4.11 Preliminary WBS

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The following Work Breakdown Structure gives the implementation activities of the SPP. The SPP Implementation Plan provides a detailed discussion of each element.

1.0 Preparation
- 1.1 Documentation
- 1.2 Capability Review
- 1.3 Infrastructure
- 1.4 Workshops

2.0 Project Selection and Implementation
- 2.1 Announcement of Opportunity
- 2.2 Selection
- 2.3 Implementation

3.0 Evaluation
- 3.1 Project Evaluation

3.2 Programme Evaluation

5.0 CONCLUSIONS

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This paper presents a baseline for a Small Payloads Program. It addresses the urgency related to the retention of a required industrial capability and presents a plan for an orderly and coherent program.

The plan presents lessons learned from recent small payload projects. Excellent science, lower project costs and good training opportunities are primary goals but no procedures nor guidelines can ensure that they are met unless the program is sufficiently supported and well organised.

Arguments have been presented to show how an SPP can benefit the SSP and Canada. A Small Payloads Program produces "cutting edge" scientific exploration and ensures new opportunities for the science community and provides for a Canadian industrial capability to build and fly innovative space hardware.

ACRONYMS

AO
: Announcement of Opportunity

CRR
: Churchill Rocket Range

DFL
: David Florida Laboratory

FTE
: Full Time Equivalent

GSE
: Ground Support Equipment

IDD
: Interface Definition Document

IO
: Investigator Organization

NSBF
: National Scientific Balloon Facility

NSERC
: National Scientific and Engineering Research Council

PI
: Principal Investigator

PDF
: Post Doctoral Fellow

PDR
: Preliminary Design Review

QA
: Quality Assurance

RA
: Research Assistant

RR
: Requirements Review

SIL
: Scientific Instrumentation Limited

SME
: Small to Medium Enterprises

SOrb
: Sub-Orbital (program)

SPP
: Small Payloads Program

SSP
: Space Science Program

WBS
: Work Breakdown Structure