APPENDIX B: SOUNDING ROCKET PLATFORM DESCRIPTION

1.0 INTRODUCTION

The CSA Space Science Program (formerly Space Division, NRC and Canada Centre for Space Science, NRC) has been conducting space science experiments on sounding rockets for several decades. As a result Canadian industry, primarily Bristol Aerospace Ltd., has developed a high degree of skill in the production of sounding rocket buses, the integration of the payload and the launch. A spin-off of the rocket program was the development of the internationally recognized Black Brant family of sounding rocket vehicles. Over 100 Canadian missions have been launched, the most recent being the very successful OEDIPUS C in November 1995, from Poker Flat, Alaska.

Sounding rockets provide a quick response capability, allowing scientists to conduct experiments at specific times and places. They provide the only means of making in-situ measurements between the maximum altitude of balloons (40 km) and the minimum altitude of satellites (150 km).

The purpose of this appendix is to provide the capabilities offered by the SPP for sounding rocket missions. Restrictions and requirements imposed by the SPP are also given.

2.0 PLATFORM DESCRIPTION

As an example of a sounding rocket, Fig. 2.1 shows the OEDIPUS C vehicle and payload.

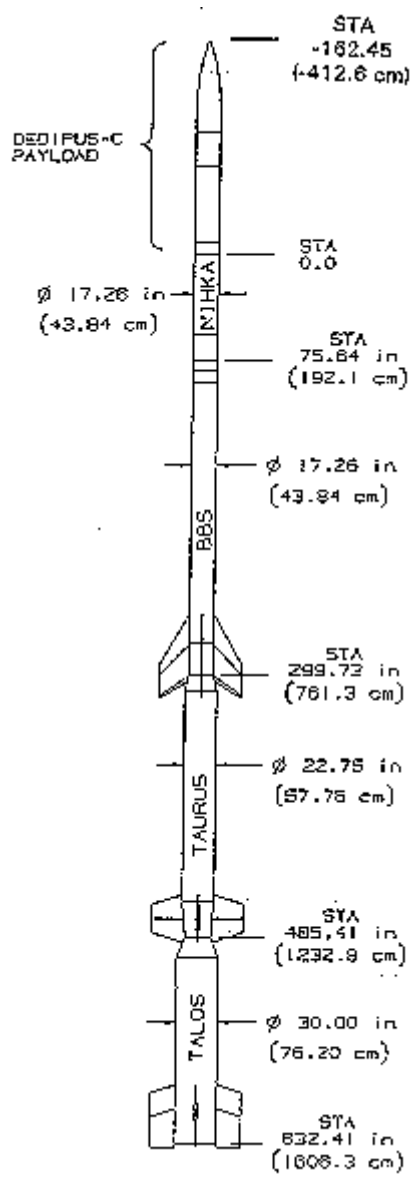

Figure 2.1 OEDIPUS-C BB 12 Launch Configuration

2.1 Vehicle

All the vehicles used in the SPP are produced by Bristol Aerospace Ltd. Figure 2.2 shows the Bristol family of Black Brant vehicles in current use. Black Brant is a solid propellant rocket system in single and multi-stage configurations that carry payloads of 70-850 kg to altitudes from 150 km to more than 1500 km. The largest, the BBXII, is a four stage vehicle, and was used in the recent OEDIPUS C launch. All of the larger vehicles require at least one booster motor, which are surplus military motors and must come from the U.S.A. It should be noted that the majority of the U.S. booster motors are not available commercially, hence the need for cooperative projects with NASA. Including NASA sponsored instruments in sounding rocket proposals greatly increases the likelihood of a project becoming cooperative.

2.2 Vehicle Support Systems

Vehicle support systems are an integral part of the Black Brant rocket. The clamshell release and Forward Ejecting Ogive System (FEOS) are means of removing the nose cone from the payload. Other

standard vehicle support systems, include stage ignition systems, boost guidance, thrust termination, and yo-yo despin.

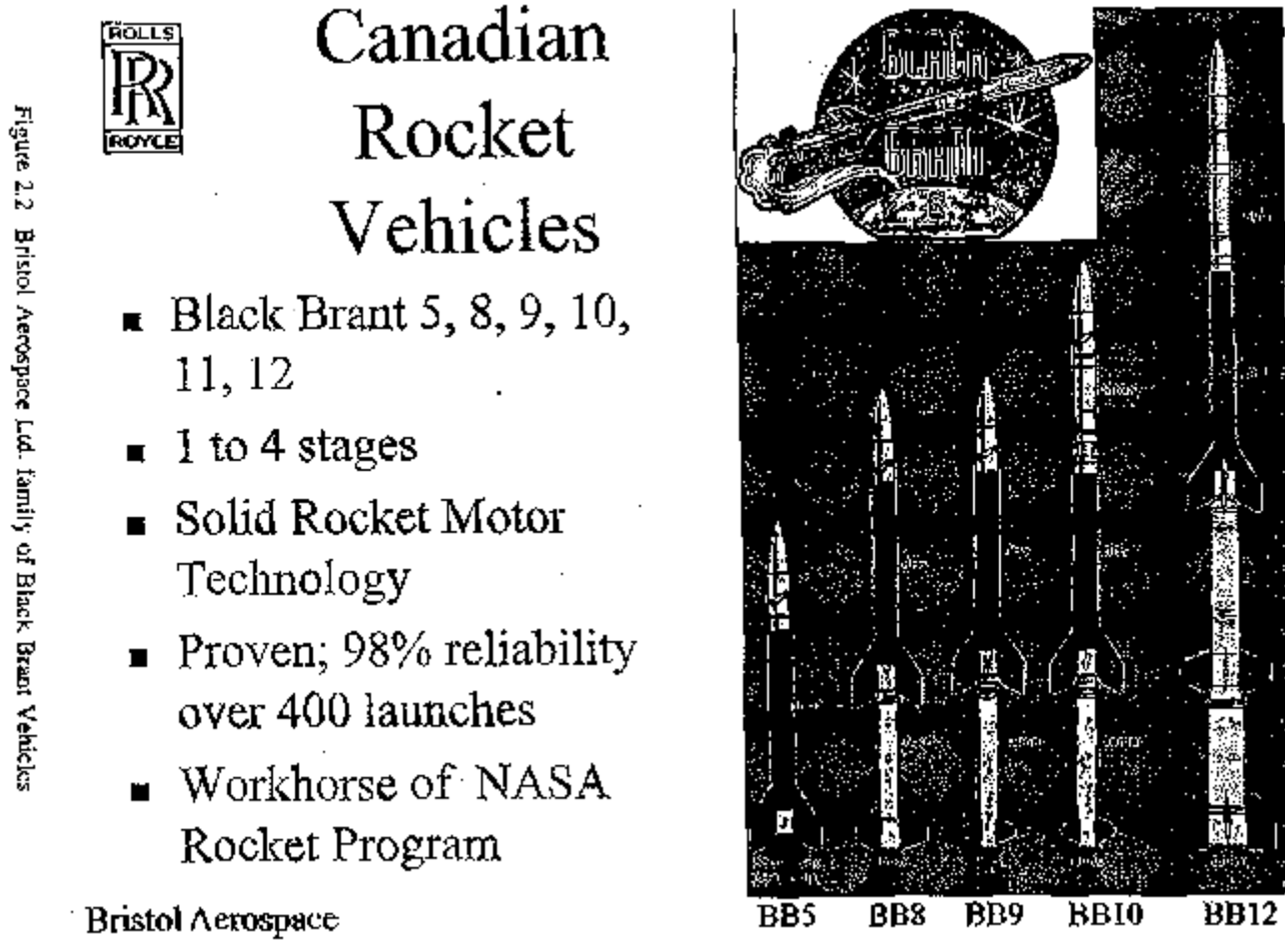

Figure 2.2 Bristol Aerospace Ltd. family of Black Brant Vehicles

The Saab/SSC S-19 Boost Guidance system is used on Black Brant vehicles to reduce trajectory impact dispersion. It is a requirement on some launch ranges when large vehicles are used. Thrust termination is a command destruct system used on small ranges to prevent exit of the vehicle from the range. The vehicle is stabilized during flight by introducing aerodynamic spin. The yo-yo despin removes the majority of the spin prior to the start of science.

2.2 Payload

The payload consists of the aluminum skin sections, structure, electrical and mechanical support systems, payload subsystems and instruments. System capabilities are discussed in Section 4. Two approaches to payload buildup are possible. The integrated approach tries to optimize the volume utilization by integrating payload systems and instruments into a common volume. This approach is more costly, however, it is a useful approach when weight is critical. The modular approach has instruments and payload systems developed with their own skin sections. Payload buildup using this approach is straight

forward and therefore less costly.

Electrical systems include pyrotechnics, sequencing and control, diagnostics, tracking, data acquisition, telemetry and power. Mechanical systems include structure, skins, doors, battery boxes, mechanisms and material selection.

Payload subsystems can include any or all of: attitude control, attitude determination, position determination, payload separation, booms, tether spool and wire, tether cutter and sealed, reclosable doors.

2.4 Flight Scenario

Figure 2.3 shows a typical mission profile for a BBIX payload (courtesy of Bristol Aerospace). (1) and (2) show launch and second stage burn; (3) second stage separation, despin and nose cone deployment; (4) door, boom and science probe deployment, and attitude control; (5) experiment operations; (6) recovery. Flight times are less than twenty minutes.

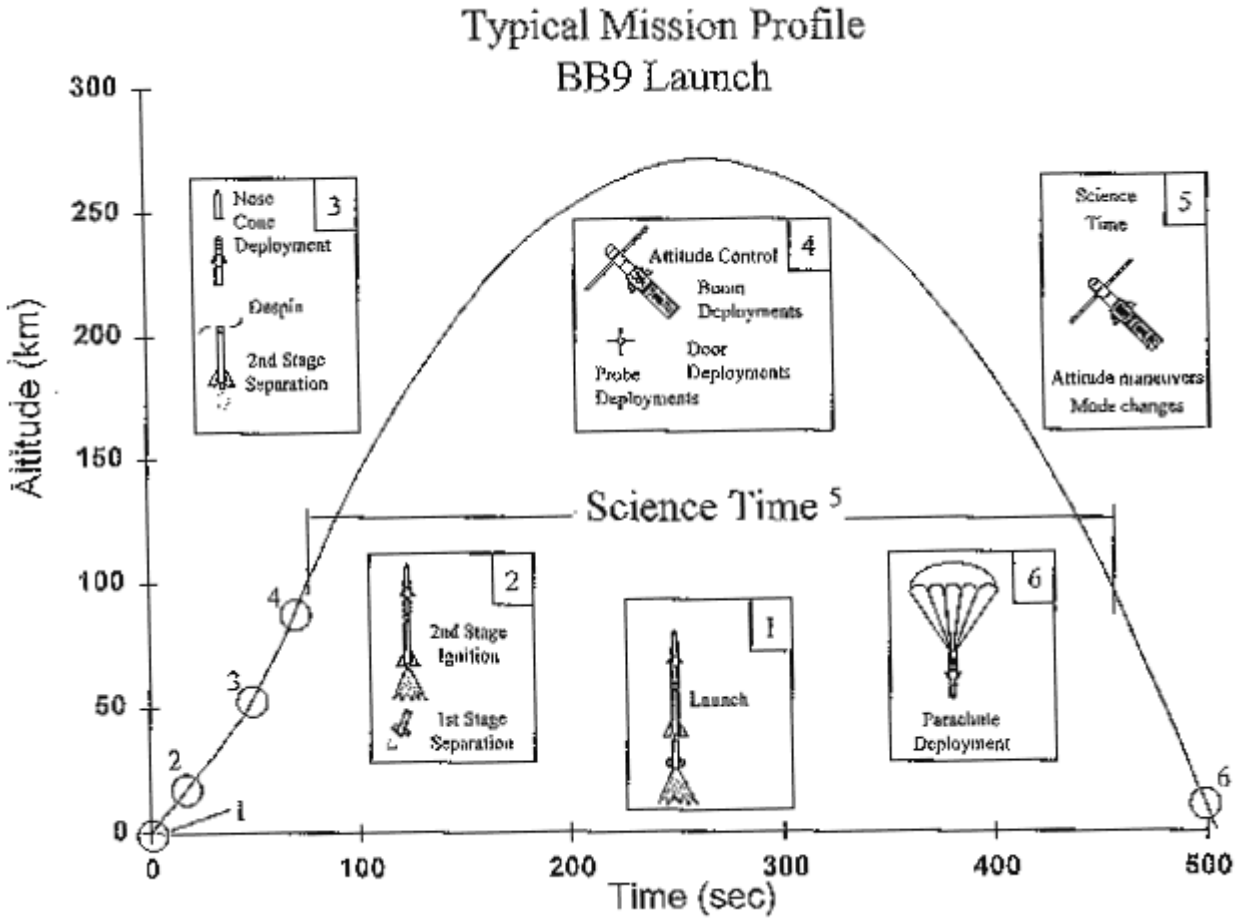

Figure 2.3 Typical BB9 Mission Profile

3.0 ENVIRONMENT AND TESTING

The following is an overview of the environment to which sounding rocket payloads are subjected and a brief discussion of the test specifications. For details of the Black Brant environment and test specifications, refer to "Environmental Specifications for 17" Black Brant Payloads and Instruments", Bristol Aerospace ER 88757/A.

3.1 Vibration

Vibration is an important factor in sounding rocket payload design. Vibration during motor burns can reach 6 grms. Payloads are tested to 12.7 grms in three axes. New payloads are also required to undergo a sinusoidal vibration test to a maximum of 3g. During the sinusoidal vibration test it is permissable to notch out known resonances since resonances can be damaging, and are not expected to be excited during flight. Parts and subsystems are vibrated at a higher level for qualification.

3.2 Thermal

Due to the relatively short flight time payload temperatures do not change greatly. The maximum temperature excursion is likely to be less than 10C. Payload systems and instruments are required to work in the temperature range 0 - 60C. Thermal testing is carried out at the system and instrument level not at the payload level.

Low payload temperatures are mainly the result of low ambient ground temperature during payload transportation to the launcher and payload mating with the motors. This is not a great concern since most launchers have heated enclosures. A greater concern is high payload temperature resulting from the operation of the payload during pre-flight checkouts. The temperature of the payload is monitored as well as that of high power components such as transmitters, during ground checks to ensure that temperatures are kept in range. During re-entry, wiring and components adjacent to open doors will sustain thermal damage.

3.3 Acceleration/Shock

The payload will experience accelerations from -3g to +23g during the powered portion of the flight as the vehicle is accelerated by each motor then coasts prior to the ignition of the next stage. Generally lighter payloads will experience higher accelerations. Payloads and instruments are not required to undergo acceleration testing. The higher vibration test levels account for the lack of acceleration testing.

Shock is experienced during travel up the launcher rail or tower plus at motor ignition. The maximum shock is less than 25g. Complete payloads are not normally shock tested, however, unqualified components and subsystems often are tested.

3.4 Vacuum

A hard vacuum is experienced by the payload as it exits the atmosphere. Undesirable effects of a vacuum include reduced convective heat transmission, corona (which occurs when high voltages are present in the payload), changes to lubrication, coefficient of friction changes, and material outgassing. Depending on the nature of the payload, materials which are susceptible to outgassing may have to be avoided.

Hypopressure and vacuum testing of payload systems and instruments are required if they contain high voltage. Vacuum testing of the complete payload is not normally performed. Test articles should be operated according to the flight timeline, at the pressures expected during the flight, to ensure that no arching problems will occur.

3.5 Electromagnetic Interference

During the design phase, EMI is minimized by identifying potential sources and susceptible systems or instruments. Formal EMI specifications are not imposed, nor is there a formal EMC analysis. EMI is

minimized by placement of systems and components, shielding, use of twisted pair leads, and wire routing and grounding to avoid ground loops. Some payloads which require low magnetic interference must undergo screening of materials to minimize residual magnetic moments. During the flight sequence test, following payload integration, all systems are operated according to the flight timeline. Data are reviewed carefully to identify possible interference. Corrections are then made if necessary.

4.0 CAPABILITIES

This section discusses the range of capabilities provided to the sounding rocket experimenters as part of the SPP.

4.1 Trajectories

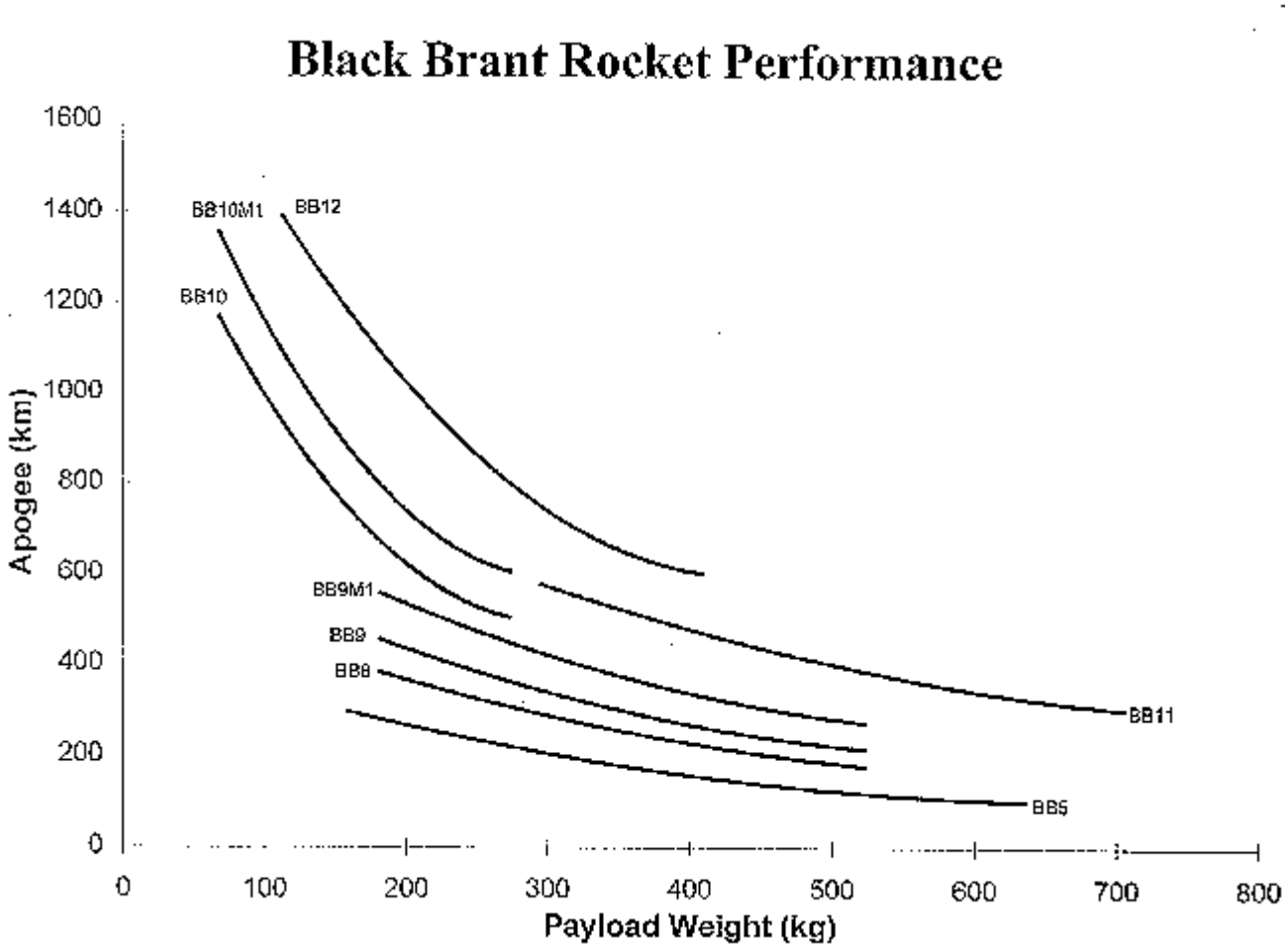

Figure 4.1 Black Brant Rocket Performance

Figure 4.1 shows the performance of available Black Brant vehicles as a function of payload weight. The corresponding science time, ie, the time above 100 km, is given in Figure 4.2.

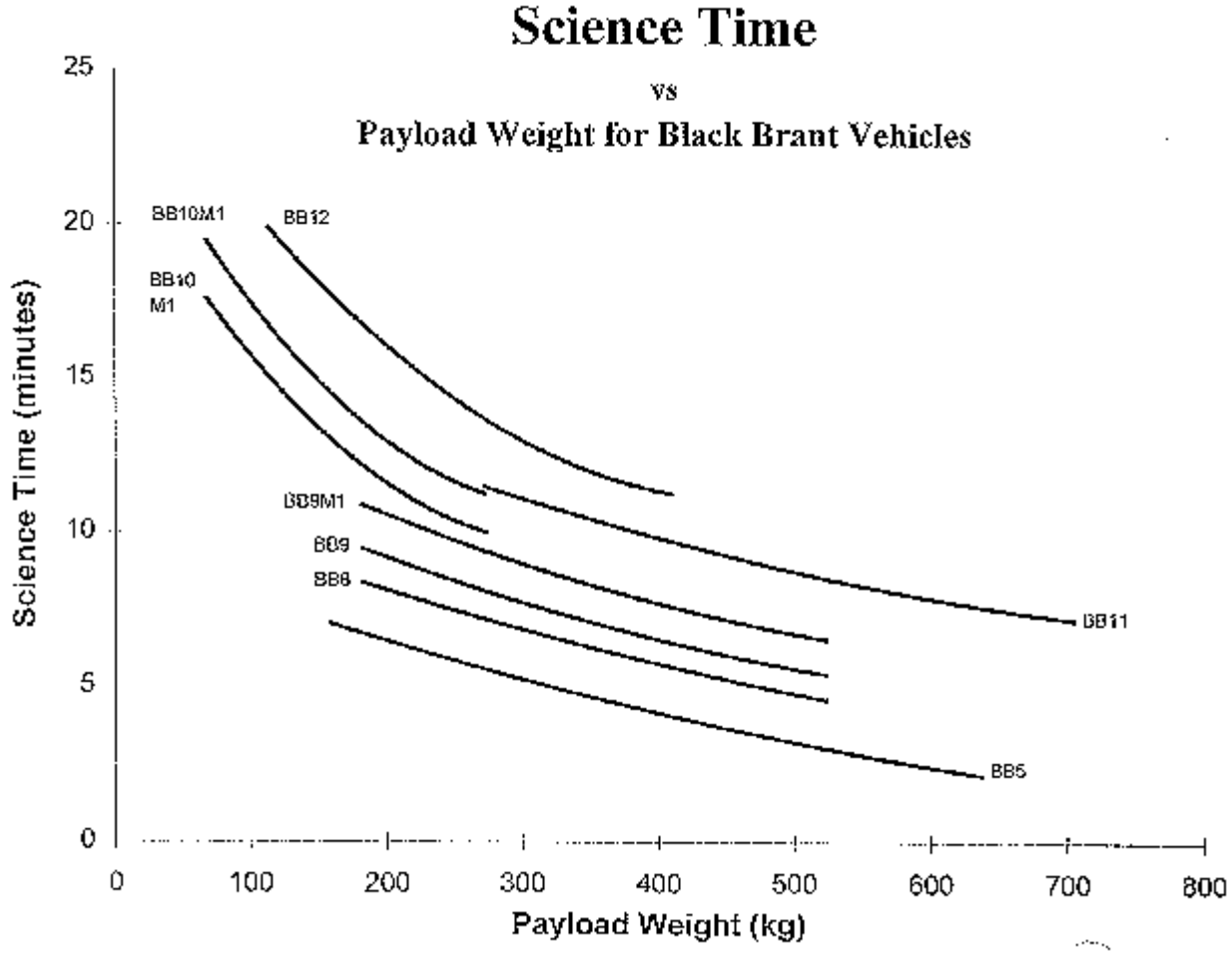

Figure 4.2 Science time for Black Brant Vehicles

4.2 Payload Support Systems

Sequence and control is primarily provided by redundant digital timers for time based payload system and instrument events. IMU based control for altitude dependent events can be provided. Ground based control of payload events is possible by uplink command. The following real-time monitor and control functions are available:

- Payload pointing, corrections
- Instrument mode control
- Instrument sensitivity control
- Charge detonation
- Trajectory event initiation

The following diagnostic data can be provided:

- Accelerations
- Vibrations
- Temperatures
- Full payload support system diagnostics
- Support for instrument diagnostics
- Full vehicle diagnostics

Vehicle and payload position are provided by various tracking and position systems. Radar skin tracking is available up to an altitude of about 100 km. Radar transponder tracking can give payload position throughout the flight to an accuracy of 10 m, however it is not available at all ranges. TRADAT is a closed loop ranging system capable of 0.1 km positional accuracy. GPS has been proven on NASA rockets to operate effectively and will give position to 100 meters. GPS could be provided if required.

The following data acquisition and telemetry capability is available:

- Data rates to 10 Mbps
- PCM downlinks
    - Analog data interface
    - Serial digital interface
    - Parallel digital interface
    - Counters
- Dedicated PCM links for instruments
- TV links
- FM/FM multiplex systems
- Onboard data storage (recovered payloads)
- Multiple TM links (up to 5)

The payload bus normally provides all payload power. It is a battery based system giving standard positive and negative power at +28V and -18V. Full protection, instrument to instrument is provided. Special requirements such as low bus noise, and dedicated sources can be accommodated.

Where payload recovery is required, either aft or forward recovery systems are available for payloads weighing up to 1000 lbs. They are parachute recovery systems for land application.

4.3 Subsystems

Attitude Control System capabilities are as follows: inertial pointing, 1 ; magnetic pointing, 1; solar pointing, arc minute; stellar pointing, arc second.

Video camera attitude determination is available to 10 arc minute accuracy.

Re-closable doors for instrument viewing which provide dust tight closure and re-entry protection are available. Standard deploying doors for boom and probe deployment and instrument viewing are also available in varying sizes.

Boom systems of different designs have been flown and could be made available to the program. They include long (18 m tip-to-tip) quadrupole bi-stem booms, instrument deployment booms such as that used on GEMINI, rigid folding booms and commercial booms such as Weitzman.

A deploying tether system is available for tether lengths to 1 km. The tether spool rotation can be measured to an accuracy of 0.3. A tether cutter system has been successfully test flown. A cold gas separation system for double-probe payloads was also test flown.

The standard payload diameter is 17 inches. Bulbous payloads, 22 inches in diameter have been successfully flown providing greater capability for instruments such as spectrometers. The use of bulbous payloads requires additional stability analyses. Impact protection can be provided to minimize shock to delicate instruments during recovery impact. A metal foam impact protection system was successfully

flown on GEMINI in 1994.

4.4 GFE

The SPP has ground support hardware in storage which could be used by experimenters during their instrument development. This includes decom systems, bit syncs, PC based recording system, digital tape recorder plus other specialized hardware for payload build-up, testing and handling. Standard laboratory equipment must be supplied by the IO.

5.0 LAUNCH RANGES/CONTRACTORS

The primary North American launch sites are White Sands Missile Range(WSMR), New Mexico, Poker Flat Research Range(PFRR), Alaska, Wallops Flight Facility(WFF), Virginia, and Akjuit, Churchill, Manitoba. The other major sites used by the SPP are Andoya Rocket Range(ARR), Norway and Esrange, Sweden.

WSMR, PFRR, and WFF require an agreement with NASA. Often cooperative missions with NASA involve provision of the launch by NASA. However, launches can be obtained on a fee for service basis. PFRR is operated by the University of Alaska, with NASA being the main customer. Akjuit, ARR and Esrange have standard rates for launch services.

PFRR, Akjuit, Andoya and Esrange are on or close to the auroral oval, hence are most applicable for auroral physics. WSMR is used for solar and atmospheric study missions where the payload is always recovered.

Other fixed sites in the world are Sao Pualo, Brazil and Woomera, Australia. They are used on a campaign basis by NASA. It is unlikely they could be justified for single Canadian launches, however it is conceivable that a Canadian rocket could be included in a cooperative campaign with NASA.

6.0 PAYLOAD CONTRACTORS

Bristol Aerospace Ltd., Winnipeg, Manitoba, is the only sounding rocket payload contractor in Canada. Bristol is capable of designing, manufacturing, and testing payload support systems and custom payload hardware. In addition they integrate the science instruments into the payload and provide launch support for the payload. They have developed many custom subsystems which are now part of the standard sounding rocket inventory.

7.0 FLIGHT HARDWARE DEVELOPMENT

7.1 REVIEW CYCLE

Periodic reviews will be held throughout the development of the flight instruments and bus. A Requirements Review (RR), Preliminary Design Review (PDR), Critical Design Review (CDR), and Instrument Readiness Review (IRR) will be held for new instrument developments funded by the SPP. This applies to the primary instrument but may not apply for secondary instruments. The IRR will be held prior to instrument turnover to the payload contractor for integration.

Parallel reviews will be conducted for the payload. A Flight Readiness Review (FRR) will be held prior to shipment of the payload to the range. It is expected that instrument development will precede payload development, ie. instrument PDR and CDR should precede payload PDR and CDR. Reflight missions may require fewer reviews.

7.2 Hardware Design

A number of mechanical and electrical factors must be considered when designing for rocket flight. The following are factors to consider when designing or buying mechanical and electrical equipment. The payload contractor can provide additional help in designing instruments.

Acceleration	**Redundancy**
Accessibility	**Rigidity**
Availability of Parts	**Temperature**
Dynamic balance - C.G.	**Testing**
Location	**Vacuum**
Cost	**Vibration**
Dimensional Stability	**Weight**
Lifetime	

The SPP does not impose restrictions on components or system selection for sounding rocket instrument development, however, MIL Spec. or good commercial parts derated for space flight are recommended. All flight hardware must pass required environmental tests.

An important part of the instrument design is designing in the capability to easily and quickly determine the health of the instrument in the few minutes prior to launch. This may require GSE development and/or software development.

7.3 Standards

Standards are in place at this time for payload environmental qualification and acceptance testing. They are referenced in Section 3. In addition accepted design practices are applied to payload design, and fabrication. Bristol Aerospace Ltd. should be consulted for the latter.

It is the intention of the SPP to investigate additional standards such as for interfaces, support systems and subsystems. Such standards may be applied to the program in the future. Participants will be notified.

7.4 Quality Assurance

The instrument developer shall follow his/her established institution Quality Assurance (QA) program through all phases of hardware and software development. Where a developer has no existing QA program, a tailored QA program shall be developed for SPP hardware that will address some or all of the following areas:

- Document change control
- Identification and traceability
- Procurement controls
- Receiving inspection
- Fabrication control
- Electrostatic discharge control
- Nonconformance control
- Inspection and tests
- Configuration verification

The CSA technical authority for the development may audit this QA program.

8.0 OPERATIONS

An example range schedule is shown in Figure 8.1. During range activities the following occurs:

- The payload is integrated and tested at the range.
- The payload and launch vehicle are integrated and the assembly is moved to the launch area.
- The payload is launched (and recovered).
- The payload is packed for return shipment to Bristol. Instruments are removed at Bristol and returned to the experimenter.

At the range and before the launch the experimenter is require to:

- Unpack and set up instrument GSE in preparation area.
- Perform final instrument examination checks.
- Turn over the instrument to the payload contractor for installation into the payload and carry out instrument functional checks.
- Participate in the range required tests, and practice countdowns.
- Set up GSE for flight mode in blockhouse and user area.
- Confirm correct operation of the instrument when the rocket is on the launcher.

(If your browser does not support tables, an image [GIF]) of this table is available here

Oedipus-C Range Schedule, October 1995.
Rev#1, Draft: 18 July, 1995.

Sun	Mon	Tues	Wed	Thur	Fri	Sat
1 Oct Travel: Bristol CSA & NASA	2 Unpack Setup Travel: experimenters Battery Fill	3 Battery Fill GSE setup GSE test Check Rng Umbi	4 Payload Buildup Payload Tests Range I/F Tests	5 Payload End-to-end tests	6 Payload End-to-end tests	7 Contingency Day
8 Oct Contingency Day	9 Range Horizontal Review Records Battery Charging	10 Move GSE to B/H	11 GSE setup/checkout Stage payload	12 Payload rigging GSE Checkout Payload pwrup	13 Range Vertical Review Records	14 Contingency Day Final Rigging Practice Counts
15 Oct First night up	16 Count (if required)	17 Count (if required)	18 Count (if Required)	19 Count (if required)	20 Count (if required)	21 Pack
22 Oct Travel	23	24	25	26	27	28

Figure 8.1 Example range schedule

9.0 PROJECT MANAGEMENT

9.1 Project Team

The CSA team will consist normally of just the Project Manager from SSP. However, where required, CSA/Engineering help will be added to manage specific technology developments required by the mission. Operations will be handled by the payload contractor and the launch contractor.

The IO team will consist of the PI, Co-Is, students, RAs, and mechanical and electrical technologists. Some instrument developers will require support from SMEs.

The payload contractor team comprises a project manager, electrical and mechanical engineer, electrical and mechanical technologists and a vehicle engineer.

9.2 Contract Management

Historically all payload development contracts were let directly to the industrial payload contractor with little involvement from the PI. The aim of the SPP is to have the PI be involved with decisions related to cost control throughout the project. Although that could be done quite effectively by contracting directly with the IO for all phases of the work, it is recognized that not all IOs have the necessary infrastructure to handle complex contracts. Therefore, we would prefer to have the IO act as prime for the planning phase and industry to be prime for the design, fabrication and testing stages.

Phase A contracts will be let by PWGSC, directly to the IO. CSA/SSP will act as the Scientific Authority. The contractor will be required to meet all contract requirements, particularly regular monthly progress reports. Follow-on payload contracts will be let to industry. Instrument development contracts will continue to be let to the experimenter.

If an IO desires to be the prime contractor for the entire project, the IO would be required to subcontract the payload development work to industry. The IO must be able to demonstrate its capability to administer subcontracts and show that there will be little cost escalation resulting from that administration.

In either contract methodology the PI will be required to ensure that costs do not go over budget through direct contract control or by recommendations to the CSA contract manager.

9.3 Project Schedule

This section describes the schedule of activities involved in launching a sounding rocket payload. Figure 9.1 is a typical suborbital rocket mission schedule from concept to launch. The following are the objectives of each payload phase to be completed by the design review date.

Feasibility/Concept Review:

- Baseline Mission Requirements
- Baseline Instrument Requirements
- Draft Payload Support System and Subsystem Requirements
- Conceptual payload layout
- Conceptual GSE configuration

Preliminary Design Review:

Review Mission Requirements
Payload Preliminary Design
- Configuration
- Weight
- Special requirements
- Instrument final design
- Support systems and subsystems: special requirements, interface, sequence and control, telemetry

Vehicle Preliminary Design
GSE Preliminary Design: consoles, umbilicals, telemetry, external power, special test equipment, special facility requirements
System Issues: safety/hazard control, interference control, contamination control, range, recovery, event list
Preliminary Integration and Test Plan: critical component survival testing, component flight acceptance testing, flight hardware integration, flight hardware testing, range testing, countdowns, Go/NoGo and success criteria

Critical Design Review:

Payload Final Design
Vehicle Final Design
GSE Final Design
System Issues
Final Integration and Test Plan
Action Item Review

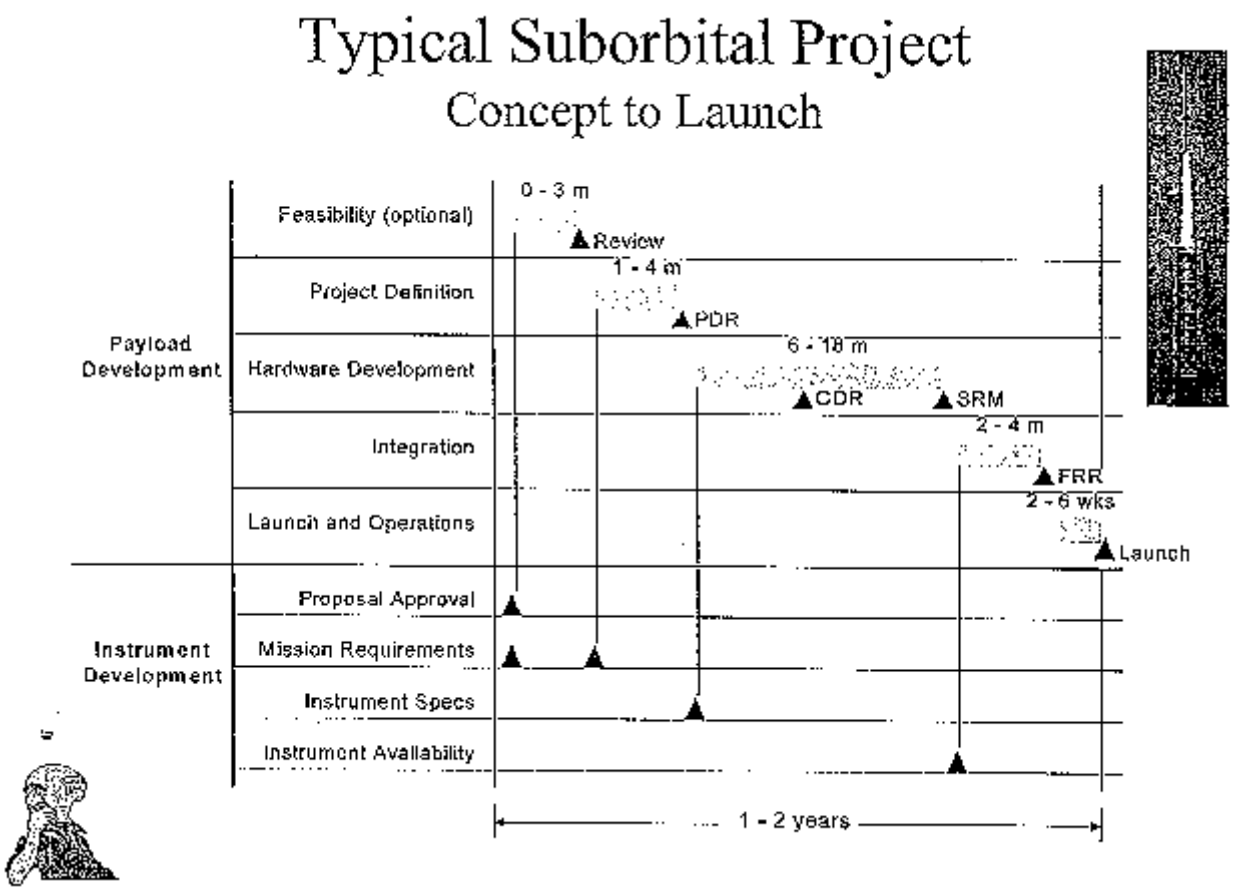

Figure 9.1 Typical suborbital rocket mission schedule

Pre-Environmental Review:

This review is non-essential and would be held at the discretion of the CSA Project Manager, at the payload or instrument developer's facilities. The timing could be from late payload construction to late integration. It would have the following objectives:

Review status of payload and instrument hardware
Review integration progress and plans
Review payload environmental test plans

Flight Readiness Review:

This review is held after successful completion of all payload testing, before shipment to the range. The objectives are:

Review FRR checklist to ensure that all requirements are met
All preflight checks and measurements are complete
The status of all payload hardware is "ready for flight"
All Action Log Items are closed
Finalize shipping arrangements

10.0 TARGET PROJECT COSTS

Total new mission costs should be $2.5 M or less, inclusive of launch costs. Reflight of existing payloads

should be less. The desire is to have average sounding rocket mission costs less than this, consequently missions costing less than the maximum amount will receive considerable attention.

With the limited funding available in the SPP, proposals offering linkages and support from other organizations would be attractive.