APPENDIX C: MICROSATELLITES

1.0 INTRODUCTION

The Space Science Program of the CSA has had limited experience with microsatellite missions in the past, although it has much experience with instruments on large and small satellites. It was decided recently at the Small Payloads Workshop in Montreal, as a result of input from attendees, that microsatellites should be included in the upcoming SPP AO on small payload missions. At present, there is no infrastructure such as that which exists for sounding rocket and balloon projects. The intention of this appendix, on microsatellites, is to provide guidelines for proposers, based on sounding rocket experience, recent reference material on microsatellites, and in-house satellite expertise. Specific requirements will be clearly indicated by wording such as "must", "shall", "is a requirement". As the SPP matures, documentation will be introduced providing clearer definition of the requirements for microsat proposals. In the meantime the proposer will be expected to carry out much of the definition of the proposed work in a Phase A contract. Although the bounds are not clearly defined, as yet, for microsats, the costs ceilings are. Therefore it is incumbent upon the proposer to enlist the help of industry to accurately define costs for the proposal. Chosen proposals will then go into a Phase A study where costs are refined to a ROM level.

2.0 REFERENCE DOCUMENTS

Microsat Presentation to SPP Workshop, H. Joyce, CSA/ST, January 22/23, 1996.

Potential of Microsatellites for Environmental Monitoring, R. Buckingham, Routes Inc., 5 September 1995.

NASA SMEX Program documentation

Course Notes: "Microsats: Design Development & Execution of Minimum Missions", Launchspace, March 1996, instructor: Dr. Rick Fleeter.

3.0 PLATFORM DESCRIPTION

A microsat is not defined so much by its size as by its cost, however, there is a correlation between size and cost. Microsats supported as part of the SPP should be 60 kg or less. In order to control costs a different philosophy has to be taken compared to larger satellite developments. The philosophy has to be closer to that of sounding rocket developments, with characteristics such as small, dedicated teams, minimum documentation, limited redundancy, restricted design margins, short build schedules and simple missions.

A microsat is considered to consist of a bus and instruments. Large satellites normally have a skeletal structure to which support systems and instruments are attached. Microsatellites, in order to keep the weight down, use an exoskeleton approach.

3.1 Microsatellite Bus

Support system and instrument boxes are joined to form the bus structure. Figure 3.1 is an exploded view of KITSAT-B, also known as Oscar 25. The outer skin is used to mount solar cells. The bus provides support systems including, power, telemetry, attitude control and determination, data acquisition and storage, command and control and thermal control.

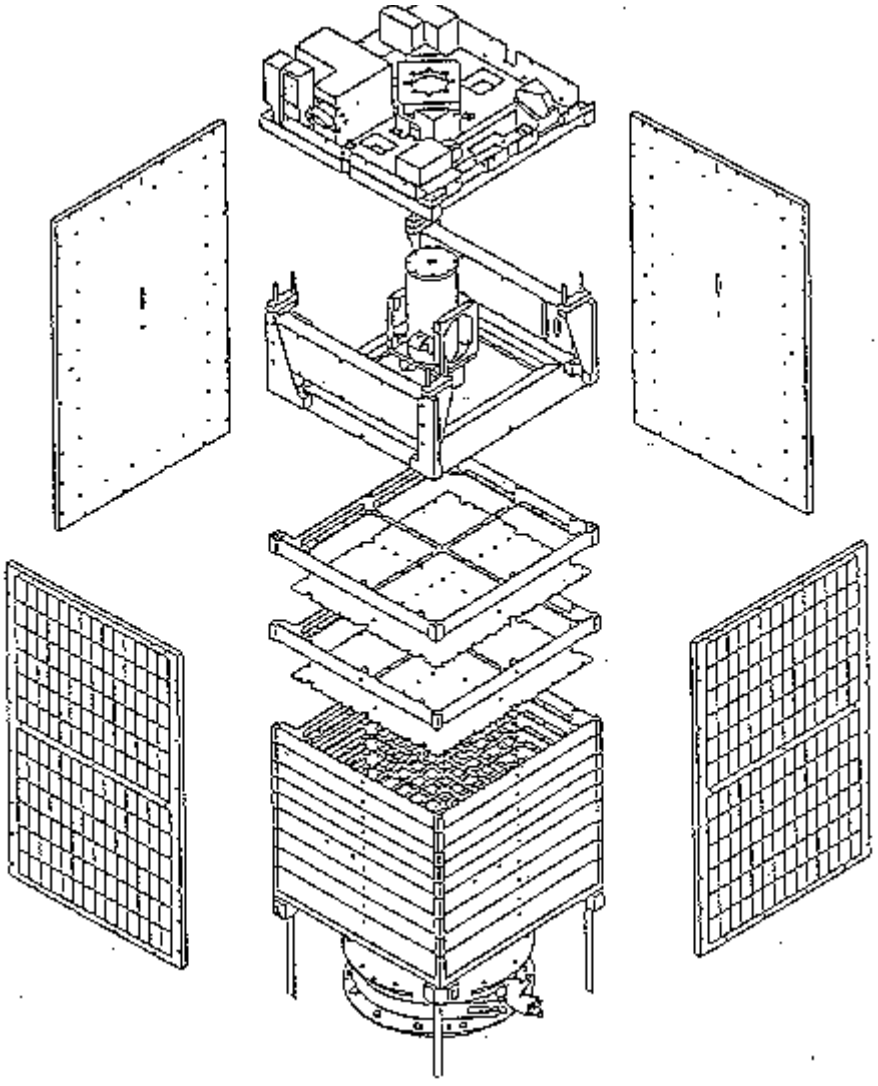

Figure 3.1 Example microsat structure; KITSAT-B

3.2 Instruments

Microsats will have one or more instruments which will carry out well defined scientific exploration in the fields supported by the SPP. Available mass for the instruments will be about 15 kg. Where resources are available, small technology demonstration experiments could be added to the payload.

3.3 Launch Vehicle

Launches will normally be as "piggybacks" on larger vehicles including ARIANE and DELTA-II. Shared launches on small launch vehicles, eg. Pegasus, are more costly, but are a possibility.

3.4 Flight Scenario

As secondary payloads on large vehicles, microsats will have the greatest launch opportunity to go into low earth polar orbit. Other orbits may be available, including MEO, GTO, and Sun-synchronous orbit, however they will be more costly, fewer in number and will impose greater requirements on the satellite.

Once in orbit the microsat will be monitored by one ground station. That ground station will either be an existing station in Canada (eg. Prince Albert, Saskatchewan or St. Hubert) or will be a small dedicated station for SPP microsats. Early microsats missions in the SPP should assume the former.

Design lifetime of purely scientific microsats will be six months, while those with some operational demonstration function could be up to one year. Although design lifetime may be short, actual lifetime could be much longer, resulting in greater operational costs. Operational scenarios must be considered along with their costs.

4.0 ENVIRONMENT AND TESTING

Hardware testing will be emphasized over analysis. Testing will uncover workmanship problems, faulty components, design errors, software glitches, poorly specified parts and interface problems. Test programs should be designed early in the program and not changed, to build confidence, as the tests progress.

4.1 Vibration

The vibration environment will be launch vehicle dependent. New instrument and bus support system tests will be vibration tested to protoflight levels since hardware development will follow a protoflight development philosophy similar to the sounding rocket program. It may be desirable to do breadboard vibrations to qualification level. The microsat will be vibrated to acceptance levels.

4.2 Acceleration/Shock

Acceleration will be treated in the same way as for sounding rocket payloads, ie, not tested.

The shock environment will vary with the launch vehicle. Shock testing will be treated on a case by case basis.

4.3 Acoustic

Acoustic testing will not be done.

4.4 Thermal

The thermal environment of a microsat is more critical than that of sounding rockets due to the extended flight duration. Thermal control in LEO is simplified by the proximity to the earth which makes it difficult to achieve extreme temperatures. Therefore temperature control should be performed by passive means. Obtaining very cold temperatures for instrument operation, on the other hand, will be difficult. This will limit the types of experiments which can be done in LEO.

4.5 Vacuum

Vacuum or transition to vacuum can possibly cause high voltage arching and overheating of components due to reduced convection. Thermal-vac tests must be carried out at the system and subsystem level and should be carried out on completed spacecraft (S/C).

4.6 EMI

EMI is treated the same on microsats as it is on sounding rockets. It is minimized through good design practices, then thorough testing is carried out at the S/C level.

4.7 Radiation

Most flights of microsats will be in LEO with relatively short durations. Any electronics will handle 1.5 KRAD total dose, which is what would be expected in LEO. Therefore radiation dose is not a concern. Radiation testing will not be performed on microsats. However SEUs are more of a problem and error detection and correction are necessary. Latchups, although devastating, if they would occur, are not probable and do not require consideration. PV degradation is not a problem for short flights (1%/yr).

4.8 Functional Testing

Extensive testing of the complete S/C should be conducted. Functional tests should be as realistic as possible. Maximize operational testing prior to flight. Do a minimum 1000 hour life test of the system in operational mode.

5.0 CAPABILITIES

Suggested capabilities available to microsat proposers are given. Limitations and requirements are stated where applicable.

5.1 Spacecraft

Microsat mass and volume will be required to match the accommodation requirements for secondary payloads or shared payloads on the selected vehicle. Nominal dimensions are 40 cm X 40 cm X 50 cm. The mass should be less than 60 kg or low enough to qualify as a secondary payload.

5.2 Trajectories

LEO is the orbit of choice for microsats because:

- Low launch cost

- High launch reliability

- Low radiation

- Short slant range

- Global coverage

- Doppler ranging and GPS

- Easy thermal (earth proximity)

- Financial chunk small

The majority of microsats supported by the SPP will be LEO polar orbits, due to the greater probability of finding rides as secondary payloads. The large number of LEO communication constellations will greatly increase the number of launches to LEO.

Opportunities will also continue to become available to GTO, however those opportunities are expected to be fewer in number. Some communications satellites will be placed in MEO, which should offer secondary payloads some flights.

Secondary payload launch capability is offered by ARIANE and DELTA-II. Costs are from $200 to $500 K U.S. Pegasus offers a shared launch capability with costs of about $1 M for a 50 kg satellite. Table 5.1 gives additional launch opportunities and available orbits for microsats (courtesy of H. Joyce, CSA/Space Technology).

Flying as a secondary payload has the advantage of containing costs by not allowing schedule

slips, since the primary payload will go anyway. The disadvantage is that if the microsat is not ready the ride is lost.

The use of motors to provide V for orbit change manoeuvres or orbit maintenance is discouraged due to the increased mass and volume requirements and the increased costs.

5.3 Microsat Support Systems

The following are some guidelines and some limitations on microsat support system capabilities. Design implications are also discussed briefly.

5.3.1 Power

Power for the microsats will be provided by body mounted solar cells or simple flap-out solar-array panels. Folding arrays/sun-tracking arrays are considered out of scope for the SPP. Silicon or GaAs cells can be used depending on power requirements and available budget, noting that GaAs has an efficiency of about 17% while silicon is about 9%. However, GaAs costs twice as much as silicon, at about $3000/W.

Spacecraft power will be about 30 W (orbit-average) for LEO applications. Instruments will be able to use 10 to 15 W. Storage batteries will be needed during eclipse. NiCds are used most commonly.

5.3.2 Attitude Control and Determination

The majority of microsat missions in the SPP will not use three axis stabilization due to cost, complexity, mass, etc. Alternative stabilization methodologies which could more easily be supported include; unstabilized, gravity gradient, spin, momentum-biased non-spin, permanent magnet and passive aerodynamic. Table 5.2 summarizes the characteristics of the different techniques.

Autonomy from ground control is a desirable feature of microsat ACSs. Operating with one ground station, the number of passes is limited and the availability of personnel to carry out orbit corrections is limited. However it is desirable to have an uplink capability to uplink new control programs in case of ACS sensor or actuator failure or change in user requirements.

Attitude determination can be provided with much greater accuracy than that of the ACS. Precise attitude determination may enable experiments which have coarse attitude control. Attitude data will be calculated based on on-board sensors, eg., sun-sensor, magnetometer, limb-crossing indicator, and star sensors.

Launcher	Availability for Microsat Launch	Microsat Orbits achievable	Cost/kg to Polar LEO ($US)	Costs for 50 kg Microsat launch	Comments
	Ariane 4 uses ASAP (Ari...	LEO/GTO (GTO			

Ariane 4 Ariane 5 (Arianesapce)	ASAP (Ariane Structure for Auxiliary Payloads) for multiple Microsatellite launches (4 x 50 kg). Ariane 5 starts in yr 2000. No small launch plans for Ariane 5 completed yet.	= 190km x 35, 786km; 7 deg incl.) Most future launches will be to GTO. CSA is currently investigating a possible Ariane 4 launch opportunity in 1988. (to be confirmed).	18.7 (Ariane 44L)	$500,000US. for single 50 kg Microsat on the ASAP.	CSA/ESA relation may facilitate Ariane launch for Canada?
Delta-II (7320, 7920, 7325, 7925). (McDonnell Douglas/NASA)	NASA ORBITAL LAUNCH SERVICES GROUP: Free-of-charge launch in exchange for mission data for missions "sponsored" by a NASA Applns. Group.	705km sun-synchr. (Landsat 7) in early 1998. 100 km X 600 km X 38 degrees with USAF GPS (on-call basis) over coming few yrs. Piggyback launch with RADARSAT-II circa year 2000. MEDLITE Launcher TBD.	14.3 (Delta 7925)	Free-of-charge launch in exchange for mission data (subject to NASA sponsorship).	Further discussion required to seek NASA sponsorship leading to data agreement.
Pegasus Pegasus XL (Orbital Sciences Corp).	Second PEGASUS failure being re-engineered. next PEGASUS launch in January 1996 with USAF Mission.	Various circular LEO orbits; typically: Altitude: 550 km to 800 km. Inclination: 25.0 to 97.6 degrees.	Approximately 50.0 (250 kg launch for $12MUS).	$1-2MUS for 50kg Microsat.	Reliability of PEGASUS must be established.
Taurus I Taurus IA (Orbital Sciences Corpp).	Small launch capability is being offered for TAURUS by OSC	Various circular orbits; typically: Altitude: 775 km, 800 km. Inclination: TBD	Approx 22 (910kg launch for $20MUS)	TBD	Operational status of TAURUS to be established.
Space Shuttle	Availability for Microsat launches to be investigated	SLC-6 launch site for Shuttle polar missions not available. Only inclinations in the range 28.5 to 57 deg. (185km circular) available	Not applicable (polar orbits not available)	TBD	Microsat launch capability to be investigated.

		available			
Atlas (I, IIa) (General Dynamics)	TBD	TBD	15.0 (Atlas IIa)	TBD	Microsat capability to be investigated.
Titan (II, III, IV) (Martin Marietta)	TBD	TBD	10.3 (Titan IV)	TBD	Microsat capability to be investigated.
LLV Series (1,2,3) (Lockheed)	Operational status to be established	TBD	Approx. 40 (400kg launch/$16MUS)	TBD	Microsat capability to be investigated
Conestoga (EER)	TBD	TBD	TBD	TBD	Not operational. First launch in 1995?
US Missile Re-use	TBD	TBD	Approx. 32. (155 kg to LEO for 5.0MUS)	TBD	Not operational
Tsyklon Proton START Missiles (Russia)	Russian launchers used for some microsats. Tsyklon used for FASat-Alpha on 31st August 1995. from Plesetsk in N. Russia. New program to use STR.Missiles	High inclination orbits + TBD.	4.2 (Tsyklon)	$398,000 (us) for Tsyklon (FASat-Alpha; SSTL)	Microsat capability to be investigated.
Long March 3 (Chinese)	TBD	TBD	13.2	TBD	Microsat capability to be investigated.

Table 5.1 Microsat Launch Opportunities

Stabilization	Typical Accuracy	Advantages	Disadvantages	Cost Drivers
Unstabilized	N/A	Simple	No antenna/solar array gain	Ensure will not spin up
Passive Magnetic	± 10 °	No active components	Limited gain, single alignment, no roll control	Damping may be required

Passive Aerodynamic	± 10°	No active elements Unique pointing	Low Altitudes only (<300 km)	Deployable drag device Dampers
Sun-Pointing Spinner	± 0.5°	best electric power protect payload from Sun	Acive control	magnetic systems need magnetometer + torque controls
Earth Pointing Spinner	± 2°	sweep through nadir aids remote sensing	active control + requires Earth sensing	Magnetometer, torque coils plus Earth sensor expenses
Earth Point (gravity gradient)	± 10°	nadir staring	Weak stability easily upset. Damping critical; attitude difficult to sense. No roll control.	Large deployable boom Active damping Costlly sensors Flip capability
Sun Pointing non-spinner	± 1°	best electric power plus minimal angle rates all axes	Active control Lifetime limitation due to moving parts	Momentum wheel Complex control logic More costly sensors
Earth Pointing non-spinner	± 3°	nadir staring	active control Lifetime limitation die to moving parts	Momentum wheel More costly sensors
Three axis	± 1°	any attitude	Active control poor solar/radio orientation	Lots of propellant or ... Multiple raection wheels (4 typ.) Complex algorithm

Table 5.2 Microsat Stabilization Methodologies
from Rick Fleeter course on Micro Spacecraft

5.2.3 Data Acquisition and Storage

Instrument sensors will normally collect data at times other than during ground station passes.

Hence the need for on-board storage. A typical solid state data storage is 4 Mbyte.

5.3.4 Telemetry

Downlink data rates are typically 10 kbps, S-Band or UHF, PCM. Instrument data rates have a daily average of 100 bps. Low rate uplink data can use FM since ground transmitters are not power limited and FM AFC avoids doppler problems. Link margins determine transmit power requirements. By tolerating occasional data drop-outs, large savings in

power can be made. The telemetry system should be designed to transmit data when the satellite is 30 degrees above the horizon to avoid concerns about obstructions. Data compression should be considered to decrease downlink requirements.

5.3.5 Thermal Control

Microsats are heat conduction limited due to their size. Convection is not effective. Coatings, in a passive thermal control system, can effectively control temperatures. There is not enough electrical power on a microsat to have any thermal effect. In LEO satellite temperatures can not be moved more than 10C due to the proximity of the earth.

Microsat structures should be made of aluminum to provide good thermal conduction. Good thermal contact should also be ensured. Thermal isolation of systems should be avoided since that will increase temperature excursions of non-isolated systems.

Simple thermal models (10 node), only, should be developed for the whole spacecraft. Once the most sensitive element is identified, another 10 node model on that element can be done.

5.3.6 Structures and Mechanisms

All structure should be aluminum for low mass, low cost and good thermal characteristics. Deployables should be avoided whenever possible, since they add cost and have the lowest reliability. Hot wax actuators are better than pyro actuators since they can be reused many times (eg. during testing).

It is quicker and often cheaper to buy flight proven mechanisms rather than trying to qualify a terrestrial component.

Carpenter tape antennas using a melting wire restraint strap are effective and reliable.

5.4 Ground Segment and Operations

Microsat proposers should assume that their mission will be supported by one ground station. The SPP will either use existing CSA Satellite Control Facilities (St Hubert or Prince Albert) or a dedicated low-cost control facility. A remote station for science data reception is also possible.

Flight operations can consume up to one third of the total mission budget. The satellite should be designed for minimum ground control, ie., monitoring of S/C functions and data collection and storage. A campaign mode of operations is likely more efficient than continuous operation.

6.0 LAUNCH RANGES/CONTRACTORS

The primary launch ranges in the U.S. are Kennedy Space Centre and Vandenberg Air Force Base. Ariane is launched from Kourou, French Guiana. Other large vehicles and suppliers, which could provide secondary launch opportunities in the future, are START of Russia, Long March of China, and H-1 of Japan. Smaller vehicles such as Pegasus and Taurus, could be launched from a number of sites in the world. Table 5.1 gives details of launch opportunities.

Akjuit Aerospace Ltd., Winnipeg, Manitoba are planning to launch small satellites from their range in Churchill.

Proposers must contact launch suppliers to identify a launch opportunity and to obtain costs. Confirmation of the launch will not be made until the end of Phase A.

7.0 BUS CONTRACTORS

There are many possible bus contractors in Canada. The following is a list of companies which indicated

their interest in the SPP by attending the SPP Workshop in Montreal in January 1996. This is not an exclusive list and there are many more companies capable of contributing to a microsat bus which could be contacted for help.

Bristol Aerospace Ltd., Winnipeg, Manitoba, 204-775-8331, attn. Mr. Barry Payne.

Routes Inc., Ottawa, Ontario, 613-592-0748, attn. Mr. Ron Buckingham.

Com Dev Atlantic, Moncton, New Brunswick, 506-853-8601, attn. Dr. Joseph Gore.

Institute For Space and Terrestrial Science (ISTS), North York, Ontario, 416-665-5473, attn. Dr. Ian Rowe.

Scientific Instrumentation Ltd. (SIL), Saskatoon, Saskatchewan, 306-244-0881, attn. Mr. Dale Sommerfeldt.

Dynacon Enterprises Ltd., Downsview, Ontario, 416-667-0505, attn. Dr. Kieran Carroll.

MPB Technologies Inc., Pointe Claire, Quebec, 514-694-8751, attn. Dr. Asoke Ghosh.

CAL Corp, Ottawa, Ontario, 613-820-8280, attn. Mr. Tony Rabb.

Realix, Dorval, Quebec, 514-421-2678, attn. Mr. Marcel Boridy.

8.0 FLIGHT HARDWARE DEVELOPMENT

SPP microsat projects will follow a protoflight development philosophy. Flight qualified systems will be used where available and where affordable. Components can be fabricated if reasonably priced qualified hardware is not available. Processes and procedures for microsat development will follow those set out for sounding rocket projects. Some adaptation will be required, which will be determined during early project reviews.

8.1 Review Cycle

Periodic reviews will be held throughout the development of the flight instruments and bus. Reviews will be short, will concentrate on technical problems and will have limited attendance. Attempts should be made to combine instrument and bus reviews. 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. The IRR will be held prior to instrument turnover to the satellite integration contractor.

Parallel reviews will be conducted for the bus. A Flight Readiness Review (FRR) will be held prior to shipment of the satellite to the range. It is expected that instrument development will precede the bus development, ie. instrument PDR and CDR should precede bus PDR and CDR. In no case will instrument CDR follow bus CDR.

8.2 Hardware Design

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

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Acceleration                    Redundancy
Accessibility                   Rigidity
Availability of Parts           Temperature
Dynamic balance - C.G.          Testing
Location                        Vacuum
Cost                            Vibration
Dimensional Stability           Weight
Lifetime.
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The SPP does not impose restrictions on components or system selection for microsat development, however, MIL Spec. or good commercial parts derated for space flight are recommended. All flight hardware must pass environmental tests.

SPP microsat projects will be successful if they are able to carry out good science investigations, within the allowed budget. The following are suggestions on how to conduct microsat missions at low cost. These suggestions were obtained largely from the reference documents:

Microsatellite missions can be optimized around cost, corporation, teaching, schedule, risk, or mission performance. It is difficult to optimize more than one element. The item to be optimized should be known by all project participants at the start of the project.

Microsatellites can not be expected to be able to fulfil all space mission requirements. Only the simplest missions should be chosen to be flown on microsats, i.e., those with minimum pointing, optical aperture, run-time, and lifetime requirements.

They should be built totally then tested rather than building and testing one subsystem at a time. They should be built with no margins. Team size should be minimized and members should be full time (overtime is preferable to more people). That is more efficient than a large team working part time.

Provide PI with full control of mission planning and timeline generation.

Microsatellite lifetimes can be expected to be up to three years, however, required lifetimes should be stated to be very short, i.e., six months.

Operations should be from 1/10 to 1/3 of the total mission cost.

Carry out tests on flight hardware. Don't replace test hardware, eg. batteries.

Provide redundancy only for high risk subsystems.

Design for graceful degradation, eg., multiple battery packs.

Consider the time required for launch preparation, ie., 100 days vs. 14 days, for piggyback vs. Pegasus.

Commercial NiCd are good enough for 1 to 2 yr. missions. They should be X-rayed to ensure that all separators are concentric.

MIL NiCds are square and pack better, will last much longer (10 yr.) due to different construction, but cost 100 times as much as commercial batteries.

Surface mount components are good since they are light weight.

Keep multiple copies of the operating system in case of corruption. Add watch dog timers in case of latch-up (in high radiation risk missions).

Everyone writing code for a project should have their own processor and S/C equivalent operating system - do not use an emulator.

It is better to time-share computer operations (1/10 sec./task) than use interrupts.

Provide a capability to uplink code. Uplinked code must be verified first on a ground-based satellite mock-up

Try using serial data for inter-communication on the satellite to avoid excessive parallel cabling.

Test at the complete satellite level rather than at subsystem level. Design a Test Program at the start and don't change it.

Test at board level if available, especially temperature cycle for workmanship.

Life test the satellite using S/W to exercise.

MIL/S parts often lower reliability since they are custom fabricated and don't go through the extensive quality control of current mass manufacturers. From experience MIL/S parts have poorer performance.

Human failure is more frequent than component failure. Therefore put more resources into getting good people rather than expensive parts.

The Israelis have a policy to use only plastic parts not ceramic.

Microsats are more reliable than big satellites since they have fewer parts.

Only write documents that will be read. Document all tests and inspections during the build phase. Formal design reviews have nothing to do with design. TIMs (technical information meetings) are more effective in solving and finding design problems since they are short, narrow in scope and involve few people.

Apparent redundancy may be less reliable.

Students or new engineers need to be closely supervised by an experienced engineer.

Save email as documentation of decisions. Have individual engineers keep updated copies of designs (hardware and software).

Photograph everything as a record of test configuration, flight configuration, etc.

Only send operations commands which are on the menu and which have been tested with the ground spare hardware.

Standardize ground operations interface (CCSDS) to allow multi-mission utilization.

Microsats must have quick data distribution to customer.

Maximize S/C autonomy to reduce ops requirements
- self protection against operator error

- on board attitude determination

- on board manoeuvre calculation

- attitude, power, data system monitoring

- smart safing

Utilize technology advances to simplify design and increase performance.

Make use of surplus components from past SSP missions.

8.3 Standards

Standards are in place at this time for environmental qualification and acceptance testing of sounding rocket payloads. Similar standards are applicable to microsats. In addition, accepted design practices are applied to payload design, and fabrication. Bristol Aerospace Ltd. can be consulted for assistance.

It was mentioned in the Sounding Rocket Appendix that Bristol Aerospace is investigating standards such as for interfaces, support systems and subsystems. Some of this work may be applicable to microsats. Participants will be notified if and when new standards are applied.

8.5 Quality Assurance/Performance 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.

9.0 OPERATIONS

S/C preparation and launch activities will be dependent on the launch range and on the type of launch, ie., piggyback or shared. In general the activities are:

- The S/C is integrated and tested at the range.
- The S/C and launch vehicle are integrated and the assembly is moved to the launch area.
- The S/C is launched (and recovered).

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

- Unpack and set up instrument GSE.
- Participate in the range required tests, and practice countdowns.
- Confirm correct operation of the instrument prior to launch.

Post-launch responsibilities will be defined in the project Operations Plan. In general the activities will include:

- On-orbit check-out and commissioning of S/C.
- Monitoring and control of S/C systems; attitude, power, thermal, telemetry.
- Monitoring and control of instruments; health, operational mode, data acquisition. This activity may be remote from S/C monitoring and control.

Attempts should be made to have the majority of S/C operations performed autonomously. In addition the design should permit upload capability to account for capability reduction which might require a change in the operations software.

10.0 PROJECT MANAGEMENT

The SSP has had limited experience with microsat projects in the past. Consequently the information in this section is provided as a guideline and has been obtained from the experience of other organizations which have implemented microsat programs.

10.1 Project Team

Maintenance of a small focused team is critical to containing costs. A small multi-disciplinary team whose members have a broad knowledge base is the ideal. A hierarchical team with specific job descriptions is not effective.

The project team will normally be made up of members from the IO, bus developer, and the CSA. It is envisaged that each part of the team will form its own small cross-linked cluster with one person in each acting as the team lead, with responsibility for communication with the other team leads. The IO and bus clusters should contain eight or fewer people, while the CSA management cluster would be two to three people.

The assumption that there will be a bus developer comes from the experience gained from sounding rocket projects. Although this is the proposed baseline, proposers can propose to do the majority of the work within their organization with smaller subcontracts to industry. They will be required to demonstrate the capability to meet the technical, cost and schedule requirements with their proposed teaming arrangement.

10.2 Contract Management

The aim of the SPP is to have the PI be involved with decisions related to cost control throughout the project. That could be done quite effectively by contracting directly with the IO for all phases of the

work. It is recognized, however, that not all IOs have the necessary infrastructure to handle complex contracts. Therefore, it is suggested that 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 may be let to industry or to the IO depending on the project management method chosen by the IO. 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 bus development work to industry. The IO must be able to demonstrate its capability in administering 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.

10.3 Project Schedule

This section describes the schedule of activities involved in developing, launching and operating a microsat. Figure 10.1 is a typical microsat mission schedule from concept to end

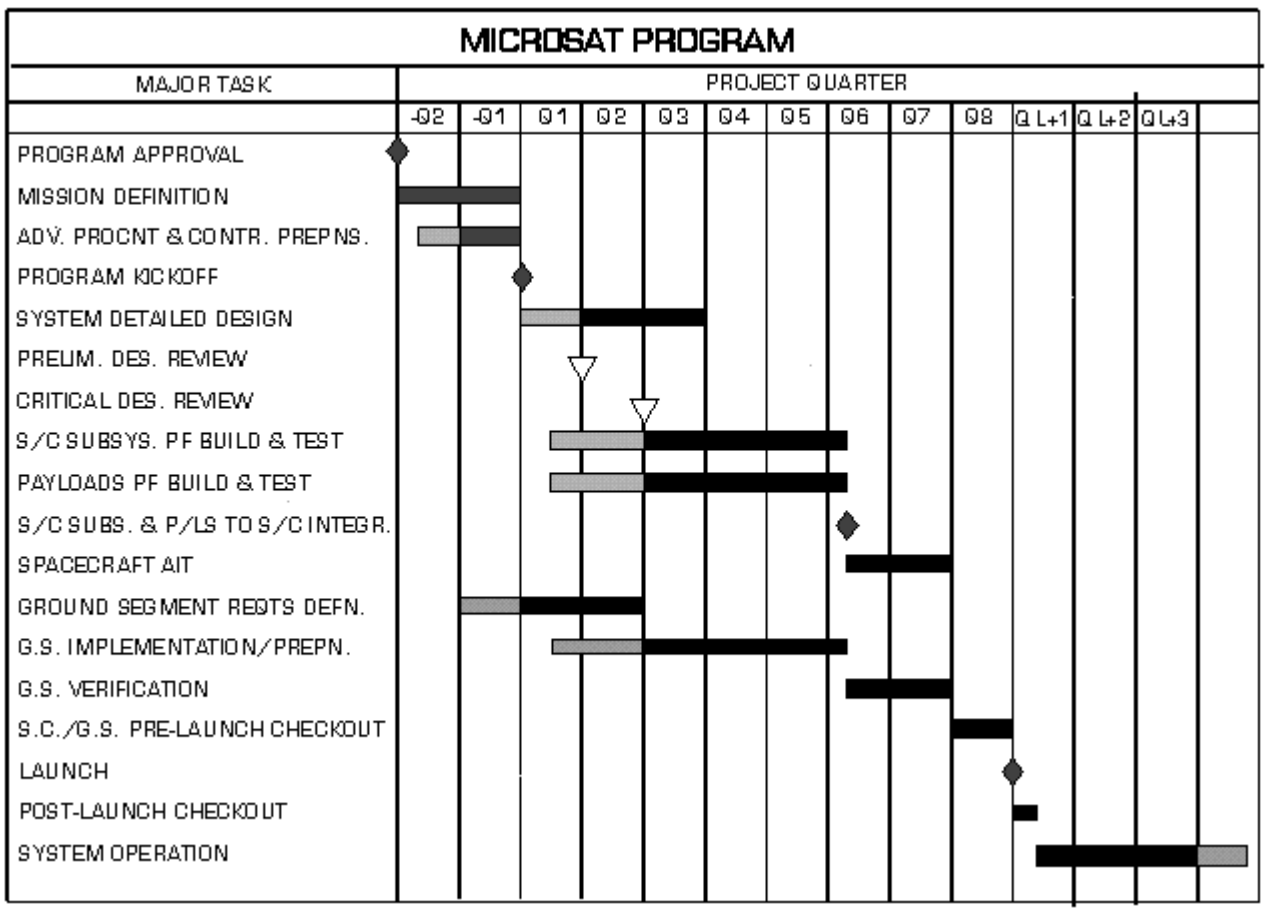

Figure 10.1 Typical Microsat Development Schedule of operations.

11.0 TARGET PROJECT COSTS

The maximum cost for new missions is $4 M, inclusive of launch costs. The SPP aim is for average microsat project costs to be about $3 M. Missions costing less than $4 M will therefore receive considerable attention.

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