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SPACE STATION USER STUDY

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PHILIP A. LAPP LIMITED

TABLE OF CONTENTS

1. INTRODUCTION

1.1 The Project

This report is prepared for Spar Aerospace Limited in fulfillment of contract #21468TC REV. 1, December 13, 1982, as part of a study for the National Research Council of Canada to determine preliminary requirements for a Space Station. The purpose of the report is to:

> Determine the major potential Canadian users of a low earth orbit space station and the potential benefits accruing to Canada as a result of participation in the international program.
>
> A detailed Statement of Work is appended (Appendix I).

This report explores one facet of the potential benefits which space activity may hold for Canada: those opportunities which may be present in a Space Station program. Such a program, comprising a range of hardware configurations, is under study in the United States and elsewhere. Canada has been invited to participate in the planning phases. The United States' National Aeronautics and Space Administration (NASA) is the lead agency for developing the Space Station proposal. NASA is canvassing national and international user needs and capabilities before deciding particular configurations for the Space Station.

Philip A. Lapp Limited was asked to report on the capability of the current and potential community of Canadian users who could contribute to and benefit from a Space Station.

During January and February of 1983 a team from Philip A. Lapp Limited contacted over 170 groups and individuals across Canada to explain the Space Station project and to gather the views of the user community. The results of that work form the basis for recommendations in respect of Canada's continuing participation in the Space Station project.

Broadly speaking, there are two areas in which Canada could participate in such a project. First is in the design, construction and operation of a Space Station; secondly, in conducting scientific and industrial missions using Space Station. Canada has strong capabilities--in industry, in the universities and in government--in both these areas.

The task of this study was therefore to assess: whether there are suppliers and users of space equipment and facilities who could contribute to and benefit from a Space Station; what the potential, longer term opportunities of a Space Station might be for Canada; and, what projects show promise for Canadian participation.

The timing of the study required that following a December start, the preliminary study findings be available on February 25, which is necessary to allow the National Research Council of Canada (NRCC) sufficient time to consider a Canadian response to the NASA request and to meet the timetable imposed by NASA on international participants. NRCC is the lead agency in Canada for the Space Station program.

The original terms of reference of the study requested Philip A. Lapp Limited to investigate financial and/or qualitative benefits of Canadian participation in Space Station. Detailed cost and financial benefits could not be assessed in any credible fashion due to the tentative nature of the individual proposals identified in the study. However, each proposal was qualitatively evaluated on the basis of strategic benefit and state of technology development.

Science and technology are rapidly evolving fields. This report was able to gather information over only a relatively short time span. For these reasons we caution that our findings be viewed as representing a "snapshot" of the Canadian situation as it exists in the Winter of 1982/83. The detail of our conclusions undoubtedly will change over the years to come. This suggests to us that if a "moving picture" of Canadian user capabilities is considered to be desirable (we believe it to be so), then a series of images will have to be assembled on a regular basis.

We gratefully acknowledge the support and encouragement of Spar Aerospace and the National Aeronautical Establishment of the National Research Council of Canada, in the preparation of this report. Philip A. Lapp Limited takes full responsibility for its contents.

1.2 Background

Canada is one of a number of nations that have been invited by NASA to suggest whether, and if so how, they might wish to participate in a proposed Space Station program. The Space Station would be launched in the 1990's. The concept of a permanent facility in space, capable perhaps of supporting a manned presence, has a long history. With the advent of the Space Shuttle, the means are now available to construct and service such a system.

For the purpose of this report, the Space Station System is considered to be an infrastructure composed of one or more of the following elements:

- a manned station in low earth orbit assembled through frequent supply flights of the shuttle STS

- unmanned, free-flying platforms, near and distant, which can be visited by man through orbit transfer vehicles (OTV), serviced by robotic vehicles (Telemanouvering System), or retrieved from orbit

- o geosynchronous (and beyond) satellites transferred to orbit by OTV
- o dedicated sections of a space station or satellite for individual projects or scientific experiments
- o tethered or co-orbiting satellites associated with a space station
- o data relay

The principal advantages of such configurations are:

- o the large physical size achievable through the assembly of separate payloads brought into low earth orbit by the Shuttle STS
- o amortization of station costs over a broader base
- o the large electrical power potentially available from such a space station
- o the opportunity of being able to re-visit the station or satellite for the purposes of maintenance, replacement or replenishment either in orbit or by retrieval back to earth
- o opportunity for on-board data processing in operational applications
- o manned satellites provide opportunity for real-time decisions
- o the ability to co-orbit or tether an accompanying satellite to provide isolation or environmental circumstances unattainable by any other means (e.g. towing in the outer reaches of the atmosphere).

There are also certain disadvantages to users of a Space Station:

- o users will be subject to constraints created by other user requirements, and by the final configuration of the platform which will have to accommodate a wide range of user needs
- o data processing capacity and Space Station downlink bandwidth will be a limiting factor for some users
- o the altitude and orbital elements of the Space Station may not be optimal for all users
- o the altitude and inclination of orbits

In the manned version, Space Station would begin with a small crew based in a life-supporting environment. In time the crew would grow to perhaps a dozen or more. Initially, scientist/astronauts will conduct mission and payload tasks.

Later on, user payload specialists will conduct on-orbit scientific and industrial tasks. Such stations could be permanently or occasionally manned.

The second possible configuration, unmanned platforms, is being pursued by the European Space Agency. Their EURECA (European Recoverable Carrier) is described as an evolutionary approach toward a space platform--a space craft with an autonomous manoeuvring capability designed to stay for some months in an orbit higher than that of the Shuttle. It would return at the end of its mission for rendezvous with the Shuttle to be returned to earth. It would be refurbished and fitted there with a new set of experiments. In the Space Station unmanned platform concept the fitting and refurbishing could take place in space.

Close and distant co-orbiting platforms would be designed to be serviceable by a permanently or occasionally manned space station. They would be semi-autonomous vehicles.

In another version of Space Station, sections or modules would be dedicated for use by individual nations or for individual experiments or sets of experiments.

Tethered satellites would be connected physically by an umbilical cord to a facility in low earth orbit (LEO). Power and data links could thus be direct. The altitude of the satellite could be varied and the satellite "reeled in" for servicing by the crew of the Space Station.

The decision as to which of these options, or which combination of options to be pursued will be determined, in part, by the results of the user studies.

It is our strong belief that a Space Station system will eventually be built. There is little doubt that the technological capability exists to construct such a facility. However, certain questions must be answered before the necessarily large sums of money are committed. What will be the benefits of participating to each nation, socially, industrially and scientifically? Are there alternatives to a space station? What are the acceptable costs of participating? What are the implications of international collaboration for national sovereignty? What place does participating in Space Station occupy in each country's national development priorities?

It is premature to attempt to answer these questions at this early stage of Space Station planning; as the process advances, however, definitive information will have to be gathered so that informed decisions can be taken.

The various international user studies which have been conducted* have not attempted to promote the concept of Space Station. Nor has this study. They have aimed rather, at assessing the possible uses of such a facility. Underlying this new phase of activity in outer space, not only in the United States, but internationally, is a growing interest and belief in the commercial potential of the space environment. Outer space offers certain characteristics which may open entirely new fields for commercial exploitation. They include:

- low gravity
- high ambient vacuum
- high temperature gradients possible due to absence of convection
- high ambient radiation incidence

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*Countries participating include: USA, Canada, Italy, Japan, West Germany and the European Space Agency nations.

From a planning perspective, there are many experiments which, requiring longer duration exposure to the space environment than now readily available, cannot now be pursued. It is therefore becoming clear that, if a long-duration space facility were available, there are commercial opportunities which could follow.

Despite the costs and risks involved, we are now starting to see the beginnings of self-financed industrial research in space. McDonnell Douglas and Johnson & Johnson (Ortho Pharmaceutical) signed the first Joint Endeavour Agreement with NASA for the production of pharmaceutical products. Their experiment, a continuous flow electrophoresis system, flew on STS-4 in June 1982. Together, the companies have invested "tens of millions" in the project.

The high costs and risks associated with the exploitation of outer space still present a great impediment. Increasingly, nations are forming international consortia for the purpose of spreading them more widely. A nation the size of Canada must weigh the costs of participating in space activity at an early stage, in the hope that technological and economic advantages will accrue, against the risk of foregoing those same opportunities later on, should they be proven commercially feasible.

1.3 Methodology

1.3.1 Introduction

The methods and techniques employed in the Space Station User Study were selected in order to permit the following outputs:

1. Identification of potential space station users by sector and end use space application.

2. Assessment of strategic benefits.
3. Space station requirements resulting from potential Canadian uses.
4. Canadian sensor requirements and sensor manufacturing capabilities.
5. Time frame of expected use.
6. Recommendations for future action.

These outputs were considered to be necessary components of the government decision-making process vis-a-vis Space Station.

If Canada is to participate in long duration space activities, a minimum requirement is a community of possible contributors to and users of the associated facilities. Canadian industrial involvement in the design, construction and operation phases of long duration facilities such as Space Station is a desirable objective, assuming that reasonable contributory arrangements can be made with international partners and equitable returns realized. The identification of these users and contributors was a key objective of the study.

Most importantly, in accord with Canadian space policy, Canadian Space Station involvement would be predicated upon an assessment of economic, social and cultural benefits to the nation. The attainment of those benefits would be contingent upon there being a community of Canadian industries, university and government scientists, and other potential users willing and able to exploit the known and anticipated potential of outer space, in the national interest.

In the expectation that some users would suggest specific proposals for use of Space Station, a means of assessing the proposals was deemed necessary. Criteria were therefore established, and weighted, that would permit an evaluation of the strategic benefits and the extent of technology development of each proposal.

It was an original objective of the study to attach costs to the suggested user proposals. In the end this was found not to be possible, in view of the inability of proposers to make credible cost estimates. In part this was due to the short time which respondents had to propose Space Station uses. Thus it was considered any detailed cost estimates would be too unreliable to serve as useful evaluation criteria at this time.

The time frame of the projected industrial contribution and uses was thought to be an important factor. Again, given the nature of most of the expressions of interest, it was considered that only a broad range of estimates should be made in the report.

Finally, a set of recommendations arising from the study findings and designed to move toward Canadian involvement in Space Station is proposed.

1.3.2. Sample Selection

The very short time frame in which conclusions had to be drawn, combined with the need for a face-to-face explanation of the technical aspects of the project, dictated a structured interview format for the information-gathering phase of the user study. The limited time available for the study meant that a selective list of study participants had to be assembled. In total, 174 groups in five geographical regions were contacted and interviews held with most of them.

Two main criteria were used to differentiate potential study participants. The group was segmented by sector and by end use application. An effort was made to contact a representative number in each category. Overall, we feel confident that we have contacted representatives of all the intended groups, though we do not claim that our interview list was exhaustive in a statistical sense. The number of groups which would potentially be affected by a long duration space facility is very large indeed.

The sectors which were used in choosing the study participants were:

- Industrial groups active in space, either as suppliers or users of space hardware or services
- Public sector groups active in space
- University space scientists and engineers
- A group of other potential users of space services including a social/cultural group

The end use application sectors in which participation was sought were:

- Remote sensing
- Communications
- Materials processing
- National defence
- Space science
- Space technology
- Medicine/biology
- Social/culture

Appendix 2 lists the groups contacted. It also contains names and affiliations of the Philip A. Lapp Limited project team.

1.3.3 The Interviews

Philip A. Lapp Limited interviewers first contacted respondents by telephone to explain the nature of the project and to seek their cooperation. In order to provide interview respondents with information on the Space Station project, a background paper was mailed to each, prior to the interview.

The preparation of this paper was facilitated by information presented at two short discussion seminars by a small number of people active in space science and technology. One group met in Toronto; the other met in Ottawa. The background paper and a list of those participating in the seminars are to be found in Appendix 3.

Interviews were held in Victoria, Vancouver, Calgary, Edmonton, Saskatoon, Winnipeg, Sarnia, Windsor, London, Fort Erie, Toronto, Kingston, Ottawa, Montreal, Quebec, Halifax, Fredericton and St. John's.

Each interviewer was equipped with a structured interview guide (Appendix 4). Four different guides were prepared, corresponding to the sector of the interviewee. The interview guides were patterned to elicit responses to similar assessment criteria. The specific questions asked were aimed at providing information on interviewees and on their comments, expressions of interest, and potential projects. Background information was gathered on the organization's activities, capabilities, future plans and attitude. Interviewees were encouraged to give their own ideas rather than mechanically answer questions.

Following the interview, interviewers completed a report form, again in a structured format (Appendix 5). The report forms provided the raw data for the assessment of the responses. Some interviewees were invited to write detailed proposals following the interview.

1.3.4 Assessment of Results

Prior to the interview phase of the study an assessment plan was drawn up and discussed with the client, Spar Aerospace, and the National Research Council of Canada. The plan comprised a matrix of criteria described either as Strategic Benefit or State of Technology Development to assess the responses classed as proposals.

The Strategic Benefit criteria against which proposals were to be rated attempted to answer the following questions:

- Did the proposal enhance existing Canadian technological capabilities?
- Did it contribute to national sovereignty?
- Did it contribute to national prestige?
- Would it result in greater access to foreign technology?
- Were there new commercial opportunities?
- Were existing commercial activities enhanced?
- What was the effect on regional development?
- Were opportunities for international exchange improved?
- Would there be new opportunities for cultural expression?
- Would the proposals contribute to world knowledge?

In the final analysis, the strategic criteria were grouped under four main headings in order of significance.

- Economic Opportunity
- National Interest
- Advancement of Knowledge
- Regional Development

It was recognized that respondents' suggestions would also have to be assessed against their ability to implement them, and the extent to which Space Station is necessary in order to have a realistic measure of "attainability". Thus, a set of Technology Development criteria was established:

- Were proposals consistent with the organization's current activities, skills and capabilities?
- Were they a natural extension of those capabilities?

- o What was the degree of commercial interest?
- o Did the proposals show some technical potential?
- o Was there a potential for new products?
- o Did the organization possess the Research and Development skills to bring the proposal to fruition?
- o What incentives might be required to make the proposal viable?
- o To what extent would Space Station be necessary?

As with the Strategic Benefit criteria, the Technology Development criteria were grouped to facilitate the analysis in order of significance.

- o Innovation potential of the proposal
- o Existing capability of the organization
- o Extent of Space Station contribution
- o Stage of development of the proposal

Thus each proposal's rating was a combination of an assessment of its strategic benefits and its technology development. The results were tabulated in a format using the eight assessment criteria (four strategic and four technology). Each assessment was assigned a number on a 1 to 5 scale (1 low, 5 high), giving eight numbers for each proposal.

In a separate exercise the project team weighted the criteria. Their combined weightings were averaged and the averages became weighting factors which were applied to the results of the criteria assessments. In order to test for consistency among weighters, the weighting exercise was tested by dropping the high and low weighting scores for each criterion. It was found that this had no significant effect on the result.

Thus the criteria ratings for a proposal were multiplied by the weighting factor for each of the criteria and a weighted score (actually, eight sub-scores) assigned to each proposal. The strategic benefit and technology development scores (four each) were each summed and averaged and the resulting numbers used to site the proposal on a graph (strategic and technology) with strategic benefit as ordinate and technology development as abcissa. The relative positions of the proposals with respect to each assessment grouping of criteria are thus displayed for comparison. The purpose is to indicate trends; the individual points should be considered as representative only.

2. FINDINGS

The interviews elicited responses ranging from enthusiasm for an immediate start on a space station program to suggestions that any activities in space are to be avoided on the grounds of lack of return on investment. In order to group this spectrum of interviewees so that an appreciation of the capability and willingness of the community to work toward a program to use space station can be assessed, the returns have been compiled under three categories:

- o proposals
- o comments
- o "nil" responses

A response was considered to be a "proposal" if it met the following criteria:

- the proposal could be carried out
- the proposal involves a payload and the ability to analyze data
- the proposal would be managed and funded by Canada
- can be a self-contained operation in space station
- may require a preparatory technological program
- potential application identified
- individual or organization are already in the business

Moving further from possible participation, there was a class of respondees ranging from those who expressed general support for Canada's pursuit of space activities to those who hold the view that there are other programs having a higher priority. This group had generally no considered proposals to use Space Station. Also included are a number of people who are more concerned with policy considerations than with specific uses. All these are collected into the category of "comments".

Finally, there was a group who see no value to their organization for expenditures on space activities or who have no opinion to offer. Some of those included in this category are colleagues of others who gave more positive replies, and who declined to be formally interviewed on the grounds that all significant information had already been obtained. These are the "nil" responses.

Each category is discussed in more detail below, and the overall results are presented in Table 2-1.

The summary information in Table 2-1 leads to a number of observations. By chance rather than intent, there were equal numbers of industry suppliers (manufacturers) and users. In fact, about half of all those interviewed fall into those two groups.

While there were a number of "nil" responses from industry, a significant proportion of this class responded in the light of the long lead time to commercialization for space station activities and a concomitant concern with the state of the economy today.

On a percentage basis, the government replies in the "comments" category are the greatest, reflecting, in part, the positions held by the people interviewed.

The individual categories will now be considered in more detail.

2.1 Proposals

The proposals fall into two groupings--those in an advanced stage of planning and those that are somewhat less well developed. In the former grouping the proposed uses are essentially sophisticated extensions of existing applications. There are others, however, that involve known processes in a new environment where the ground-based laws no longer apply and behaviour is not possible to predict.

Table 2-1

SUMMARY BY SECTOR

	PROPOSALS	COMMENTS	NIL	TOTAL
INDUSTRY				
supplier	21*	9	12	42*
user	21	5	14	40
UNIVERSITY	26	2	6	34
GOVERNMENT	20	23	17	60
TOTAL	88*	39	49	176*

* - one respondee represents both supplier and user

The statistical information pertaining to "proposals" is given in Table 2-2. One half of those interviewed responded with information that could be assessed in terms of the strategic benefit to Canada. Also, each sector is well represented, and it can be concluded that the ingredients are present to develop programs that will have wide support and which will involve many segments of the economy.

Two application areas dominate the "proposals"--remote sensing and technology. This can be attributed to the active program that has been pursued for the last fifteen years in the former field, and the level of capability that has been developed in Canada as a result of the support space programs have received for almost three decades. There appears to be a firm base from which to proceed to the next stage of space activity.

The areas of materials, medicine (including biology) and science produced a number of proposals for advanced projects in space. The spread of interest is what would be expected, with the university community strong on space science and all sectors making proposals in the other two fields. The fact that communications does not seem to have evoked many proposals is primarily a consequence of the present strong program focussed on geo-stationary satellites and does not signify a lack of interest in future space programs. One proposal was made from the social field. This has promise for quick application when Space Station is in place and if pursued, will generate interest among the public for space activities.

2.2 Comments

Responses falling within this category spanned the spectrum from general support for the concept of participation in Space Station to belief that there is little justification for activity in this area at this time. Some also remarked on possible legal or jurisdictional problems, mainly associated with rights

Table 2-2

PROPOSALS BY SECTOR AND APPLICATION

	Remote sensing	Communic- ations	Mater- ials	Science	Tech- nology	Social	Medicine	Total
INDUSTRY								
supplier	3	1	0	0	17*	0	0	21
user	9	1	5	0	1	1	3	20
UNIVERSITY	5	0	6	7	4	0	4	26
GOVERNMENT	9	1	2	1	3	0	4	20
TOTAL	26	3	13	8	25*	1	11	87

* - supply of remote sensing/communications technology

to technology, data, etc., when Canada is involved in international space programs.

Table 2-3 shows the general areas within which the comments fall, by sector. The wide range of observations is clearly demonstrated. It should be emphasized that the generally negative replies are somewhat "soft" in as much as they do not represent an opposition to Space Station; rather, that such a program is not very important in their view at this time. Almost twice as many responses in this category were supportive as were unsupportive. The community represented by this group expressed an essentially "wait and see" viewpoint and with a few exceptions, it is unlikely that any significant proposals will be developed within the foreseeable future.

2.3 "Nil" Responses

About 30% of those interviewed responded with observations that have been classified as "nil". The type of "nil" response is presented in Table 2-4. Forty percent of those in the group see no use for, or have no interest in, Space Station. The industry response is evenly split between supplier and user - nearly all of whom are working toward the development of technology. These are the ones that might expect to contribute to and benefit from Canadian participation in Space Station. As mentioned previously, this situation may be due to the present economic climate. With respect to the government sector, this is partly a reflection of the range of people interviewed, many of whom are engaged in competing programs that have needs not in keeping with the concept of Space Station.

Table 2-3

ANALYSIS OF COMMENTS

	National or technical opportunity (1)	Will advance knowledge	Should position ourselves for space	Low priority	Low tech. econ. opport. (2)	Not now in national or regional interest (3)	Legal/ jurisdictional problems
INDUSTRY							
supplier	4	0	5	3	1	1	0
user	2	0	3	1	1	0	0
UNIVERSITY	0	0	0	1	0	0	0
GOVERNMENT	8	5	11	5	2	5	2
TOTAL	14	5	19	10	4	6	2

(1) - deemed to be in national interest
- advocated continuing with space technology

(2) - space servicing not effective
- minor economic opportunity

(3) - very long term payoff
- too few companies benefit
- no regional benefits
- reservations on joining with NASA
- postpone decision
- assess alternatives

Table 2-4

ANALYSIS OF NIL RESPONSES

	No use or interest	No direct connection with work	Not within mandate	Too far in future	No idea	Nothing to say	Total
INDUSTRY							
supplier	7	2	0	0	0	3	12
user	4	2*	0	1	4	4	15*
UNIVERSITY	2	0	0	1	2	1	6
GOVERNMENT	8	4	1	1	0	3	17
TOTAL	21	8	1	3	6	11	50*

* - one respondee expressed two views

Many of those who had nothing to say are in organizations where others have, in fact, spoken for that organization. In that sense, one cannot attach a great deal of significance to their "nil" response. There were only one or two people who criticized space programs in general on the grounds that they are far from cost effective.

3. RESULTS

3.1 Introduction

The findings described above revealed a number of subject areas under which proposals can be grouped, and within which proposals could be assembled from the interests expressed by many of those interviewed. In this section, such groupings are formed, thus creating a structure for depicting the Space Station Canadian user community requirements. The moulding of this structure in order to articulate benefits from Canadian contributions to Space Station, and to establish cross-national liaison and communication will be critical to the success of any future Canadian participation. The groupings are summarized in Table 3.1 by sector of interviewee.

Each group is discussed in the context of the proposals made, the comments received and "nil" reports. Proposals have been summarized in tabular form with reference to strategic benefits and state of technology development. The results of this process have been translated into graphical form, upon which certain observation may be made and from which conclusions can be drawn.

Seven groups have been identified:

- o remote sensing
- o communications
- o materials
- o science
- o technology
- o medicine/biology
- o social/culture

Each group is treated separately below.

The proposals received covered a range in respect of degree of preparedness; some were conceptual, others quite well

Table 3-1

SUMMARY OF RESPONSES BY APPLICATION

	Remote sensing	Communic-ations	Mater-ials	Science	Tech-nology	Social	Medi-cine	Other	Total
INDUSTRY									
supplier	5	7*	2	0	28	0	0	0	42*
user	12	4	9	0	7	1	7	0	40
UNIVERSITY	9	0	6	8	4	0	7	0	34
GOVERNMENT	20	8	3	9	8	1	9	2	60
TOTAL	46	19	20	17	47	2	23	2+	176*

* - one respondee represents both supplier and user
\+ - Traffic Control and Defence

developed. For the latter, it has been possible to attach some estimates regarding timing and potential application. The results of this exercise are shown separately in Appendix 6. The discussion which follows, however, includes all proposals.

One intended result from the study was the identification of requirements to be met by Space Station in order to satisfy the needs of users. During the interview process it became apparent that hard specifications would not be obtainable. User views on space station configurations are discussed in the following sections to the extent that information is available.

3.2 Remote Sensing

Of those organizations or persons interviewed, 47 were associated with remote sensing. Of these, 28 made proposals for the use of a Space Station, a further 9 had comments to contribute and the remaining 10 were classified as "nil" responses. A total of 32 proposals were evaluated from the 28 groups making proposals, falling into five groupings:

1. Thematic Mapping--6 proposals
2. Topographic Mapping and Surveying--3 proposals
3. Change Monitoring--11 proposals
4. Sensor and Data Processing Development--9 proposals
5. Special Applications--3 proposals

It is worth noting that 17 of the proposals stated that a space station infrastructure was essential, whereas 15 were such that while a Space Station was sufficient, the requirement could be fulfilled by a conventional, free-flying satellite or space platform.

Proposals, comments and "nil" responses are covered in the following sections.

3.2.1 Remote Sensing Proposals

The 32 remote sensing proposals are listed in Table 3-2, grouped under the five headings listed above. They also have been plotted in Figure 3-1 using the methodology outlined in Section 1.3. There were no advanced proposals within the remote sensing group, and so those listed in Table 3-2 were extracted from interviews in which interest was expressed.

The remote sensing proposals are divided into five subject areas:

1. Thematic Mapping
2. Topographic Mapping and Surveying
3. Change Monitoring
4. Sensor and Data Processing Development
5. Special Applications

The overall distribution of the array of points in Figure 3-1 suggests there are proposals that would yield significant strategic benefits with relatively little need for technology development (those points lying in the upper left corner of the array). An imaginery line pivoting about the lower left corner of the graph clockwise from the vertical sweeps out a sector that will contain proposals of increasingly lower strategic benefit and state of technology development. For example, Sector "S" contains seven of the nine sensor and data processing development proposals which rate the highest of the five groups in terms of strategic benefits and state of technology development. Sector "C" contains eight of the eleven proposals labelled "change monitoring" which as a group rank lower than the sensor proposals.

1. Thematic Mapping

Six proposals were evaluated under the heading of thematic mapping which is the assignment of attributes to a planimetric map in accordance with a variety of themes. Typical themes include forest inventory, land use, surficial geology, bed rock geology, agriculture, hydrology, etc.

TABLE 3.2 (Page 1 of 3)

REMOTE SENSING PROPOSALS

No.	Proposal	STRATEGIC BENEFIT: Economic Opportunity	National Interest	Regional Development	Advancement of Knowledge	TECHNOLOGY DEVELOPMENT: Capability	Development	Potential	Space Station Advantage
Thematic Mapping									
T-1	High Resolution Synoptic Imaging Radar	Useful	Very important	Contributes	Significant	Growth	R&D	Favourable	Sufficient
T-2	Passive Microwave Radiometer with 1 km array	Useful	Beneficial	Moderately Distributed	Significant	Embryonic	Concept	Favourable	Necessary
T-3	High-Resolution Microwave Scanner	Useful	Beneficial	Moderately Distributed	Significant	Embryonic	Concept	Favourable	Necessary
T-4	Determination of shorter wavelength features of earth's gravity field	None	Little importance	Concentrated in existing areas	Very significant	Embryonic	Concept	Average	Necessary
T-5	Thematic Mapper on 50° Space Station	None	Beneficial	Concentrated in existing areas	Insignificant	Mature	Proven	Unfavourable	Sufficient
T-6	Monitoring earth deformations via laser ranging	None	Little importance	Concentrated in existing areas	Insignificant	Embryonic	Concept	Average	Necessary
Topographic Mapping and Surveying									
M-1	Recovery of film from on-board cameras	Major	Beneficial	Well distributed	Insignificant	Mature	Proven	Unfavourable	Necessary
M-2	High resolution sensors and geodetic positioning	Minor	Beneficial	Moderately distributed	Moderate	Mature	Proven	Unfavourable	Sufficient
M-3	studies of atmospheric refraction with geodetic emphasis(distribution of water vapour in troposphere)	None	Little importance	Concentrated in existing areas	Very significant	Embryonic	Concept	Average	Necessary
Change Monitoring									
C-1	Monitoring Lake Levels for Hydroelectric Power Application	Major	Beneficial	Well Distributed	Moderate	Embryonic	Concept	Unfavourable	Sufficient
C-2	Remote Sensing Power Line Conditions	Moderate	Beneficial	Well Distributed	Moderate	Embryonic	R&D	Average	Sufficient
C-3	CCD Array Scanners for water, vegetation analysis	Useful	Beneficial	Concentrated in Existing Areas	Moderate	Non-Existent	Concept	Average	Sufficient

TABLE 3-2 (Page 2 of 3)

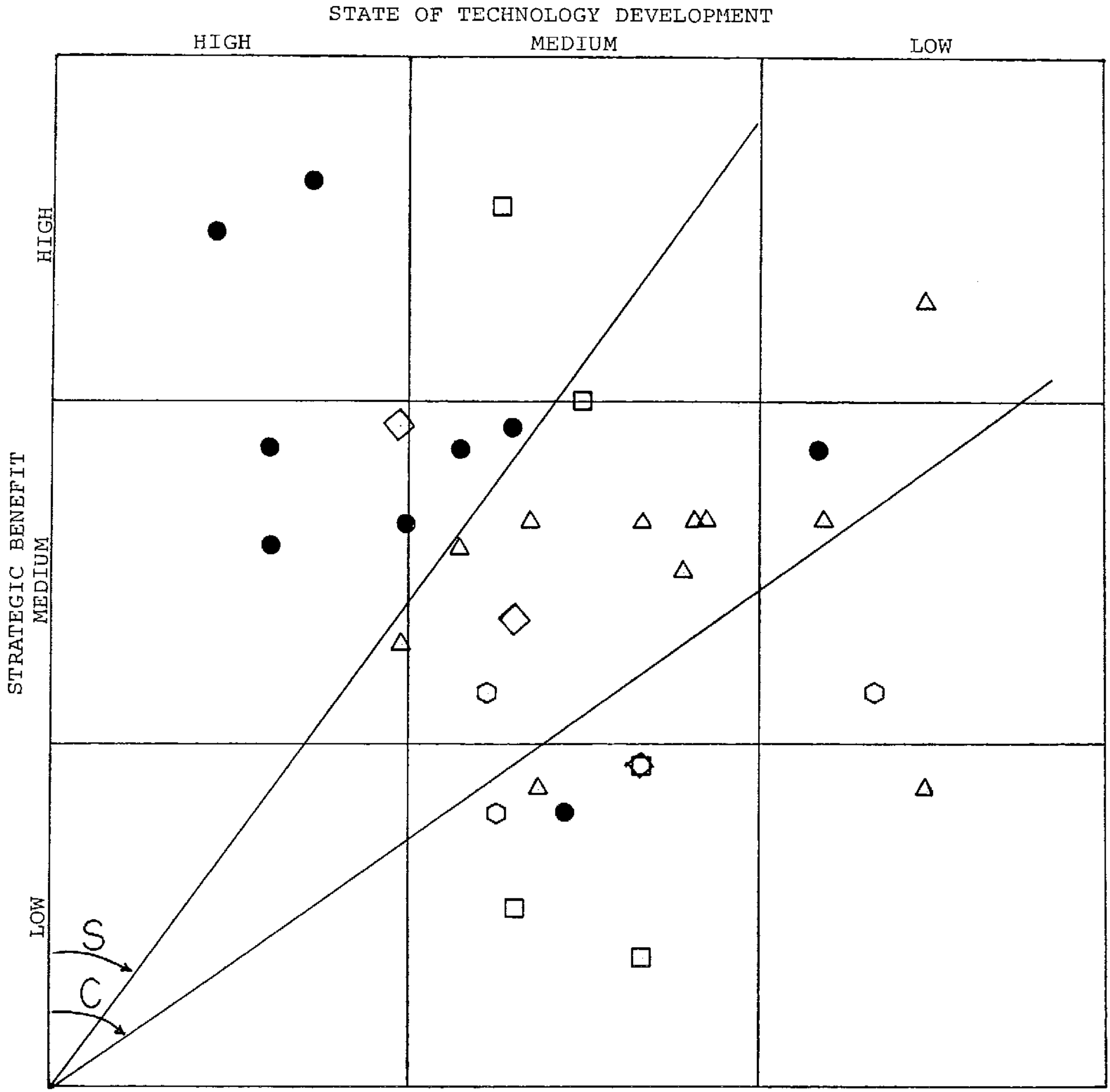
No.	Proposal	STRATEGIC BENEFIT Economic Opportunity	National Interest	Regional Development	Advancement of Knowledge	TECHNOLOGY DEVELOPMENT Capability	Development	Potential	Space Station Advantage
C-4	Navigation and Remote Sensing Hydrological Applications in B.C.	Moderate	Beneficial	Moderately Distributed	Moderate	Early Growth	Concept	Average	Sufficient
C-5	High resolution stereo imagery for Woodlot inventory	Useful	Beneficial	Concentrated in existing areas	Moderate	Early Growth	R&D	Average	Sufficient
C-6	Surveying and Mapping of Woodlots during Cutting application	Useful	Beneficial	Concentrated in existing areas	Moderate	Embryonic	Concept	Favourable	Sufficient
C-7	High resolution stereo, geo-referenced Imagery for forest inventory	Useful	Beneficial	Concentrated in existing areas	Moderate	Growth	Prototype	Average	Sufficient
C-8	Test Ice Space Radar	Minor	Beneficial	Concentrated in existing areas	Significant	Growth	R&D	Average	Necessary
C-9	Human observations of icebergs and episodical events	None	Very important	Contributes	Insignificant	Mature	Proven	Unfavour-able	Necessary
C-10	Pollution (SO_2, NO_x) Monitoring	None	Beneficial	Concentrated in existing areas	Moderate	Growth	Prototype	Average	Sufficient
C-11	Remote Sensing of Migratory Bird Habitats	None	Little importance	Moderately distributed	Moderate	Embryonic	Concept	Unfavour-able	Sufficient
Sensor and Data Processing Development									
S-1	Scanner and Pollution Sensor Development	Major	Very important	Concentrated in existing areas	Significant	Growth	Proven	Favourable	Necessary
S-2	Space Laser Radar Development	Major	Very important	Concentrated in existing areas	Very signifi-cant	Growth	R&D	Very favourable	Necessary
S-3	Testing of Sensors and On-Board Processors	Useful	Beneficial	Concentrated in existing areas	Significant	Mature	Prototype	Favourable	Necessary
S-4	On board processing of R/S Data	Moderate	Beneficial	Concentrated in existing areas	Significant	Mature	Prototype	Favourable	Necessary
S-5	Multi-Frequency SAR - 8 -10 KW	Useful	Beneficial	Moderately distributed	Moderate	Growth	R&D	Average	Necessary
S-6	High-Resolution Sensors and On-Board Processing	Useful	Beneficial	Well distributed	Moderate	Embryonic	R&D	Favourable	Necessary
S-7	CCD Imager	Useful	Beneficial	Concentrated in existing areas	Moderate	Growth	Prototype	Average	Necessary
S-8	Wide-Swath Scatterometer	Useful	Beneficial	Concentrated in existing areas	Significant	Non-Existent	Concept	Average	Sufficient
S-9	Fluorescence Line Imaging from Space	Minor	Beneficial	Concentrated in existing areas	Insignificant	Early Growth	R&D	Favourable	Sufficient

TABLE 3.2 (Page 3 of 3)

		STRATEGIC BENEFIT				TECHNOLOGY DEVELOPMENT			
No.	Proposal	Economic Opportunity	National Interest	Regional Development	Advancement of Knowledge	Capability	Development	Potential	Space Station Advantage
Special	Applications								
Sp-1	Spotlight SAR for S.A.R.	None	Very important	Well distributed	Insignificant	Early Growth	Concept	Favourable	Necessary
Sp-2	Limb Scanning of the Atmosphere	None	Beneficial	Concentrated in Existing Areas	Very significant	Embryonic	R&D	Unfavourable	Sufficient
Sp-3	Planetary Fluid Dynamics Simulator	None	No Importance	Concentrated in Existing Areas	Very significant	Embryonic	Concept	Very favourable	Necessary

FIGURE 3-1

REMOTE SENSING PROPOSALS



LEGEND

- ● - Sensors
- △ - Change Monitoring
- ◇ - Surveys and Mapping
- □ - Thematic Mapping
- ⬡ - Special

The projects proposed fell into a narrow technology development middle band, spanning a wide range of economic benefits from almost the highest to the lowest in the Figure 3-1 array. High benefits were attributed to active and passive microwave thematic mapping.

The high incidence of cloud cover over Canada and the arctic darkness have limited the usefulness of visual and infrared imaging sensors. Active microwave sensors, particularly synthetic aperture radars (SARs), are capable of penetrating cloud and darkness to provide high-resolution images of value for thematic mapping. The full extent of the benefits of SAR are not yet understood because of the limited civilian experience with such space-borne radars (Seasat for 100 days). The remote sensing community believes that SAR can be of major economic benefit to Canada, principally for ice reconnaissance in the arctic and for geological mapping over land.

Microwave radiometers provide radiance maps at a variety of wavelengths which can be related to physical features on the earth's surface. They operate in a variety of wavelength bands corresponding to windows in the atmosphere, and can penetrate clouds and darkness like SAR.

Both SAR and microwave radiometers can and have flown on free-flying satellites, but the applications envisaged for Space Station involve large antenna arrays (in the case of radiometer, up to 1 km. in dimension) , as well as complex, on-board data processing in order to minimize telemetry bandwidth requirements. Both requirements necessitate a large enough vehicle with sufficient space and power to be classified as a Space Station.

Three proposals assessed with relatively low strategic benefits include mapping of specific parameters (earth deformations and gravity field) and higher coverage frequency of a Landsat 4-type thematic mapper.

2. Topographic Mapping and Surveying

Three proposals fell into this category. The first, M-1, was the use of a space station to recover film from a metric, photogrammetric camera of appropriate focal length for mapping from orbit. It scored the highest rating in strategic benefit and state of technology development. Photographic film still offers the highest resolution of all current sensors, and the ability to conduct otherwise conventional photogrammetry using photographs taken at orbital altitudes can be of major strategic value when cloud cover is sufficiently low.

The second proposal was general, and indicated the value of receiving imagery of sufficient geometric and resolution quality to be used for topographic mapping. Such a requirement might be met with push-broom CCD scanners that could be developed in Canada (see"Sensor and Data Processing Development" below). A space station is sufficient for such sensors but not essential for an operational system.

The Landsat 4 Thematic Mapper is being evaluated for use in revising 1:50,000-scale maps (the largest federal scale). Difficulties have been encountered in viewing the terrain under varying light and seasonal conditions, and in the geometric accuracy of some images. These early problems should indicate appropriate directions for future sensor development. With the present cessation of Landsat 4 Thematic Mapper transmissions, it may be necessary to wait until the launching of the French satellite SPOT in 1984, which will provide stereo coverage with a ground resolution of 10 metres, before proceeding further with space-based topographic mapping applications.

The use of silicon devices to replace photographic emulsions is moving forward very rapidly, and "silicon mapping" from space will be commonplace before the end of the current decade. The space station in $\pm 50^{\circ}$ LEO will provide the necessary coverage of the culturally-developed regions of Canada to make it a prime platform candidate for experimental silicon mappers before they reach an operational status.

The third proposal was to use Space Station as a base for measuring atmospheric refraction due to water vapour (using laser and microwave imagers) for the purpose of improving the accuracy of geodetic measurements using satellites. It was rated lower in strategic benefits and technology development than the other two proposals.

3. <u>Change Monitoring</u>

Change monitoring received the greatest number of separate proposals of all remote sensing categories, eleven in number. It embraces such activities as forest monitoring, crop monitoring, ice reconnaissance, water resource monitoring, flood monitoring, wildlife habitat monitoring, etc. Figure 3-1 shows that the change monitoring proposals fall mainly into the medium range of strategic benefits and state of technology development. The proposals cover the monitoring of changes in:

- lake levels for hydroelectric power applications
- Power line conditions
- water and vegetation analysis
- hydrology
- woodlot inventory
- ice and icebergs
- episodical events
- air pollution
- migratory bird habitats.

The above list is ranked in descending order of assessed strategic benefit. Ice monitoring requires large radars necessitating the power available in a Space Station; iceberg and episodical event monitoring requires that a person be on-board as an observer and interpreter, and thus also needs a space station. For all of the other applications, a Space Station is sufficient but not necessary.

However, among the total community that use satellite imagery for the monitoring of change, there is a universal complaint: they cannot obtain the data frequently or fast enough to be able to use it operationally. A Space Station in $\pm 50^{\circ}$ LEO would increase the coverage of the populated areas of the world enormously over the present Landsat coverage which is every 18 days at these latitudes. Thus Space Station could be of particular value for monitoring of change more because of its orbit than because of its other features, except for the two essential requirements stated above.

4. Sensor and Data Processing Development

There were nine proposals received that pertained to interest in developing sensors or data processing systems for space. In descending order of assessed strategic benefits, they cover:

- space laser radar for pollution monitoring and survey applications
- CCD pushbroom scanner for pollution monitoring and mapping applications
- On-board data processing, to simplify data management and transmission from Space Station
- multi-frequency synthetic aperture radar (SAR) using 8-10 kw. of power
- wide-swath scatterometer for ocean wave monitoring
- fluorescent line imager for ocean productivity mapping

Figure 3-1 shows that in terms of strategic benefits and state of technological development, sensor and data processing activities rate higher than any of the other remote sensing categories.

It is not surprising that sensor and on-board processing development rate as highly as they do. The related industries have been supported principally by the Canada Centre for Remote Sensing since the early to mid-1970s in establishing their technical teams and capital facilities. The space station application is a natural extension of the range of use for this Canadian technology. A listing of Canadian sensors with potential for use in space is contained in Appendix 7.

Sensor developments couple back to the other remote sensing categories because they require sensors of the type listed above. In particular, the CCD push-broom scanner and multi-frequency SAR sensors (coupled with on-board array processors to make telemetry tractable) rate highly among the sensor proposals because they are very relevant to topographic and thematic mapping, and change monitoring.

5. Special Applications

Three proposals were made by remote-sensing interviewees that did not fall within the above four categories. The first is the use of a spotlight SAR (high definition, narrow beam, synthetic aperture radar) to help identify the location of search-and-rescue transmitter signals-- a worthy cause which rated only moderately under strategic benefits, but at a potentially high state of technological development. It likely would require a Space Station to provide the power and pointing stability needed.

A second special application is the development of a limb scanning spectrometer for detecting and measuring molecules in the atmosphere such as OH, O_2, NO, NO_2, O_3, etc. While the purpose serves mainly scientific objectives, the remote sensing instrument itself falls within the sensor category and brings with it a major Canadian capability.

The final special application proposed by a remote-sensing group is to develop a laboratory model of planetary fluid dynamic phenomena for use in the space station. It would be used to study such problems as the effect of waves impinging on continents, ocean circulation around the poles, etc. An analogue spinning globe would be mounted in the space station complete with fluid and an atmosphere. Various perturbations could be applied to such a model, and the resulting effects measured. It would need to be visited periodically, but could be set up in an unmanned space vehicle. While this proposal is essentially scientific in nature, it was made by a remote sensing group, and remote sensing technologies would be needed to make it work.

3.2.2 Remote Sensing Comments

Comments on remote sensing applications of the Space Station were made by nine interviewees. Their interests spread across a wide spectrum and thus there was little coherence in the comments noted by the interviewers. They included the following thoughts synopsized for the sake of brevity:

- o there were a number who believed that Space Station should be used as a test facility for new sensors before they are committed for operational use on free-flying, dedicated satellites

- a number commented on the limitations of current Landsats and expressed hope that new sensors on Space Station would overcome them. Most noted shortcomings were frequency of coverage, need for higher resolution, speed of turnaround of data

- a particularly useful suggestion was a program to develop a technique for pointing satellite-borne sensors at cloud openings

- a view was expressed against on-board processing of remote sensing data, arguing that most users want to work with original data sets

- several contributors expressed a desire for polar orbits to obtain better coverage of Canada's arctic; and one commented that GEO would provide the frequent, synoptic coverage needed by those in the meteorology field

- it was commented that 3 metres per pixel is the resolution needed to revise 1:50,000 NTS maps; also, there would be little need for stereo imagery of Canada in the 1990s because almost all of Canada will be mapped by then (at 1:50,000)

- the largest use for space mapping will be in the third world

- it was pointed out that the space station infrastructure would not be needed for position fixing because of the GPS program and other spacecraft that can be used in Very Long Baseline Interferometry (VLBI) techniques

- one group expressed concern about the proprietary aspects of data from space station and the patent implications of sensors and other payloads placed on board the station vis-a-vis NASA and US interests.

3.2.3 Remote Sensing "Nil" Responses

The "Nil" responses by remote sensing organizations can be classified into three general areas: those that are end users of remote sensing data but see no particular advantage of space station (4 in this group); those that would have an interest at GEO (2 in this group); and those that feel space station is just too far ahead for them to plan or think about it

(3 in this group). One respondent expressed alarm that "Canada would seriously consider getting involved in the program given the state of the economy and the esoteric nature of a space station project".

It was generally believed by those that conducted the interviews that a significant proportion of the "nil" responses would become positive toward Space Station should the program gain momentum in Canada, and investments be forthcoming from government or industrial sources.

3.3 Communications

Eighteen interviewees gave infomation that has been classed under the heading of Communications. Of these, four made proposals which could be rated for strategic benefit and state of technology development, eleven made comments and four were "nils".

3.3.1 Communications Proposals

The assessment of the four proposals is given in Table 3-3 and the graphical display in Figure 3-2. It is apparent that the state of technology development is high, resulting from a long history of space-based communication systems, and from the need for Space Station in order to proceed with the proposals. The strategic benefits do not appear large, due in part to the operational and technology programs already operating.

The four proposals fall into two distinct groups, the one ranking higher containing proposals for space hardening of telecommunication equipment and extension of current experiments dealing with waves in space plasma. In both cases a long duration space flight with a recoverable feature is necessary.

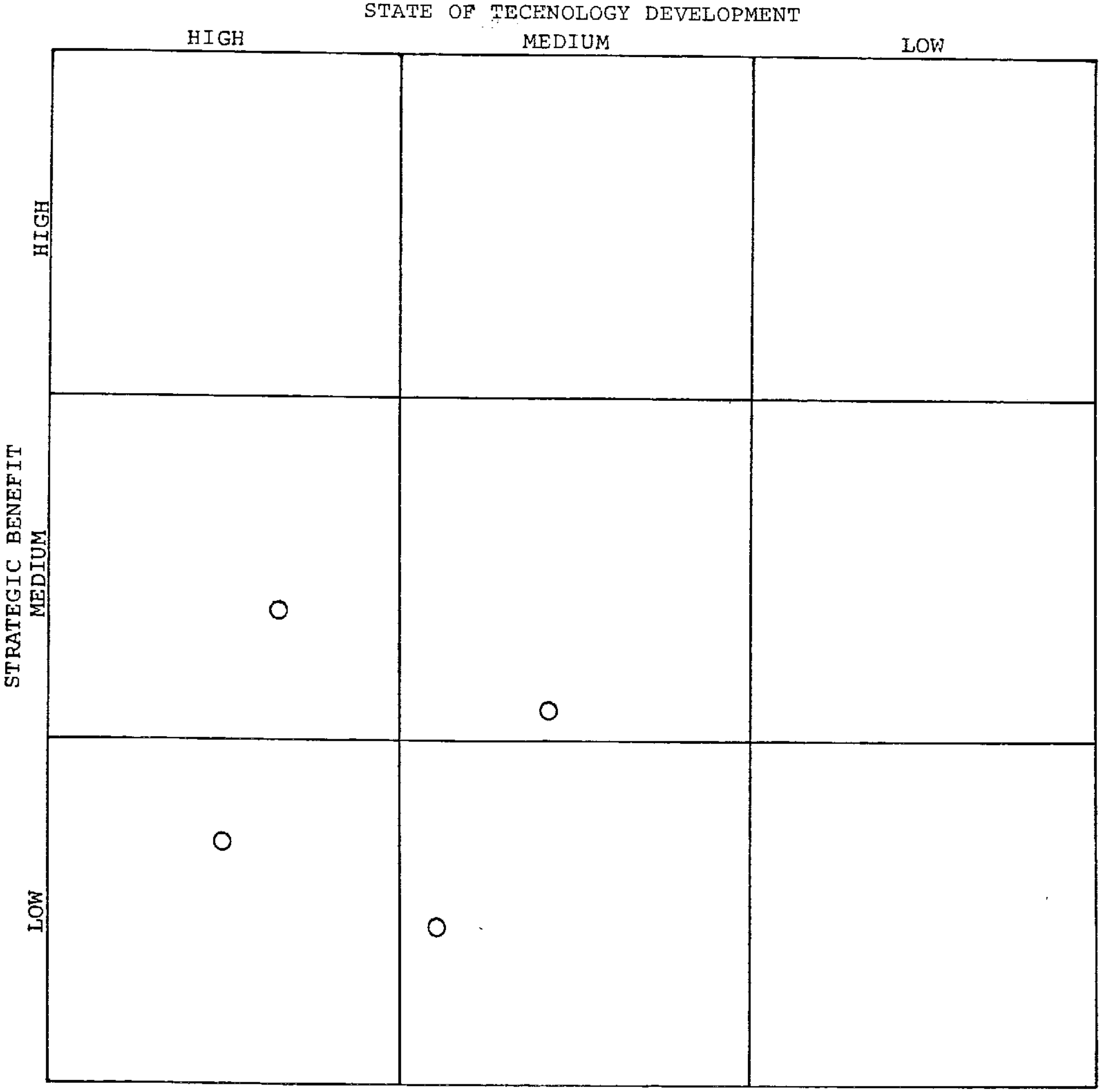
TABLE 3.3

COMMUNICATIONS PROPOSALS

		STRATEGIC BENEFIT			TECHNOLOGY DEVELOPMENT			
Proposal	Economic Opportunity	National Interest	Regional Development	Advancement of Knowledge	Existing Capability	State of Development	Innovation Potential	Space Station Advantage
Low earth orbit satellite for store and forward video and audio from non-North American satellites.	None	No importance	Could contribute to services in remote countries	Insignificant	Mature	Proven	Average for development of store and forward operation	Necessary
Repair, re-supply proving and hardening of telecommunications satellites	Moderate	Beneficial	Concentrated in existing areas	Insignificant	Embryonic	Concept	Favourable	Necessary
Provision of space station Communications systems	Minor	No Importance	Concentrated in existing areas	Insignificant	Early growth	R&D	Favourable	Necessary
Waves in Space Plasma	Moderate for construction of wave injection facility	Beneficial to maintain Canadian competence	Concentrated in existing areas	Moderate	Mature	Prototype	Favourable	Necessary shuttle times too short, interference from other pay loads.

FIGURE 3-2

COMMUNICATIONS PROPOSALS



The remaining proposals did not score highly in respect of strategic benefits. In one case, comments received from other interviewees suggested that the opportunity identified could be captured by other means using existing systems.

3.3.2 Communications Comments

Over one-half of the interviewees in the communications field responded with "comments"; this is the highest fraction encountered, and is consistent with the state of development of the subject. While there were relatively few proposals from this community, there is considerable support for pushing ahead into new space technologies.

An overwhelming proportion of the comments (12 out of 18) see space station as a national opportunity for which we should position ourselves. This observation came equally from industry and government and in the former case even where there did not appear to be any discernable commercial opportunity. This view was tempered, however, with a number of suggestions that space station will have little application for communications.

3.3.3 Communications "Nil" Responses

There were four "nil" responses, two industry interviewees who had no interest in Space Station and two from the public sector who had nothing to say.

3.4 Materials

The subject of materials processing in space has received considerable attention both in Canada and elsewhere. This survey will not attempt to retrace steps that are well known and documented; a comprehensive report on the subject has been prepared by the National Research Council of Canada (1). Many of the people who participated in that study were interviewed during the course of our survey. Their observations, along with others, are catalogued and assessed.

Twenty interviewees responded with information that has been classified in the field of materials. Of these, thirteen made specific proposals, two offered comments and the remaining five are "nils". Activity in this subject is well distributed both by geographic location and by sector, extending from coast to coast and including all three sectors.

3.4.1 Materials Proposals

Assessment of the thirteen proposals is presented in Table 3-4 and the results plotted in Figure 3-3. One proposal significantly exceeds the others in both strategic value and state of technology development. This relates to the study of the effect of the space environment on polymer matrix composite materials. These materials could have an important role to play in space structures provided the environment has no deleterious effects.

The upper enclosure encompasses a family of proposals relating to crystal growth and solidification studies. This grouping rates above average strategic benefit primarily as a result of the potential for advancement of knowledge in a subject area of considerable importance to a metal-producing country

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(1) - New Opportunities in Space: Proposed Canadian Research in Microgravity, Report of the Ad Hoc Committee on Microgravity, National Research Council of Canada, September 1982.

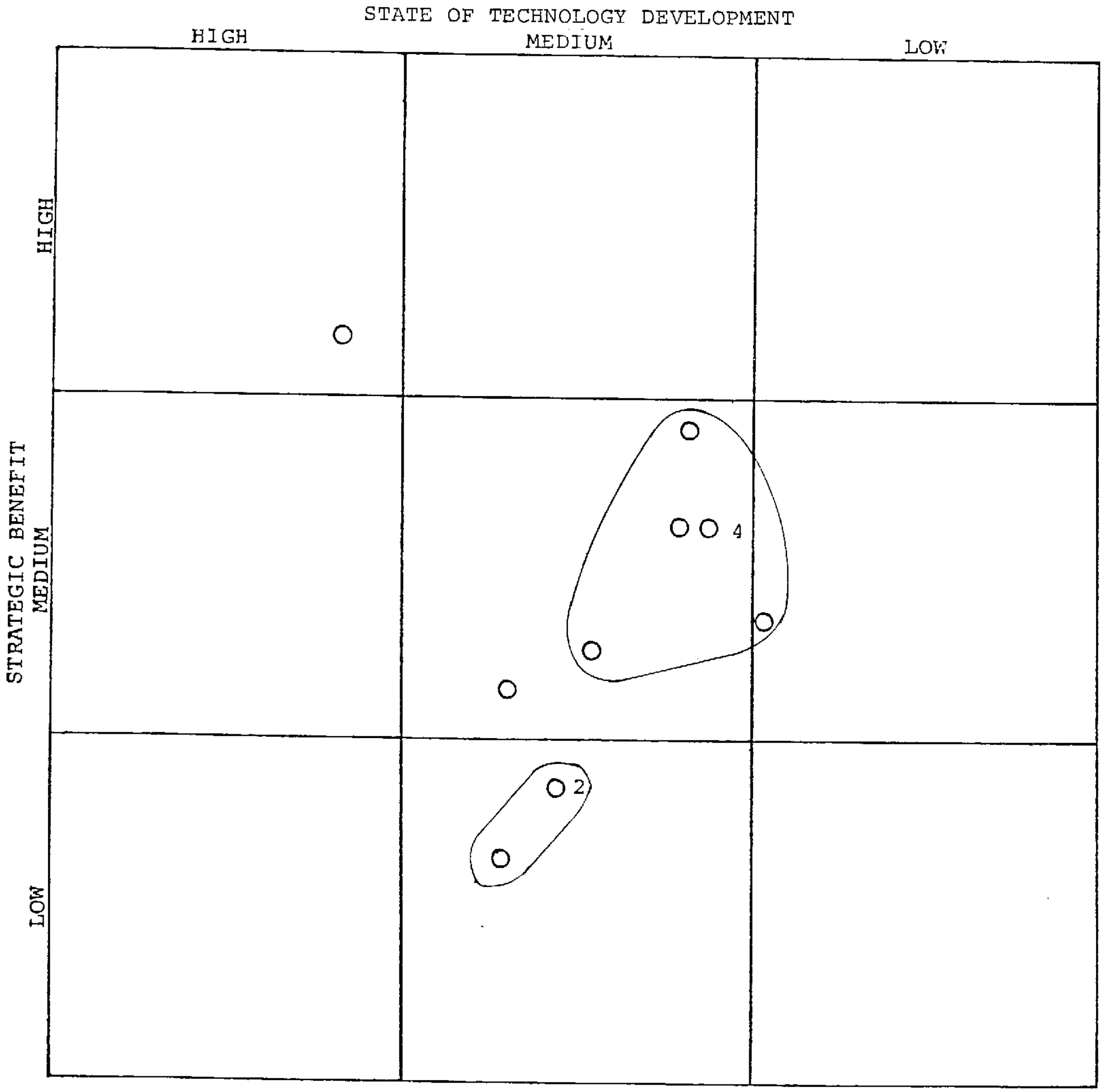
TABLE 3.4

MATERIALS PROPOSALS

		STRATEGIC BENEFIT			TECHNOLOGY DEVELOPMENT			
Proposal	Economic Opportunity	National Interest	Regional Development	Advancement of Knowledge	Existing Capability	State of Development	Innovation Potential	Space Station Advantage
investigate the processes by which radiation damage occurs in solid state memories.	Moderate if a method of overcoming the problem is developed.	No importance	Concentrated in existing areas.	Potentially significant	Growth	R&D	Favourable	Sufficient
Build a micro gravity furnace for growing highly-refined Hg-cd-Te crystals.	Minor unless studies reveal advantages for processing in space.	Little importance unless processing in space proves advantageous	Work is well distributed	Insignificant	Early Growth	R&D	Favourable	Sufficient
Study of alloy processes in absence of gravity and crucible.	Moderate	Beneficial	Contributes to regional development	Significant	Embryonic	R&D	Average	Sufficient
Design and fabricate facilities for materials processing in space	Minor	No importance	Moderately distributed	Insignificant	Early Growth	Concept	Favourable	Necessary
Study of solidification processes in entectics	Minor	Little importance	Moderately distributed	Significant	Growth	R&D	Average	Sufficient
Study of crystal growth Process in space	Moderate	Little importance	Well distributed	Significant	Embryonic	R&D	Average	Sufficient
Study of growth of Bi-Sb single crystals of high quality	Minor	Little importance	Well distributed	Significant	Embryonic	Concept	Average	Sufficient
Study of interface phenomena in metallic and semi-conducting crystal growth	Moderate	Little importance	Well distributed	Significant	Embryonic	R&D	Average	Sufficient
Effect of space environment on polymer matrix composite materials	Useful for construction of future space structures	Very important if Canada is to undertake construction of space structures	Concentrated in existing areas	Significant	Growth	Prototype	Favourable	Necessary
Materials research in space	Moderate	Little importance	Well Distributed	Significant	Embryonic	Concept	Favourable	Sufficient

FIGURE 3-3

MATERIALS PROPOSALS



LEGEND 2 (4) - Same Proposal from 2 (4) Sources such as Canada. The economic opportunity is uncertain at this time and there is not a concensus that processing in space will be a determinant in future applications. A further point to note is that Space Station is not a requirement, although it will be used when it becomes available. This view is primarily a reflection of the need for preparatory programs before embarking on expensive space experiments.

The lower enclosure bounds proposals for construction of materials processing facilities. Technology development has been rated about average, but stratetic benefit appears to be somewhat lower. The general impression gained is that there is considerable fundamental work to be done before a processing facility becomes valuable.

The final proposal suggests an investigation of the process by which radiation damage occurs in solid state memories. This is an area of some importance but it does not require Space Station, at least in the initial stages.

This whole subject is one in which Canada has a history of competence and which will continue to be important. This capability can be enhanced by taking advantage of the opportunities that are provided in the micro-gravity of space.

3.4.2 Materials Comments

Only two respondents offered comments--one in support of maintaining a presence in space activities and the other suggesting that space has a low priority.

3.4.3 Materials "Nil" Responses

There were five "nil" replies, four from industry, expressing the view that space activities are of no interest to their respective organizations.

3.5 Space Science

There were 17 responses among those interviewed that were placed into the category of Space Science. They have been divided into 8 proposals, 4 comments and 5 "nil" responses. The responses were divided evenly between university and government researchers, 8 and 9 respectively, and reflected the views of a community that has nearly 20 years of experience in operating payloads in space.

There are approximately 200 space scientists active in pure research in Canada, mostly in universities and government. They cover a wide variety of specialties and, when asked to make suggestions for a Space Station, there was no shortage of ideas. Since space research is costly, their main opportunities are to use rockets and balloons, or alternatively, to join U.S. teams in their experiments on NASA spacecraft. In the latter case, very few of them attain the status of Principal Investigator because preference is given to U.S. experimenters.

Not since the days of Alouette and ISIS have Canadian space scientists had the opportunity of managing their own satellite. This led one respondent to suggest that Canada should have an autonomous module on Space Station or a co-orbiting satellite in which there would be prime opportunities for Canadian principal investigators not subject to the usual expensive and time-consuming delays associated with U.S. approval cycles.

3.5.1 Space Science Proposals

The eight responses classified as proposals were assessed as six separate proposals because two pairs of respondents had identical suggestions. The assessment is summarized in Table 3-5, and plotted in Figure 3-4 using the methodology described in Section 1.3.

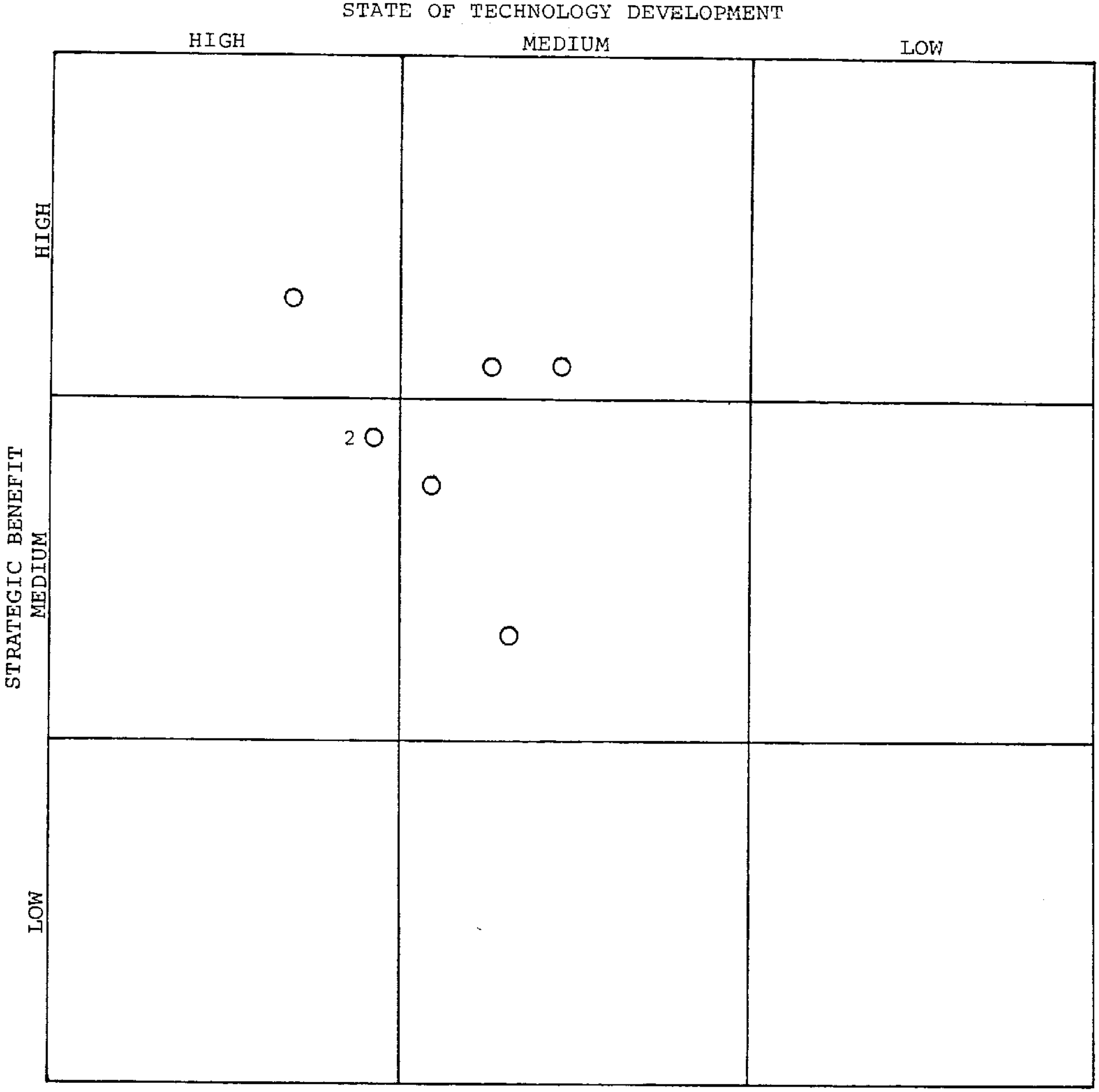
TABLE 3.5

SPACE SCIENCE PROPOSALS

	STRATEGIC BENEFIT					TECHNOLOGY DEVELOPMENT		
Proposal	Economic Opportunity	National Interest	Regional Development	Advancement of Knowledge	Existing Capability	State of Development	Innovation Potential	Space Station Advantage
STARLAB	Moderate	Very important extends Canadian competence	Moderately Distributed	Very significant at leading edge	Growth	R&D	Very favourable	Necessary-needs to be retrieved
High resolution spectrographs auroral studies	Minor	Very important auroral studies important in Canada	Moderately Distributed	Significant	Mature	Prototype	Favourably	Sufficient
Testing of very long antenna	Useful for Canada's continuing involvement in space	Very important	Concentrated in existing areas	Moderate	Early growth	Concept	Average	Necessary-shuttle can't handle
Use of space station for advanced WAMDI and electron probe measurements.	Minor	Beneficial as a continuation of Canadian space science	Concentrated in existing areas	Significant	Growth	Concept	Average	Necessary-requires power and weight capability
Extension of Canadian Long Base Line Array	Minor	Very important if VLBA project goes forward	Well distributed	Very significant	Early growth	Concept	Favourable	Necessary to extend VLBA beyond earth stations.
Assembly and deployment of huge receiving apertures, optical and electrical, for astrophysics research	Moderate	Beneficial to maintain Canadian competence	Moderately distributed	Significant	Growth	Concept	Favourable	Necessary for assembly

FIGURE 3-4

SPACE SCIENCE PROPOSALS



LEGEND 2 - Same Proposal from 2 Sources

With only eight points it is difficult to draw strong conclusions from Figure 3-4 except to observe that the state of technology development is reasonably advanced, and that higher strategic benefits are identified with the more mature technologies--a desirable state for investment. All but one of the proposals stated that a Space Station was necessary.

The most advanced proposal is that for STARLAB, a one-meter diameter telescope operating in the visible and ultraviolet ranges. This is a joint Canada/U.S./Australia program that is in the planning stages. It places severe constraints on the base to which it is attached because of the need for pointing accuracies in the order of 0.02 seconds of arc. Thus the base must be free of vibrations (human activity and moving parts such as electric motors), and at an altitude free of plasma effects. These and other stringent requirements suggest a free-flyer, but which might be part of the Space Station infrastructure.

Canadian space scientists have been developing high-resolution spectrographs for many years to study auroral phenomena. The Space Station offers the possibility of on-board processing which would reduce data transmission problems, and the opportunity to test new sensors for space applications. Space Station will provide an opportunity to advance studies in radio wave propagation through the use of very long antennas and tethered satellites. Such experiments are not possible with Shuttle because of severe space limitations. The ability to assemble large antennas and receiving apertures in space is a major factor influencing the interests of scientists in Space Station.

Canada is pre-eminent in ionospheric studies, and the Space Station is seen as a means of furthering this work using wide-angle Michelson Doppler interferometry (WAMDI) and electron probes. Space Station would provide an opportunity to measure ionospheric temperatures and densities as well as solar energy deposition in the region between the ionosphere and the troposphere to determine how the solar wind couples with the atmosphere. One experimenter sees Space Station as a means to further work in long base-line interferometry (LBLI) using a large radio telescope in combination with a planned radio astronomy satellite known as QUASAT. The latter would operate with a network of ground stations, but Space Station offers the advantage of working with frequencies that will not pass through the atmosphere.

3.5.2 Space Science Comments

It is worth noting that NRC's Canada Centre for Space Science (CCSS) implements the federal program in space science. Most of the work is contracted out to industry, but some is also contracted to the universities. Thus such scientific research generates technology that takes place largely in industry, thereby contributing to the strategic benefits of space science.

All comments came from government sources and generally supported the notion that Canada should continue to participate in space science with NASA. A wide range of ideas were suggested including the development and use of high-powered lasers for space, the potential for conducting high energy physics in the space milieu, novel uses of the micro-gravity environment in the building of delicate structures, the development of new strains of bacteria and even the use of solar energy for climate modification and control.

3.5.3 Space Science "Nil" Responses

Several scientists involved in space, five in total, responded with what amounted to "nil" reactions. Responses ranged from mild interest ("If a Space Station were available, I'm sure we would find some research activities which could utilize it"), to entirely negative ("Higher vacuums can be obtained in the laboratory than on Space Station, and so we see no use for Space Station whatsoever"). Others were either heavily pre-occupied with other work or had no particular ideas at the time of interview. It is our view that when Space Station comes closer to reality, a much greater interest will develop within Canada's space science community. One individual expressed the opinion that some highly-touted proposals for research in space are disappointing as to their originality or their practicality, and exhibited a strong "bandwagon" syndrome. These tendencies were not observed by the interviewing team on Space Station--the scientists contacted had good ideas and were highly cognizant of the associated strategic benefits.

3.6 Space Station Technology

Space Station Technology is another category that drew a large response. About twenty-five percent of those surveyed fall into this group, a total of 47, from which 30 proposals were received, 8 "comments" and 14 "nils". As happened in other areas, some of the interviewees made more than one proposal, accounting for the fact that there are more "proposals", "comments" and "nils" than respondees. Some interviewees advanced the same proposal. Another point to be noted concerns the relationship of space technology to other application areas. There is room for a difference of opinion on the allocation of some proposals to particular areas. Again, a change will not affect materially the overall conclusions on the benefits and technology development aspects of our findings.

3.6.1 Space Station Technology Proposals

Technology proposals can be further subdivided by end purpose into five groups:

- o space station construction--16 proposals
- o provision of payload--8 proposals
- o instrument testing--2 proposals

- o experiments on Space Station--3 proposals
- o ground stations--1 proposal

The assessment of these proposals in terms of strategic benefit and technology development is presented in Table 3-6, segregated into the above groups. Figure 3-5 displays the same information in graphical form.

A significant feature of the assessment is the group of three identical proposals ranking at the top of strategic benefit. This proposal is to construct and use a Canadian module as part of the Space Station, and was put forward by people working in each of the three sectors and in three different regions of Canada. This is of high strategic value to Canada because

- o there is control over the whole module
- o the trade-offs on Canadian experiments are made in Canada
- o experiments with unique Canadian applications can be accommodated
- o Canada will have direct control over data obtained
- o there will be no problems regarding rights to technology
- o the survey has exposed a wide range of interest in Space Station that could justify such a module

There is a direct relationship between this proposal and the five construction proposals lying in the top left of the figure.

With regard to potential use for Space Station, fourteen respondents indicated that it is necessary; ten would find it sufficient for their purposes; and five could see no advantage.

1. <u>Space Station Construction</u>

A second result inferred from Figure 3-5 is the relatively high strategic value and high technology development placed upon the group involving Space Station construction technologies. As mentioned previously, this can be attributed to the long

TABLE 3.6 (Page 1 of 3)

SPACE STATION TECHNOLOGY PROPOSALS

	STRATEGIC BENEFIT				TECHNOLOGY DEVELOPMENT			
Proposal Space Station Construction	Economic Opportunity	National Interest	Regional Development	Advancement of Knowledge	Existing Capability	State of Development	Innovation Potential	Space Station Advantage
Design and production of simulators for testing space structures	Major if Canada decides to participate	Important as part of tech. sovereignty	Concentrated in existing centres	Significant in relation to technology	Growth	Concept	Average	None
Design and test of a Canada-wide communications and information processing system	Useful as part of Canada's capability	Improved communications equipment	Will moderately distribute industrial activity	Moderate	Growth	Concept	Favourable	Necessary
Supply of solar arrays for space platforms	Major-based on large market for present line and potential international market	Very important to maintain and increase national capability	Concentrated in existing areas	Significant	Mature - systems have been designed	Prototype	Very Favourable	Sufficient
Construction and servicing of Space Station	Major-Canada will be a partner in overall program and will contribute substantially to the technology.	Very important to advance national capability	Well distributed-Canadian suppliers available throughout the country	Signficant	Mature - based on systems developed	Proven	Very Favourable	Necessary
Evaluation and control of space structures	Major - tied to construction and servicing	Important as part of national capability	Well distributed-broad base of Canadian competence exists	Significant	Mature	Prototype	Very Favourable	Necessary
Information display panels and microwave components	Minor benefit	No particular national interest	Concentrated in existing areas	Moderate-as developments will occur anyway	Mature	Concept	Low	Necessary
Packaging applications for articles in space	Useful as new industry could be developed	Important if Canada joins space station	Possibility for moderate distribution	Insignificant	Embryonic	R&D	Very Favourable	Necessary
Manufacture of panels, booms, support structures, antennas and wave guides	Useful - some could be high volume	No particular national interest	Impact in a regional area	Only moderate	Mature	Proven	Favourable	Sufficient
Orbit transfer solid rocket motors and local space traffic control systems	Major opportunity for an industrial leader	Important to maintain capability	Impact in a regional area	Insignificant	Mature	Prototype	Favourable	Necessary

TABLE 3.6 (Page 2 of 3)

Proposal	STRATEGIC BENEFIT: Economic Opportunity	Economic Interest	Regional Development	Advancement of Knowledge	TECHNOLOGY DEVELOPMENT: Existing Capability	State of Development	Innovation Potential	Space Station Advantage
On-board image analysis and data processing	Useful when used with robotics	Some importance	Concentrated in existing areas	Moderate	Growth	R&D	Favourable	None
Manufacturing methods in space for mechanical and electrical components	Useful if space is commercia-lized.	Important as possible Canadian contribution	Probably concen-trated in existing areas	Insignificant	Embryonic	Concept	Average	Necessary
Construction of high reli-ability energy management systems for spacecraft	Useful	Of little national interest	Concentrated in existing areas	Moderate contribution	Mature	Proven	Favourable	Necessary
Simulators for spacecraft	Minor-except for spin-offs and maintenance of capability	Important to build on existing capability	Concentrated in existing areas	Moderate-evolutionary	Mature	Prototype	Favourable	Sufficient
Investigation of the dynamics of large flexible structures	Major as contin-uation of RMS	Very important as part of space program	Concentrated in existing areas	Very significant in field of large structure design	Growth	Prototype	Very favour able	Sufficient
Design and testing of large solar arrays and space trusses	Useful as part of on-going program	Some importance as part of on-going program	Concentrated in existing areas	Very significant if space construc-to materialize	Embryonic	R&D	Very favour-able	Sufficient
New manufacturing techniques and testing of large space structures	Useful to capitalize on superior analytical techniques	Little importance	Concentrated in existing areas	Significant	Mature	R&D	Favourable	Sufficient
Provision of Payload								
Development of millimetric microwave technology	Useful oppor-tunity for sales	Very important to enhance Canadian strength	Concentrated in existing areas	Insignificant-primarily engineering	Growth	Concept	Favourable	Necessary
Design manufacture and testing of precision IR and visible spectro photometers	Minor for sale of instruments	No importance	Contributes to regional development	Insignificant	Mature	Prototype	Average	None
Development of Canadian module for space station	Major	Very important as Canada would be a world leader	Contributes to regional development	Very significant	Non-existent	Concept	Very favour-able	Necessary
Payload integration	Moderate	Little importance	Contributes to regional development	Insignificant	Mature	Prototype	Average	Sufficient

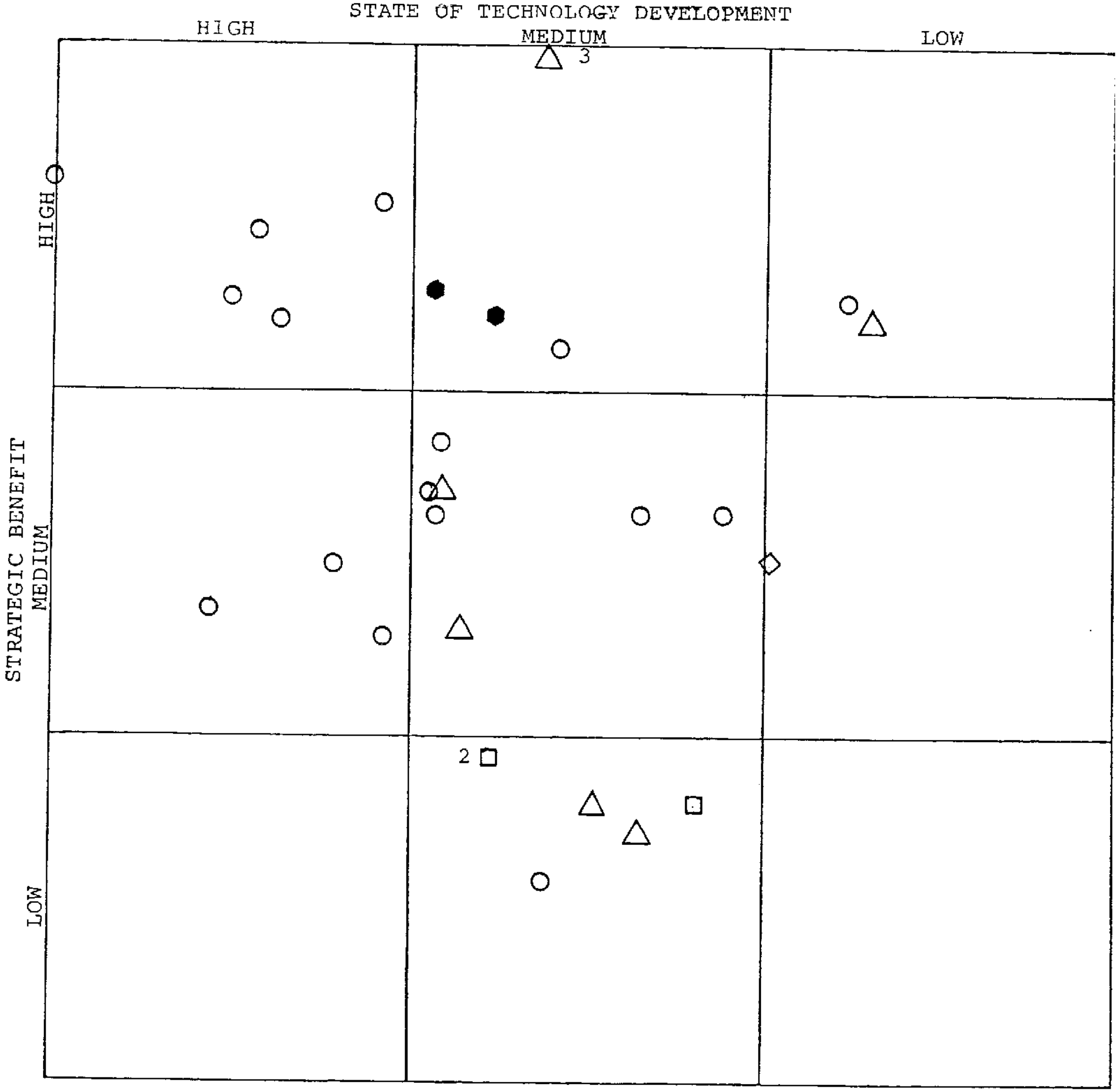
TABLE 3.6 (Page 3 of 3)

Proposal	Economic Opportunity	Economic Interest	Regional Development	Advancement of of Knowledge	Existing Capability	State of Development	Innovation Potential	Space Station Advantage
Adaptation of ozone and atmospheric sensors	Useful-might capture a share of monitoring business	Important	Contributes to regional development	Moderate	Mature	Concept	Low	None
Small scale construction/ fitting	Moderate	No importance	Concentrated in existing areas	Insignificant	Embryonic	R&D	Favourable	Sufficient
Instrument Testing								
Testing of sensors and processors	Useful-satellites too long, shuttle too short	Important if Canada is to maintain space capability	Builds on existing strength	Very significant	Early growth	Concept	Very favourable	Necessary
Testing of control systems for remote manipulator arms in natural working environment	Useful as a continuation of present programs	Very important	Concentrated in existing areas	Significant	Early growth	R&D	Very favourable	Sufficient
Experiments								
Study of spacecraft charging	Insignificant	Little importance	Concentrated in existing areas	Very significant	Early growth	R&D	Favourable	Sufficient
Study of combustion in micro-gravity	Insignificant	Little importance	Concentrated in existing areas	Significant	Non-Existent	Concept	Average	Necessary
Ground Stations								
Development, testing and ground control of next generation of spacecraft	Useful for sale off-shore	Little importance	Concentrated in existing areas	Moderate	Growth	Concept	Average	None

FIGURE 3-5

SPACE TECHNOLOGY PROPOSALS

TECHNOLOGY



LEGEND
○ - Space Station Construction
△ - Provision of Payload
● - Instrument Testing
□ - Experiments
◇ - Ground Stations
2(3) - Same Proposal from 2(3) Sources

history of space activities in Canada. The nature of the grouping suggests that these are moving in an orderly manner to bring benefits to Canada and to develop needed technologies.

The five construction proposals referred to above (top left of Figure 3-5) constitute a major Canadian capability in this subject area. Taken as a group, they form a strong base from which Canada can make major contributions to Space Station. The technologies are currently finding application in international space programs, and there is every indication that this will continue to be the case. It is an area where Canada is in the forefront, and one which provides an opportunity for Canada to be an equal partner in international alliances.

Table 3-6 demonstrates the range of construction technologies in which there is interest. Industry dominates the picture but some of the most important work is taking place in the university sector. In many cases, the individual proposals appear small--design of information display panels--but the overall picture is one of considerable diversity with potential for significant contributions to Space Station.

2. Provision of Payload

With the exception of the Canadian module noted above, this sub-group presents a diverse picture, with about average strategic benefit and technology development. The development of the technologies is above average, but the strategic value is no better than medium. This is in some measure a reflection of the size of the proposals; they are all relatively small and in the absence of a great need, they tend to represent a technology push.

3. Instrument Testing

The two proposals classed in this sub-group rated high in both strategic value and technology development. They represent a use for Space Station that will encompass other application areas and one for which Space Station appears to be well suited. The particular aspect that is attractive relates to the duration of flights available with Space Station; current recoverable systems do not provide sufficient time to acquire the necessary data.

4. Experiments on Space Station

The three experiments that have been placed in this sub-group fall into two categories; one deals with the study of combustion and the other with spacecraft charging. Although technology development falls in the medium range, there appears to be low strategic value associated with the proposals. Spacecraft charging may turn out to be important, but at present the experiments are at an early stage, and the main contribution to strategic benefit lies in the possibility of acquiring new knowledge.

5. Ground Stations

One proposal was received for the development, testing and ground control of the next generation of spacecraft. This has strategic value if the technology can be developed and off-shore sales obtained. There is also a modest opportunity for the advancement of knowledge. The capability to develop the technology is fairly advanced but the proposal is at the conceptual stage.

3.6.2 Space Station Technology Comments

A number of people interviewed had no specific proposal to put forward but did have views on Canadian participation in Space Station. In all, fourteen comments were received, about evenly split between those supportive and those unsupportive.

The generally supportive comments came from industry and the generally unsupportive from the public sector. The university community was silent.

Industry comments focussed on the need to position ourselves for use and participation in Space Station. Those expressing reservations generally observed that expenditures on Space Station are not in the national interest.

It needs to be emphasized that given the size of the sample, the relatively few unsupportive comments suggest that there is predominant support for continuing activities in space.

3.6.3 Space Station Technology "Nil" Responses

Fourteen responses have been classified as "nil", with all but one coming from the industrial sector. They are evenly split between those who see no use (for themselves) or have no interest in Space Station, and those that simply had nothing to say. No inference can be drawn from this finding except to note that somewhat more than 25% of those falling in the technology category had little to say in regard to pursuing space activity.

3.7 Space Medicine/Biology

Twenty-four of those interviewed gave replies that fall within the fields of medicine/biology. Twelve are proposals, one is a comment and the remaining eleven are "nils". All but two of the proposals require Space Station, with its ability to sustain experiments in space for a long time and still permit either recovery or visiting. Another feature of this group is the experience gained by participation in programs using currently available space vehicles. This has provided a firm basis upon which to proceed toward experiments on Space Station.

3.7.1 Space Medicine/Biology Proposals

The result of assessment of the proposals is shown in Table 3-7 and Figure 3-6. Investigation of the adaptation of the nervous system to various gravity fields has been rated highly on the basis of the knowledge that can be acquired and the state of technology development. Considerable work has been done for NASA on the measurement of the way the nervous system adapts to various gravity environments, and present experiments will probably be extended to the Shuttle for one of the 1985 launches. For this work a permanently manned Space Station is preferred, as its long lifetime permits detailed and uninterrupted study of vestibular and other life sciences mechanisms.

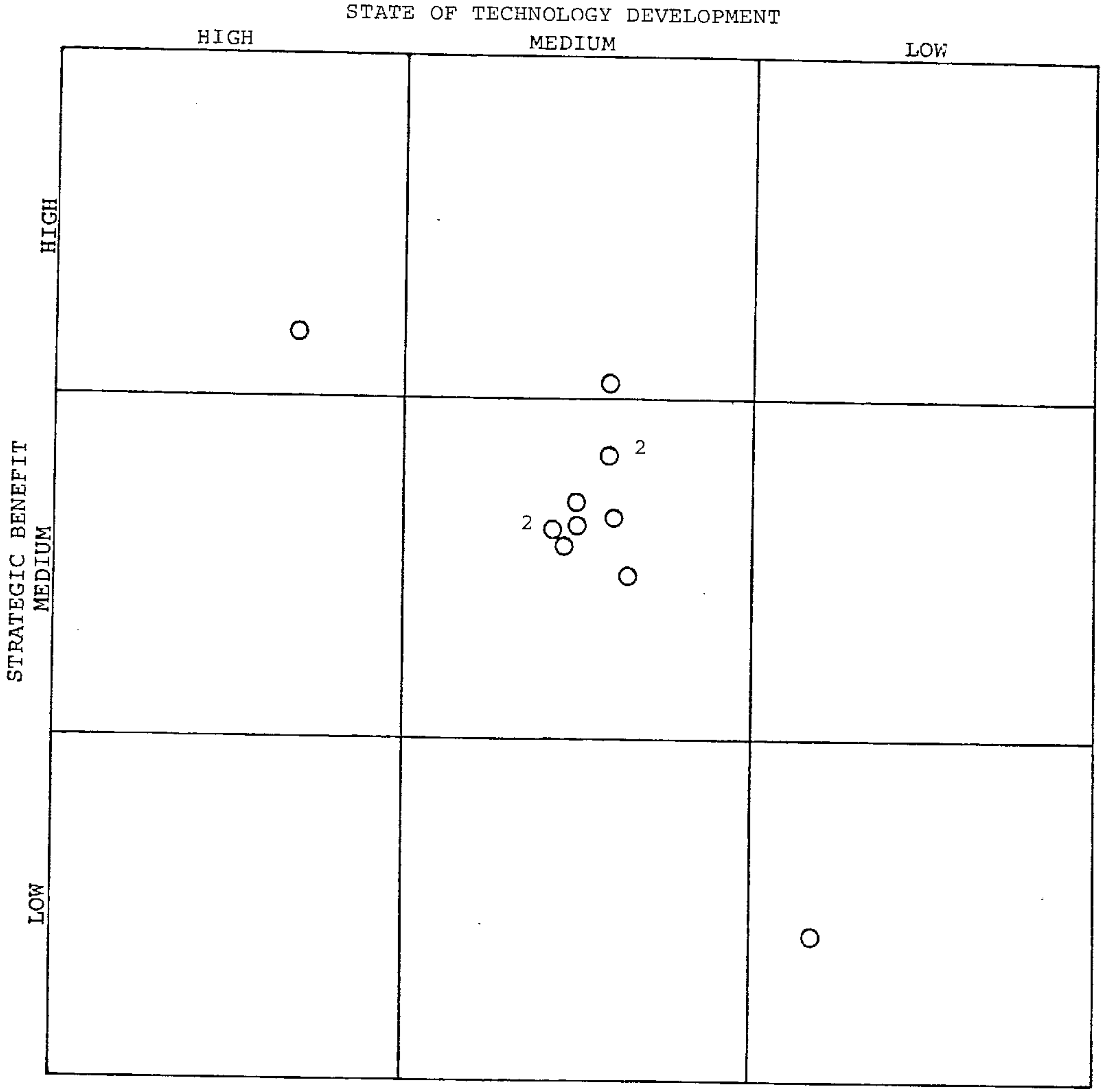
TABLE 3.7

SPACE MEDICINE/BIOLOGY PROPOSALS

	STRATEGIC BENEFIT				TECHNOLOGY DEVELOPMENT			
Proposal	Economic Opportunity	National Interest	Regional Development	Advancement of Knowledge	Existing Capability	State of Development	Innovation Potential	Space Station Advantage
Separation of proteins and trace blood elements in microgravity	Moderate	Beneficial	Concentrated in Existing areas	Significant	Non-existent	R&D	Favourable	Necessary
Develop a biological regenerative closed cycle life support system	Minor	Beneficial	Contributes to regional development	Significant	Embryonic	R&D	Average	Necessary
Investigate problems to be solved if space colonies are to be developed.	Useful as man-in-space programs progress	Beneficial as may contribute to land systems in harsh environments	Concentrated in existing areas	Significant	Non-existent	Concept	Favourable	Necessary
Investigate adaptation of nervous system to various gravity environments	Useful if Canadian companies can exploit opportunities	Very important for Canadian astronauts	Concentrated in existing areas	Significant	Growth	R&D	Very favourable	Necessary
Investigate the effect of gravity on disease and healing mechanisms	Moderate	Beneficial-maintain Canada's reputation	Concentrated in existing areas	Very significant	Embryonic	R&D	Average	Necessary
Investigate technique for cell separation in a microgravity environment.	Moderate	Little importance	Could be moderately distributed	Significant	Embryonic	R&D	Favourable	Sufficient
Investigation of bone loss in space	Minor	Very important for Canadian astronauts	Concentrated in existing areas	Significant	Embryonic	Concept	Favourable	Necessary
Use of space station as a gene bank	Moderate as many gene banks are being established	Very important for genetic pools specific to Canadian needs.	Well distributed	Moderate	Non Existent	Concept	Favourable	Necessary
Biochemical studies in space	None	No Importance	Concentrated in existing areas	Moderate	Non Existent	Concept	Average	Sufficient
Fish behaviour and evolution in space	Minor	Little Importance	Contributes to regional development	Very significant	Non Existent	Concept	Favourable	Necessary

FIGURE 3-6

SPACE MEDICINE/BIOLOGY PROPOSALS



LEGEND 2 - Same proposal from 2 sources

A second proposal that ranked above average suggested the establishment of an agricultural gene bank in space. The lower ambient temperature could reduce the cost of cryopreservation of germ plasma. This would have particular application to agricultural strains, which are important to Canada.

A small cluster of proposals rating above average relate to studies involving the health of humans. In one case, the effect of gravity on disease and healing mechanisms, there is evidence that the shift from the horizontal to vertical position, even on earth, has a detectable impact. Micro-gravity offers a significant opportunity to extend these observations.

Two proposals deal with the investigation of problems expected to be encountered when space is colonized. One of these suggested a program to develop a self-contained ecosystem which would maximize the recycling of wastes and materials. The scope of the investigation would include:

- food cooking techniques
- plant growth in space--possibly food supplies
- solar radiation to produce methane for food processing
- long term storage of food
- food production
  - single cell proteins
  - hydroponics
- waste conversion
- hygiene in space
- man and beast co-habitation
- cultural aspects of space living

This would be a long-term program but the potential exists for significant payback not only for applications in space but also in relation to existence on earth in harsh environments.

The possible enhancement of separation of proteins and trace blood elements in a micro-gravity environment was noted. Suggested areas of investigation included:

- genetic engineering of bacteria and yeast
- fermentation technology
- use of electrophoresis
- growth of cells in tissue cultures

There could be commercial opportunities in the long term; the main stumbling block is believed to lie in the issue of licensing--not in the technology.

Canada is well positioned to participate in medical/biological programs involving Space Station. There is experience upon which to build and significant benefits to be obtained from knowledge gained in the micro-gravity enviroment.

3.7.2 Space Medicine/Biology Comments

Only one comment was received and that to the effect that Canada should position herself to take advantage of opportunities that might arise with the advent of Space Station.

3.7.3 Space Medicine/Biology "Nil" Responses

Eight of the nil responses fall in the class of no perceived use to the interviewee or no connection with current work. The remaining three offered no ideas. Replies were evenly split between the three sectors, and apart from the obvious lack of interest, no further conclusions can be drawn.

3.8 Other Applications

There were four agencies visited that do not fall into the categories listed heretofore. They are:

- National Defence
- Transport Canada
- External Affairs
- TV Ontario

The following paragraphs summarize the results of these interviews:

3.8.1 National Defence

Four interviews were held within the Department of National Defence. At present the Defence Services Program for the next five years does not contain a major space component. However, there are a number of space-related activities on-going in DND including SARSAT, MSAT and some studies on future applications. It is likely that any DND projects related to Space Station will be coordinated with the U.S. Department of Defense, and so are not included in this study.

3.8.2 Transport Canada

Transport Canada's interest in space is as an end user only. Specific programs of current interest include SARSAT, MSAT, RadarSat, INMARSAT and Navstar. Space Station is unlikely to contribute to Transport Canada's operational mandate at least in its early phases.

3.8.3 External Affairs

The interests of the Secretary of State for External Affairs in the Space Station would involve principally the terms and conditions of the international agreements required to set up such a project. Of particular concern would be the selection of partners that would lead to the greatest benefits to Canada.

3.8.4 Cultural Applications--TV Ontario

On Dec. 9, 1982, a briefing on Space Station was given by members of the study group to the Executive Committee of the Canadian Conference on the Arts. While there was no specific proposal forthcoming, a conference is being considered on the cultural and artistic uses of outer space.

A specific proposal was made to the study group by TV-Ontario to use a manned Space Station as a set for producing films. The proposal included the recording of daily events on board the Station, the use of interactive programming to allow an earth audience to converse with astronauts and mission specialists, and the filming of educationally-related programs for use by schools.

TV Ontario proposed to lead an international consortium to finance the venture. This organization is one of the world's largest users of stock film footage from NASA. It has filmed sequences at NASA and at other U.S. aerospace companies in the course of creating educational TV films. It is a major source of film library material for film makers.

On the basis of the criteria used to rank other proposals, the TV Ontario response rated highly. Since it should be self-financing, it is not an area for significant federal government investment, but it could yield useful cultural and educational benefits.

4. CONCLUSIONS AND RECOMMENDATIONS

4.1 Conclusions

The following conclusions are based on the substance of the interviews, the findings, results of the analysis and ratings of the projects. We have concluded that:

1. Canada's technological capabilities for space activities have developed through the balloon and rocket programs, space research (e.g. ionospheric studies), communications satellite programs, surveys, mapping and remote sensing and defence research. Strong expertise has been established in:

   - program management and systems engineering
   - space hardware and instrumentation
   - space science
   - communications
   - space structures and thermal design
   - space mechanisms
   - remote sensing technology and applications
   - surveying, mapping and geodesy
   - space medicine/biology

2. The Canadian remote sensing community divides its interests into two major groupings:

   o remote sensing technology--sensors and data processing

   o remote sensing users--image interpretation, thematic mapping and change monitoring.

   Work in both these areas is of world class, and good use can be made of a space station in advancing the use of remote sensing to the strategic benefit of Canada. Specifically, emphasis should be focussed on techniques for directing sensors toward cloud openings, the advancement of SAR technology and applications, and the use of Space Station to improve the frequency of Canadian coverage. The Canada Centre for Remote Sensing is the obvious agency to coordinate these types of efforts.

3. Topographical surveying and mapping, while being included in remote sensing for the Space Station study, is a separate activity with different background and roots. Space is looming as a major contender for future mapping applications (geodetic

surveyors already use satellites for accurate horizontal positioning, and with GPS may be able to add vertical positioning). Improved sensors of adequate resolution (3-5 metres for 1:50,000 scale) and new techniques for geometrical correction will make it possible to use space for revision mapping and possibly original topographical mapping. The major benefits will be for use in mapping the third world. Space Station will be needed as a development tool to acquire this capability, and the Canadian mapping industry, being of world class, is in a strong position to capitalize.

4. Current programs serving the communication needs of Canada will continue to be the main vehicle for advancement of that technology. There are some exceptions, but in the main, support for Space Station comes from the belief that opportunities will arise in the future, and Canada should position herself accordingly.

5. The work of the National Research Council of Canada Ad Hoc Committee on Microgravity and the results of this survey support the conclusion that there is both interest and capability in Canada to participate in Space Station activities relating to the processing of metals and intermetallic compounds in a microgravity environment. There are many phenomena that can only be studied in that environment and information gathered on solidification processes in particular may have far-reaching effects on Canada's ability to stay in the forefront of technologies that are important to our economy.

   It is also apparent that a significant effort must be initiated in order to develop the basic competence among the younger scientists on whose shoulders the success of future materials research in Space Station will depend. There is a need for preparatory programs started now in order that the community will be ready when Space Station is available.

6. Canadian space science, coordinated by NRC's Canada Centre for Space Science, can make good use of the Space Station which was considered to be necessary for 7 of the 8 proposals evaluated. The skills and experience of this community are strong and deep with roots extending back into auroral and ionospheric research using Alouette in the early 1960s. New ideas for sensors and experiments abound, and Canada needs a good mechanism of sorting and filtering to assure the very best are put forward for competition against other nations' suggestions.

7. Space technology is an area where Canada has a long history of achievement and it is apparent that this capability can play a large role in Space Station. There is a strong domestic base and the international cooperative programs that have been developed ensure Canada's place in the forefront of future space activities. Not only is there a core group of industries who have been leaders in this field, but our survey has found that many other companies can be brought into a national program. It is important for Canada to continue its activity in space technology, not only for the direct benefits that will accrue, but for the advancement of diversified technologies that will result from a continuing program.

   Canada can make significant contributions to Space Station technologies, and the opportunity to continue with international programs of this nature provides the only means for a country such as Canada to enjoy the future benefits. It is essential then, that steps be taken to ensure continued participation in international space technology programs.

8. Although our survey did not uncover a great deal of activity in medical/biological space research, what we did learn demonstrated that the work is of very high quality and is being pursued vigorously. Several scientists are already working with NASA and have plans to use Shuttle. There is great interest in the unique opportunities offered by micro-gravity, not only for what may be discovered that will reduce the medical risks associated with space living, but also for what may be learned that will aid medical practice on earth.

   With this base of competence, there is a good chance that Canadian medical and biological scientists working in this field will be able to make significant contributions to knowledge through participation in Space Station. This is a specialty that should be encouraged. It has been stated earlier in this report that we do not claim that our survey has been exhaustive; this is an area where further probing may be necessary to determine the full extent of Canadian capability.

9. The proposal from TV Ontario needs to be encouraged through whatever mechanisms Canada establishes to further its efforts on Space Station.

10. There is sufficient interest and capability to warrant a continuing program to prepare for the eventual use of a Space Station. The competence revealed by those with specific projects or interest in one or more of the seven project groupings identified leads to the conclusion that a significant involvement in Space Station would be technologically successful, and would benefit Canada.

11. The only significant funding available for Space Station related activities will probably come from the public sector (with the possible exception of TV Ontario, which could be financially self-supporting through the sales of film footage).

12. The bringing together of these disparate interests will require national leadership and continual effort on the part of the responsible agencies.

13. The estimation of quantitative benefits and the establishment of social impact must be an important component of an ongoing program on Space Station.

14. The opportunities envisaged today represent only a snapshot in an evolving Canadian social and economic scene. Since the Space Station is in the order of a decade away, projects may come into view that are not foreseeable today, further emphasizing the need for continual updating of user needs.

15. The expertise identified in the study is spread across Canada from coast to coast. Opportunities exist to involve all regions of Canada.

16. The concept of Space Station is not sufficiently advanced to permit identification of detailed user specifications.

4.2 Recommendations

1. A program should be established allowing Canada to retain the option of full participation in Space Station.

2. The principal goals of this program should be:

   a) development of technologies required for construction, operation, servicing and use of Space Station.

   b) to move toward an unmanned (but visited) Canadian platform as part of Space Station.

3. The National Research Council of Canada should establish Associate Committees in the following subject areas:

   a) Materials processing and investigation in space;

   b) Medical/biological investigations in space.

4. The Canada Centre for Space Science should assume responsibility for coordination of science activities involving Space Station.

5. The departments of Communications and Energy, Mines and Resources should be encouraged to take similar action, and as a minimum each should designate one centre responsible for maintaining the national interest in their particular subject area.

6. The granting councils should be encouraged to participate in developing Canadian readiness for participation in Space Station.

7. The Canadian Council for the Arts should be kept informed of the status of the program and encouraged to take on a role similar to that of an Associate Committee.

8. The National Research Council of Canada should take overall responsibility for Canadian interests in Space Station and should formally designate a leader who can speak for a national program.

9. Funding should be made available now to initiate preparatory programs and studies that will allow Canada to take full advantage of the opportunities that will arise through participation in Space Station.

10. A process should be established that will permit an on-going assessment of Canadian readiness to participate in Space Station, and the benefits to be derived therefrom.

APPENDIX 1

SPACE STATION REQUIREMENTS STUDY

APPENDIX 1

SPACE STATION REQUIREMENTS STUDY

1.0 Statement of Work

The following defines the tasks to be performed in the proposed study.

1.1 Canadian Space Station Requirements

(a) Conduct a survey of Federal, Provincial, Industrial and Educational departments/ institutions to determine the major potential Canadian users of a low earth orbit space station and the potential benefits accruing to Canada as a result of participation in the international program.

The survey will include, but may not be limited to uses in four areas:

i) Manufacturing, including bio-technology

ii) Scientific use as a micro/zero gravity platform

iii) Observatory for space-based sensors for monitoring and control of earth resources, man-made or astronomy

iv) Surveillance, pertaining to resource management and sovereignty.

It will also provide:

i) A listing of space station requirements resulting from the potential Canadian uses

ii) A listing of existing sensors and those that have potential for development to meet Canadian needs.

iii) The requirements to be met by Canadian sensors where developed or where new sensors are needed.

The identified benefits will include both direct financial and/or qualitative, and be presented against an annual base. In assessing the benefits, the expected growth of the space station beyond LEO applications will be considered.

1.2 Methodology

The first step will be to establish, based on the current space station capabilities a framework within which the information will be gathered. This will be followed by personal interviews. The information obtained will be collated and presented in a form that will permit broad priorities to be set. It should also serve as a framework to allow updating as the programs develop during the coming decade.

The survey will identify:

i) Who are potential users

ii) Their present activity in the subject area including level of effort

iii) Their projected needs and time scale

iv) A listing of existing sensors and those that have potential for development.

v) Requirements to be met by sensors

vi) Space station requirements to meet Canadian needs

vii) The expected benefits to users

viii) Opportunities and benefits for Canadian industry.

1.3 Tasks

The following tasks will be undertaken:

i) Review reports on recent surveys of the remote sensing community, particularly those completed by Bercha Associates and D. Clough. It is assumed that these will be made available by the Federal government (CCRS).

ii) Survey and report on Canadian based organizations that produce space-based sensors.

iii) Survey and report on major Canadian based companies operating in the metallurgical and bio-technological field that may foresee opportunities for novel or improved processes.

iv) Through the National Research Council of Canada and the Natural Sciences and Engineering Research Council, identify potential scientific users. Interviews will be held, the results collated and a report prepared.

v) Working through the Canadian Advisory Committee on Remote Sensing, its associated Working Groups, and provincial agencies supporting the Canadian Council of Resource and Environmental Ministers, identify major users (and potential users). Such identification to be followed by interview. The results of these interviews will be collated and a report prepared.

vi) With the support of the National Research Council of Canada, establish a working group comprising representatives of federal departments and agencies to obtain federal requirements. Canadian Defence requirements will be polled through the ICS representative. These will be included in the final report.

vii) A one day structured seminar will be held toward the end of the contract, to provide the federal working group with an opportunity to comment on findings to that date.

viii) Prepare a benefit assessment.

(b) Determine the potential financial benefits from investment through technology development.

(c) Prepare interim and final reports.

PROJECT STUDY GROUP

The project team assembled by Philip A. Lapp Ltd. to carry out the study is listed below with their affiliations.

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6.ABDA Ltd. Mr. A.D.Gagnon
7.Can. Sat.Comms.IncMr. H.J.Underhill
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40.Panarctic Ltd. Mr. G.Hood/Mr.Martin van Ipere
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42.Intera Env.Ltd. Mr. B.L.Pollock
43.BED Systems Mr. A.Curran
44.ECO-TEC Instrum. Mr. W.Brooks
45.Philom Bios Inc. Dr. George Khachatourians
46.Boeing of Can.LtdMr. E. Murray Sloane
47.Bristol Aero. Mr. B.Weibe
48.Dow Chem.Can.Ltd.Dr. Mike Baldwin
49.Fleet Industries Mr. R.K.Fraser
50.Raytheon Can.Ltd.Mr. J.H.Stewart
51.OVAAC Mr. E.Miller
52.Northern Telecom Dr. D.A.Chisholm
53.TV Ontario Mr. Wally Longul
54.Ontario Hydro Mr. Fred J.Kee
55.Warner/Lamb/P.D. Dr. Jennifer M.Sturgess
56.Abitibi Price Mr. K.Thomas Neill
57.Barringer Res. Dr. Richard D.Clews
58.CGE Dr. P.E.Pashler
59.Cominco Dr. Charles P.Lewis *
60.Connaught Res.In.Dr. W.Cochrane
61.Div.Res.Labs Mr. R.Edamura
62.Falcon.Met.Labs Mr. R.A.Bergman
63.Allelix Inc. Dr. Derek Burke
64.Opto El.Ltd. Dr. S.R.Garside
65.ORF Dr. W.R.Stadelman
66.Bayly Eng. Mr. T.H.Walther
67.Chromalox Mr. C.R.Hollaman
68.High Vac.Sys. Mr. F.Ladd
69.MA Elect. Mr. F.Mercer
70.Moniteq Mr. D.A.Whiteman
71.Optech Inc. Dr. A.J.Carswell
72.Sinclair Rad. Mr. R.W.Weir
73.Varian Mr. Connell Smith
74.N-B Mr. R.Marcelle
75.CN-CP Mr. Charlie Webster
76.Digital Tele.Ltc Dr. Colin Batin
77.DSMA Mr. Lloyd Secord
78.CAL Mr. J.Taylor
79.CAE Mr. Ken Hansell
80.ITRES Res. Ltd. Dr. C.D.Anger
81.Remotec Appl.Ltd.Dr. S.Parashar

* linked with 77

University Interviews

1.Queen's Met.Eng	Dr. R.W.Smith
2.McGill Physiology	Dr. G.Melville Jones
3.McGill Physiology	Dr. D.G.D.Watt
4.Inst.Armand Frapp.	Dr. V.Pavilanis
5.Mtl.Gen.Hospital	Dr. Harry Goldsmith
6.UNB,Inst for Phgmt	Mr. Angus Hamilton
6bUNB	Mr. David Wells
7.C-CGR	Mr. Harold Snyder
8.UBC Geoph.&Astron	Dr. GordonA.Walker
9.UBC Met.Eng.	Dr. F.Weinberg
10.UBC Path & Chem	Dr. D.E.Brooks
11.UBC R.S. Council	Dr. Peter Murtha
12.UofC Physics	Dr. Venkatesan et al
13.UofSask IASPhys	Dr. D.McEwen
14.UofWind Eng.	Dr. W.V.Youdelis
15.UWO Physics	Dr. P.Forsyth/Dr. D.R.Morcroft
16.UofT Elect. Eng	Dr. K.Balmain
17.UofT Elect. Eng	Dr. Alan Yen
18.UofT Met.Mat.Sci.	Dr. J.W.Rutter
19aUofT Inst.Aero St	Dr. R.Tennyson
19bUofT Inst.Aero St	Dr. P.Hughes
20.UofOttawa-OGH	Dr. Uhthoff
21.York CRESS	Dr. Ralph Nicholls
21aYork "	Dr. Frank Bunn
21bYork "	Dr. J.Lamframbois
21cYork "	Dr. J.Miller
21dYork "	Dr. J.McConnell
21eYork "	Dr. R.Kohler
21gYork "	Dr. A.Carswell
21iYork "	Dr. G.Shepherd
22.UBC ME	Dr. Modi
23.Tech.U NS	Dr. N.R.Ymenidjian
24.McGill H-K Lab.	Dr. Milic-Emili
25.UofT Astronomy	Dr. E.R.Seaquist

Government Interviews

1.NRCC Dr. Keith Glegg
2.NRCC Mr. Ken Pulfer
3.NRCC Dr. I.B.McDiarmid
4.NRCC Dr. Fred Lipsett
5.NRCC Dr. D.M.Wiles
6.NRCC Dr. J.L.Locke
7.NRCC Dr. P.A.Redhead
8.NRCC Dr. C.T.Bishop
9.NRCC Dr. A.J.Alcock
10.NRCC Dr. G.Atkinson
11.NRCC Dr. J.P.Hobson
12.NRCC Mr. E.H.Dudgeon
13.NRCC Dr. K.H.Doetsch
14.NRCC Dr. G.L.Bata
15.MOSST Dr. Mac Evans
16.SCC Mr. J.Miedzinski
17.NSERC Ms. Janet Halliwall
18.CCRS Mr. Lee Godby
19.CCRS Dr. E.Shaw
20.CANMET Dr. Dennis White
21.DOE Dr. Jim Patterson
22.AECB Mr. Ian Fraser
23.DOE Dr. J.Harrington et al
24.DOE Mr. J.P.Bruce
25.DOC Mr. Gourd
26.DOC Mr. Ken Hepburn
27.DOC Dr. J.Chambers
28.DOC Dr. B.Blevis
29.DOC Dr. C.Franklin
30.DOC Dr. R.Warren-RADARSAT
31.DOC Mr. Sam Altman
32.DOC Dr. Andy Molozzi
33.DOC Dr. R.Barrington
34.F&O Mr. E.R.Edel
35.AC Dr. R.Halstead et al
36.MRC Dr. J.Roxburgh
37.H&W Mr. Allister Thompson
38.H&W Dr. R.A.Heacock
39.H&W Dr. E.Somers
40.EA Miss Anne Pollock
41.TC Mr. Boris Borodchak
42.EIO Dr. Clive Mason
43.NSLSI Dr. John Wightman
47.IOS Dr. Jim Gower
48.BC F.S.Mr. Frank Hegyi
49.P/C Mr. Ken Croasdale
50.P/CR&D Mr. G.Derbowka
51.ARC Mr. Peter Williams
52.DoE/AltMr. Cal Bricker
53.PRL Dr. Fred Constabel
54.NR/Man.Mr. W.G.Best
55.DCIEM Dr. R.Heggie
56.DCRS Dr. Victor Zsilinsky
57.AES Dr. G.Morrisey/S.Peteherych
58.AES Dr. W.Evans
59.AES Dr. W.Godsen
60.AES Mr. D.Champ
61.DND Mr. John Collins et al
62.NRC EEDMr. Robin C.Black
63.EMR S&MMr. Ray E.Moore

APPENDIX 3

BACKGROUND PAPERS

PARTICIPANTS IN DISCUSSION SEMINARS

Attendees at Toronto Seminar

Dr. Ralph Nicholls	York University
Dr. J. W. Rutter	University of Toronto
Dr. Arthur Porter	Arthur Porter and Associates
Dr. G. Morrisey	Atmospheric Environment Service
Dr. L. W. Morley	Teledetection International
Mr. Jim Middleton	Spar Aerospace Limited
Dr. Philip A. Lapp	Philip A. Lapp Ltd.
Dr. J. D. Keys	Philip A. Lapp Ltd.

Attendees at Ottawa Seminar

Dr. B. Blevis	Communications Canada
Dr. R. Kriegler	Bell Northern Research
Mr. T. Paine	Transport Canada
Mr. J. M. Belcher	Transport Canada
Dr. K. H. Doetsch	National Research Council of Canada
Dr. I. B. McDiarmid	National Research Council of Canada
Mr. L. Godby	Energy Mines and Resources Canada
Dr. W. G. Schneider	Consultant
Dr. L. W. Morley	Teledetection International
Mr. R. M. Freedman	Philip A. Lapp Ltd.

SPACE STATION PROJECT

SPACE STATION PROJECT

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

1.0 INTRODUCTION

NASA is investigating the feasibility of a low earth orbiting space station for the 1990's. Other nations with space capabilities, including Canada, have been invited to make proposals for participation. Canada, through the National Research Council, has been asked to decide, early in 1983, whether or not she wishes to participate, and if so, how.

Whether to be manned or unmanned and whether the orbit is to be near equatorial or polar are matters which will be decided after the input from potential users has been received. In any event, it will be assembled in space, using the Shuttle for supply, and it will be designed for periodic Shuttle dockings.

Within the next few months, the international technology and user teams to plan the configuration and missions, will be appointed. If Canada wishes to take advantage of this opportunity, she must make viable proposals.

Two preliminary meetings, attended by a few potential Canadian users, were held in order to solicit an initial reaction. Some of their ideas are reflected in the "Applications" portion of this paper.

In December 1982, January and early February 1983, NRCC contractors will be interviewing a cross-section of Canadian engineers and scientists from governments, universities and industry, in order to receive specific suggestions as to what Space Station Applications Canada might propose. You will be contacted shortly by the contractor. This paper is intended as a starting point for discussion.

2.0 SPACE STATION CONCEPT

2.1 Background

A Space Station program could stimulate a wide range of social and economic development for Canada as we advance into the 21st century. Canada should experience an even greater surge of technological growth than witnessed in the recent past.

The potential for this future economic growth is directly linked to the vastness of Canada's natural resources. But the realization of this potential is dependent upon how Canada faces the challenges of the future. One of these challenges is the expansion of man's role in space and the establishment of a permanent presence there.

The Space Station is a concept which includes establishment of both manned and unmanned facilities in space and their interconnection through specialized transfer vehicles - all dependent upon the Shuttle for access to and from the earth.

The elements of a Space Station program are linked to the management and planning of science and technology, communications, and resources from which emerge user needs for the Space Station. These needs are translated into requirements for architecture and configuration of the Space Station. From this will stem the resources, communication, science and technology requirements to establish the capabilities for the Space Station. Figure 1 shows the elements of a space infrastructure.

The development of advanced technologies as a result of the Space Station program will be across many disciplines and would permit commercial utilization of space for development and then manufacture of commercial products.

The Space Station program represents a space-related venture involving both NASA and industry with potential products/processes having a commercial value to industry. Based on a growing awareness of the characteristics and value of the

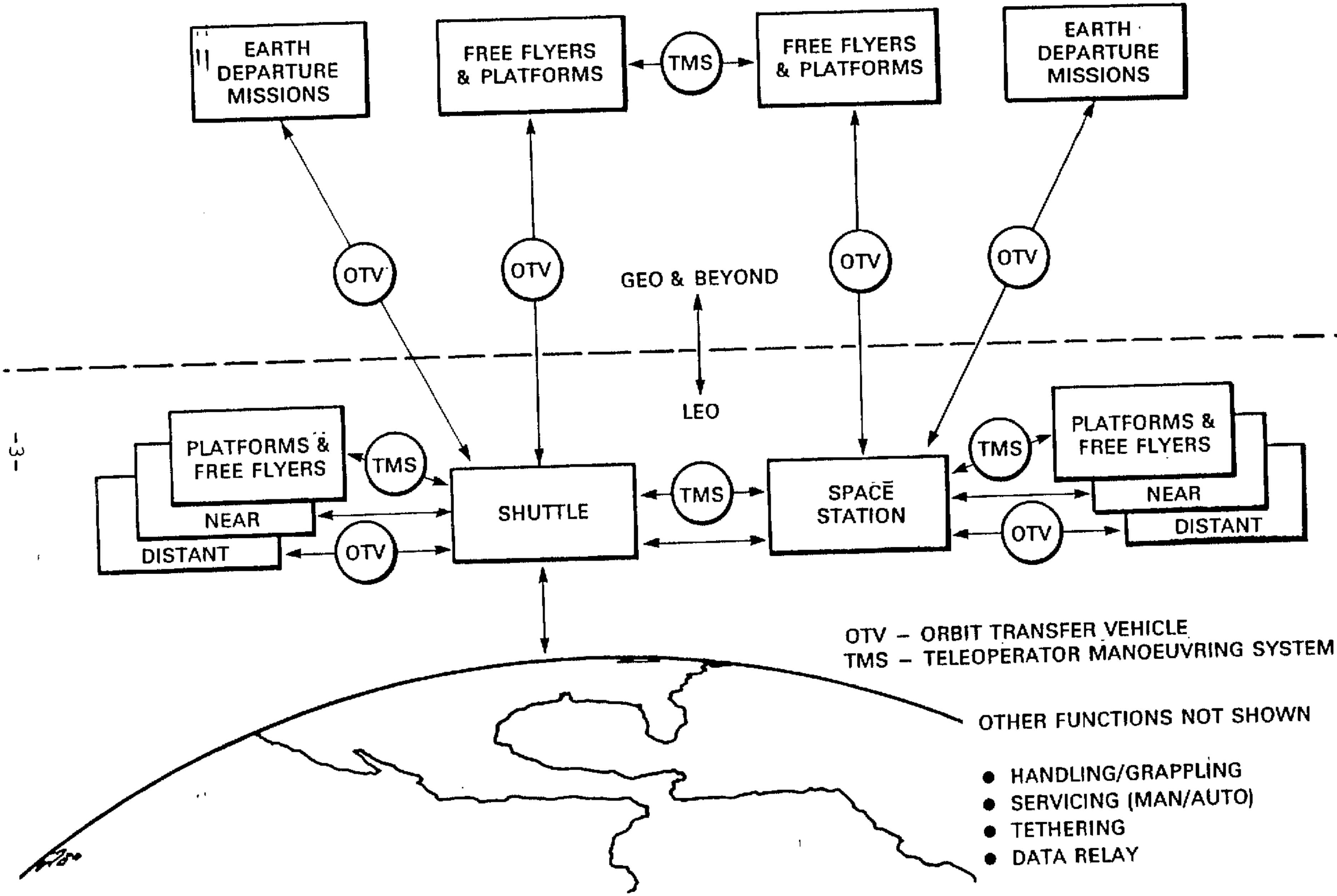

FIGURE 1 ELEMENTS OF SPACE INFRASTRUCTURE

space environment, industry will be able to assess risk versus return and the likelihood of financial success. The policy of this joint endeavour is to reduce industry's financial exposure and risk associated with technological performance, R&D costs, and markets, thereby making it possible for industry to enter into this "partnership" in a cost-effective manner.

Some possible benefits realized by this arrangement are:

(a) the exchange of technical information and cooperation in the conduct and analysis of ground-based research,

(b) corporate scientific representative collaboration with NASA involving information on space flight experiments,

(c) legal agreements having commercial product/process as end objectives.

Thus far, NASA has made agreements in each of these areas for various activities, such as, biological materials processing/research, crystal growth, materials processing research/services and hardware development for space-related activities.

The Space Station program will be developed gradually to cost-effectively support early, long-duration missions (manned or unmanned) with flexibility for modular growth into more complex missions. An early manned platform would have payloads similar to those slated for the Spacelab. With more developed capabilities, major operations such as large structure assembly, orbital transfer vehicle basing and spacecraft servicing will be possible.

Payloads that fly remotely from a Space Station because they are highly automated, such as, high-accuracy pointing for astronomy, very low G materials production, and repetitive terrestrial coverage, require periodic tendering, modification or servicing by station-based teleoperators or are brought back to the station for major servicing. Such payloads operate more efficiently with only periodic manned involvement.

The Space Station would be used as a laboratory as well as an operations base. In the case of a laboratory, long term observations of the land and sea for scientific, commercial or defense purposes is provided. Crew members would be available for data integration, equipment operation and adjustment, and system maintenance. As an operations base, orbitally based propulsive stages could be fueled and launched to place satellites in geosynchronous orbit or to manoeuvre in low Earth orbit. For structures too large for launching directly from the ground, the Station could serve as a construction base for assembling and erecting large systems such as antennas or imaging systems. Also, the Space Station could maintain and service free-flying, unmanned satellites.

An area of commercial Space Station utilization is in remote sensing. Detection of geological minerals, petroleum, or monitoring crop development, water resources, and timber are all possible through earth observations. A manned Space Station will provide opportunities to increase the effectiveness of these remote sensing systems and pave the way for future resource management.

2.2 Architecture and Technology

NASA's current planning centers on the Space Station as a laboratory and an operations base, and is considering requirements and architecture rather than specific configurations. The agency is examining constraints, systems interdependencies, growth alternatives, and limitations of flexibility in this early stage of planning.

Consider NASA's concept of a Space Station architecture as shown in Figure 2: A manned base in orbit with several manned laboratories, facilities, or platforms dedicated to scientific, applications, commercial or national security missions. The Shuttle would deliver platforms to orbit and retrieve them when necessary. The manned base, or station, consists of a docking hub, a power/utility module and a habitat. A Teleoperator Manoeuvring System (TMS) is used to

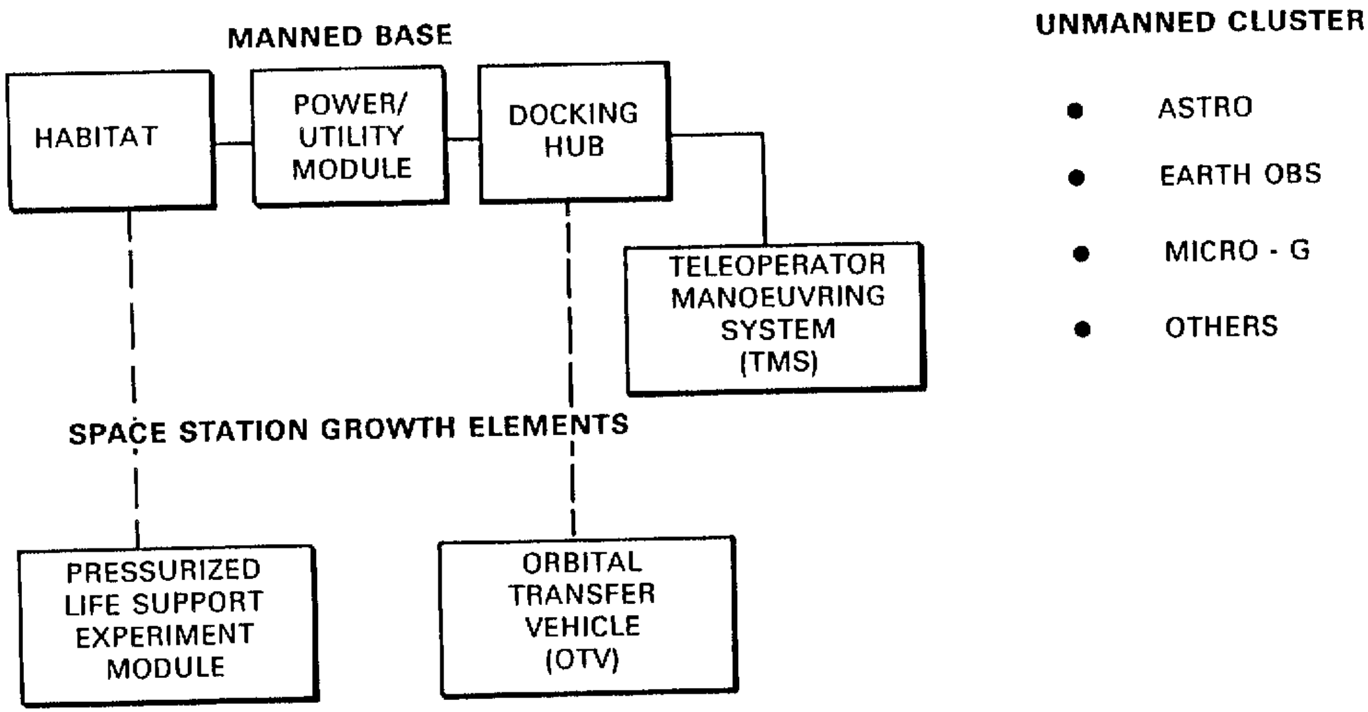

FIGURE 2 POSSIBLE SPACE STATION ARCHITECTURE (NASA)

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service the platforms. Manned laboratories could be transported to the station by the Shuttle and become integrated with the station and returned to Earth, at the end of their intended missions, for later use.

2.3 Space Platform

An unmanned, free-flying Space Platform that could accommodate numerous scientific and applications payloads as shown in Figure 3.

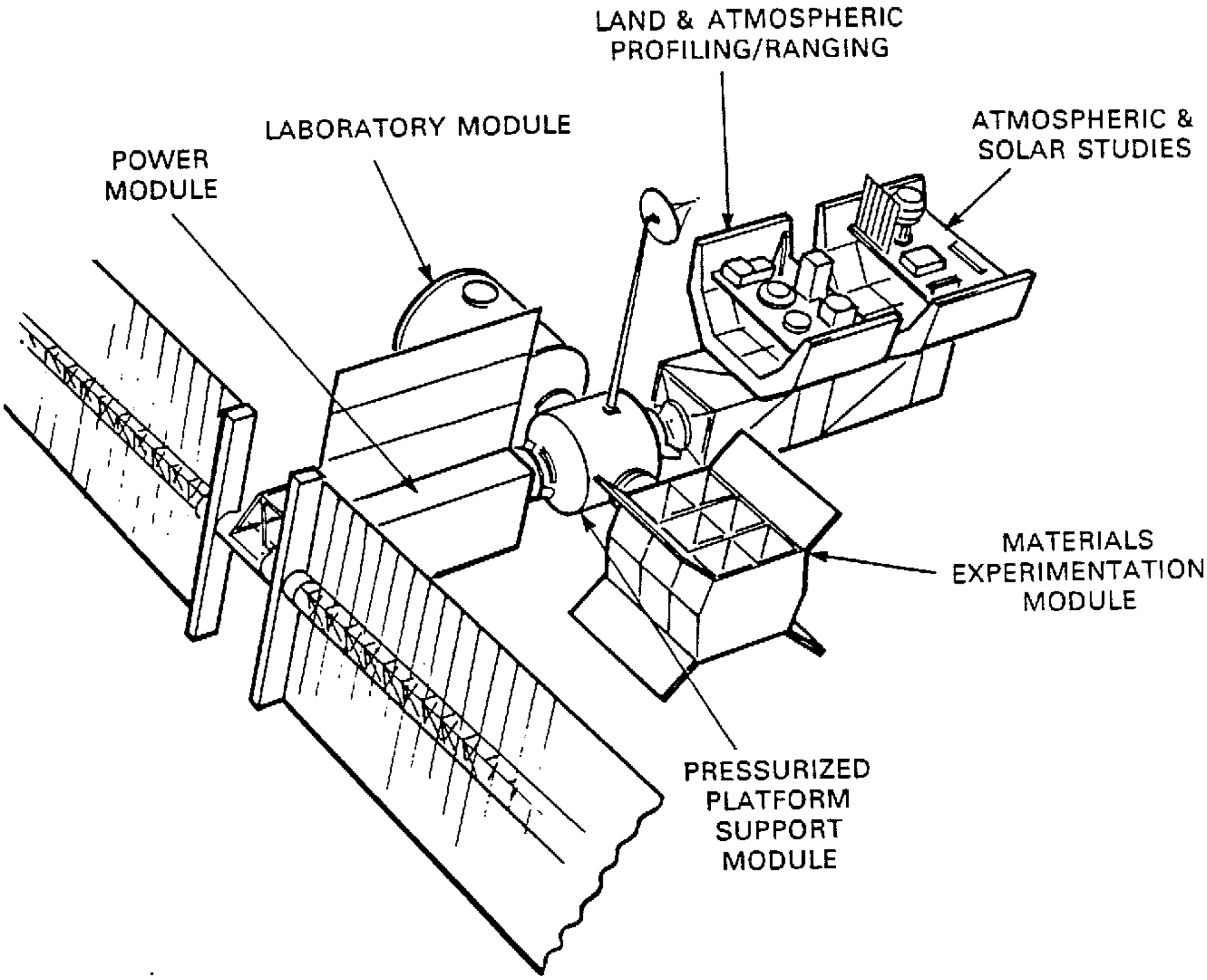
This option provides long-term missions required for many scientific observations and provides high power levels needed for materials processing on a commercial operational level. Adding manned modules to the Space Platform provides an additional degree of autonomy.

2.4 Space Station

The Space Station is expected to begin with a small crew, and eventually evolve into a crew of a dozen or more. Initially, scientist/astronauts will be trained to conduct mission and payload tasks. User payload specialists will later be involved in on-orbit science and applications research, material processing and other activities.

Modular design, delivery and assembly involving the use of the Shuttle provides flexibility in meeting a variety of user needs. Figure 4 shows a typical evolution of station configuration and capabilities.

In the initial phase, laboratory facilities are allocated for a variety of application and commercial payloads, while in the full operational phase facilities grow to meet user needs for dedicated facilities, Orbit Transfer Vehicle (OTV) basing and manned Geosynchronous Earth Orbit (GEO) payload operations.



ONE OF SEVERAL SPACE STATION CONCEPTS, THIS SCIENCE AND APPLICATIONS SPACE PLATFORM WAS DRAWN BY GENERAL DYNAMICS FOR NASA'S CURRENT STUDY ON SPACE STATION NEEDS, ATTRIBUTES AND ARCHITECTURE OPTIONS.

FIGURE 3 SPACE PLATFORM ACCOMMODATING SEVERAL USER NEEDS

The initial phase will place a Space Station in a low-altitude orbit (typically between 250 and 470 km), with inclination in the range of 28.5 to 57 degrees depending on user requirements. Lower inclination orbit allows the full shuttle payload delivery (approximately 29,500 kg) and provides good placement for launching payloads and OTV's to GEO.

Orbits having higher inclination such as polar orbits provide greater earth viewing potential, although payload delivery capability is significantly reduced.

Only raw materials, manufactured products, and periodic replacement of equipment need be transported and not an entire facility if equipped modules are transferred to orbit and remain with the Space Station for long periods. Long term attachment of modules to the Space Station can significantly decrease mass transfer to and from orbit for a given laboratory or manufacturing facility.

2.5 Orbit Transfer Vehicles

Initially, most autonomous spacecraft launched to Low Earth Orbit (LEO) will operate at GEO and transferred from LEO via a transfer ellipse using propulsive stages or placed in GEO by the Inertial Upper Stage (IUS).

Later, orbit-to-orbit transfer will be performed using high-energy propulsive stages for larger or multiple payloads. At the start, the OTV and its payloads will be placed in LEO without the use of the Space Station. Eventually the Space Station will be available for use as a launching base for GEO payloads thus allowing larger spacecraft to be assembled, checked out in LEO, and then transferred to GEO using a station-based OTV.

2.6 Teleoperator Manoeuvering System (TMS)

The TMS is a remotely controlled reuseable propulsive stage capable of performing spacecraft and payload placement, retrieval, assembly or servicing support for large space systems. In addition to the initial functional capabilities of placement and retrieval the TMS is adaptable to a variety of applications. These include satellite viewing, debris capture, cryogen servicing, materials processing, and advanced space observatory servicing.

The TMS can be space-based at the Space Platform for refuelling and battery charge for continuing operations. Space-basing allows fast response for exploratory inspection, debris control, and contingency use, such as rescue missions. A major use of the TMS is support of Space Platform or Space Station assembly, such as, bringing a structural module to the platform for installation by an on-board remote manipulator system (RMS). After hand-off to the RMS, the TMS aids in the assembly and is used to observe and inspect overall operations. Under remote control the TMS is manoeuvred for strategic viewing and other exploratory data which is transmitted real-time to a control station.

2.7 Support Facilities

Support elements include launch complexes and Shuttle and cargo ground processing facilities at Kennedy Space Centre (KSC) and Vandenberg Air Force Base (VAFB), and the communications and data-handling network. The Tracking and Data Relay Satellite System (TDRSS) will provide near-continuous, real-time communications links between the Space Station and users on the ground and will enable data transfer to the earth at rates of 50 kbps continuously and up to 300 kbps for a single access channel. Other terrestrial and satellite links will tie in to ground control and data analysis stations internationally.

2.8 Typical Space Station Designs

A typical design is illustrated in Figure 4, showing habitability or command modules with multiple docking ports which allow connection to produce three dimensional architectures and path redundancy, and allows synthesis of numerous module shapes from a few structural elements.

First order Space Stations having this new technology might consist of a command module, a habitat or experiment module, a support systems module, and a module for docking and tending space platforms. Docking ports allow growth in three dimensions and provide alternate astronaut paths.

A completely operational Space Station could be developed readily from the Space Station illustrated in Figure 4, which one might recognize as in a recent study of a Space Operations Center (SOC). Addition of other components and modules results in the configuration and architecture shown in Figure 5. Complete redundancy is attained with this configuration: dual command modules, dual elements of the power system and support elements, dual habitat enclosures and modules, redundant logistics modules, and several logistics ports. Upper stages can be assembled, mated and checked out together with payloads, and a hangar is shown for housing orbit transfer vehicles and other items. Additional modules for space operations can be added and supported, whether large structure assembly modules or specialized servicing modules for holding platforms or other elements of the Space Station.

2.9 New Technologies for Space Stations

For a space station to grow in capability, it must encompass new technology. Examples of these technologies are shown in Table 1. For example, providing closed-loop water and air systems, in a closed environmental system provides longer times between resupply and less mass transfer. Extensive use of manipulators and automation to aid operators in remote and/or routine functions allows more time to concentrate on tasks requiring personal judgement, extreme precision or contingencies.

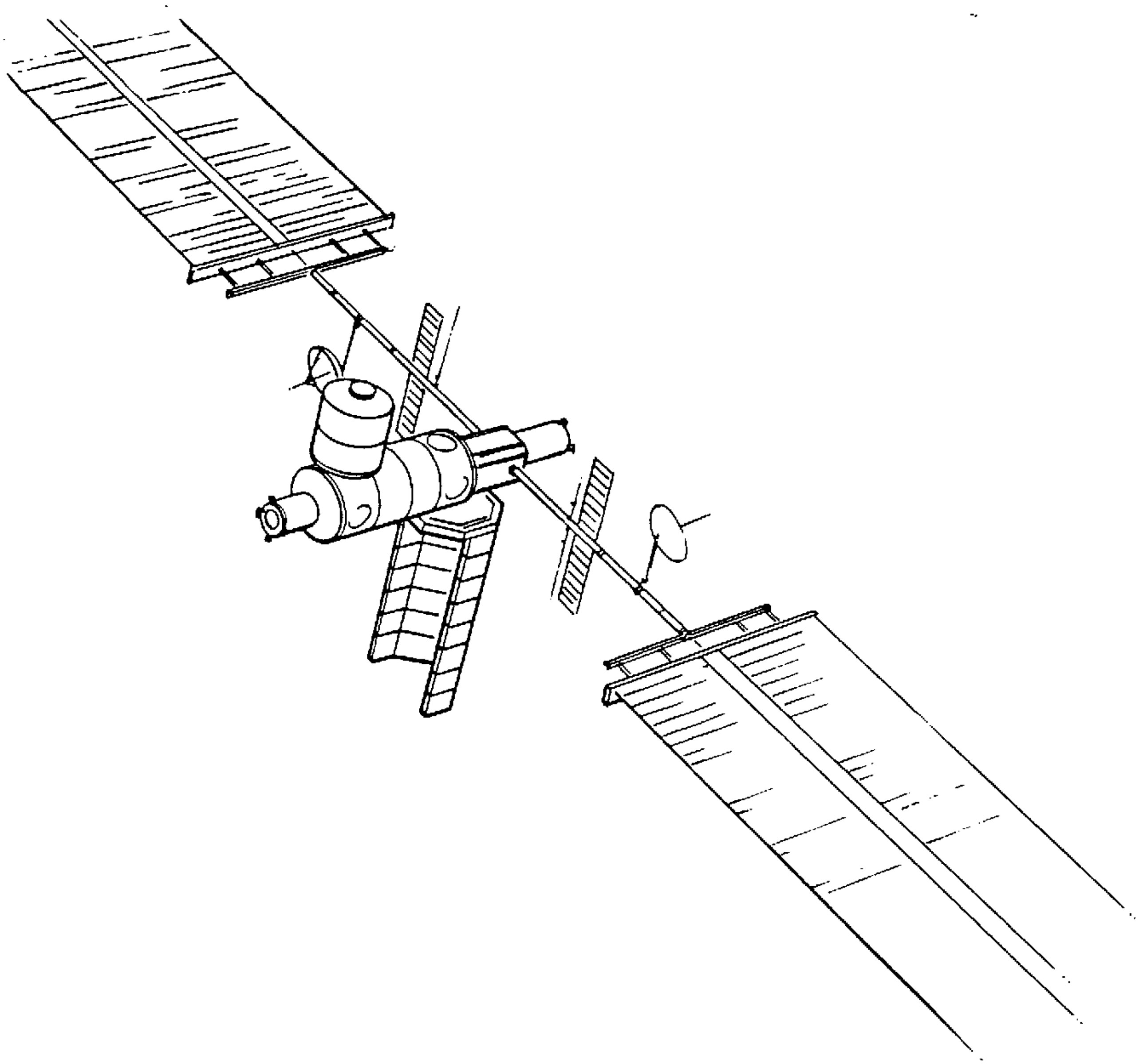


FIGURE 4 INITIAL PHASE SPACE STATION

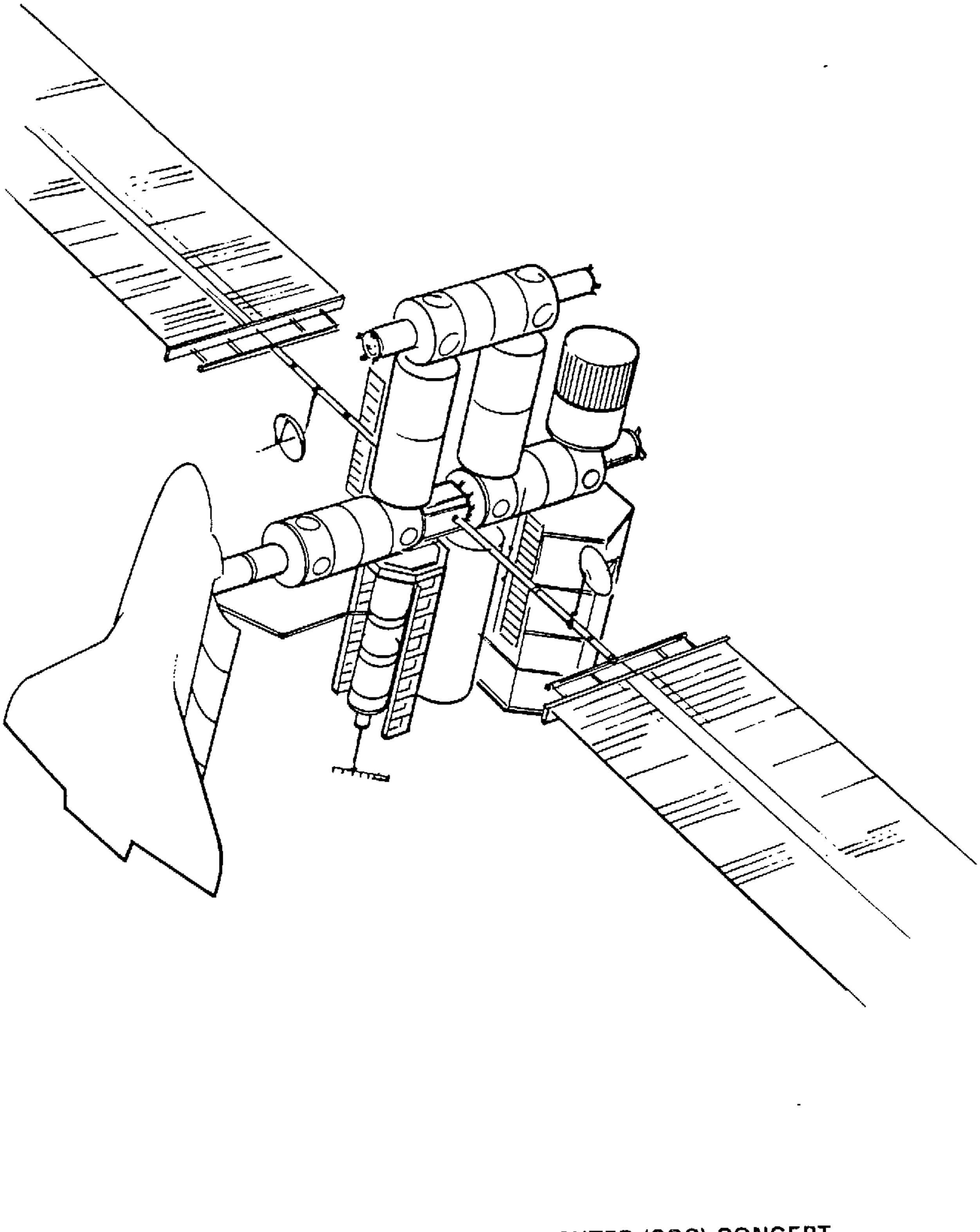


FIGURE 5 SPACE OPERATIONS CENTER (SOC) CONCEPT

2.10 Technology Development

Current planning for science and applications requirements for the Space Station are in the areas of life sciences, astrophysics, environmental sciences, earth and planetary exploration, materials processing and spacelab evolution. This planning involves reviews by NASA, the Space Science Board (SSB), the Space Application Board (SAB) and inputs from the scientific community. From these reviews came recommendations and integration of all scientific inputs to identify science and applications requirements.

The SAB is tasked to determine generic technical requirements for consideration in conceptual design of Space Stations or Platforms to maximize the utility of practical applications. One significant recommendation of the SAB system design panel is emphasis on the improvement of capabilities and technology of man in space with careful tradeoffs between telepresence and physical presence.

NASA is also involved in an experimental project to create technical development (TD) missions aimed at advancing space technology through support of the Space Station. The scope of these missions are quite broad, with value for science, applications, commercial uses, national defense and enhancing NASA's capabilities and role in space. In general, TD mission requirements will influence the design of the Space Station that will support them. Technology development (generic, flight mission-supporting or operations categories) and science (physics, chemistry, other experiments in space) missions may be required in support of the Office of Aeronautics and Space Technology (OAST) or Space Station disciplines and working areas. These are shown in Figure 6.

TABLE 1

NEW AND IMPROVED TECHNOLOGIES FOR SPACE STATION

- Closed-Cycle Life Support
- Cryogenic Fluid Storage and Transfer
- Unified Oxygenhydrogen Propulsion
- High Voltage AC Energy System
- Distributed Processing Architecture
- Adaptive Control of Evolving Configuration
- Remote Manipulation and Handling
- Others

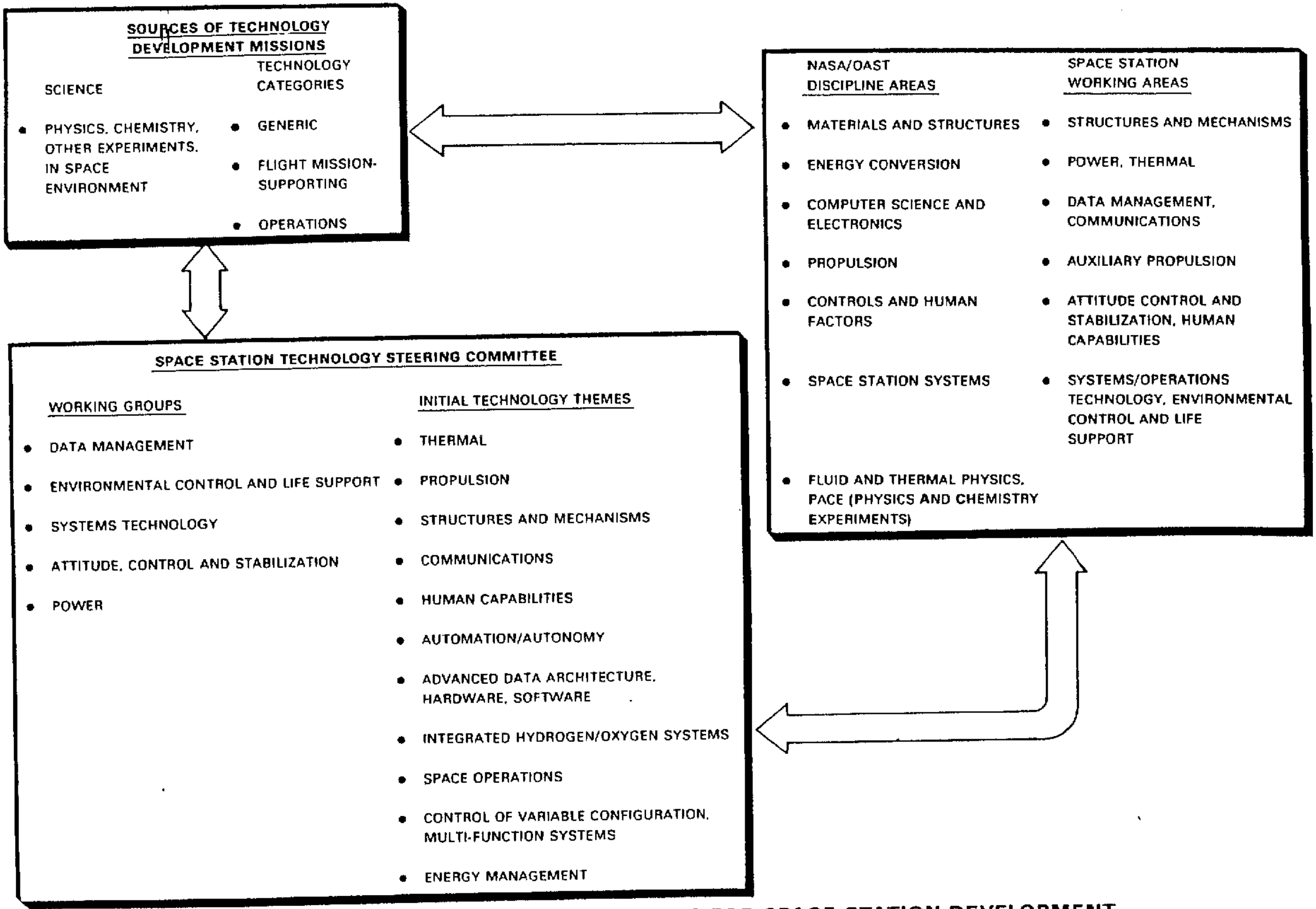


FIGURE 6 TECHNOLOGY CONSIDERATIONS FOR SPACE STATION DEVELOPMENT

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3.0 APPLICATIONS OF SPACE STATION

3.1 Space Science

What opportunities would be provided by a low earth-orbiting Space Station? By the time this becomes a reality in the 1990's, Canadian scientists will have been productive in space science for more than 35 years in the following areas:

(a) Atmospheric Science,
(b) Solar Terrestrial Interactions,
(c) Solar Physics,
(d) Planetary Physics,
(e) Earth Science,
(f) Lunar Studies,
(g) Astronomy in Space,
(h) Space Telescope,
(i) Ultra-Violet Explorer,
(j) Star Lab.

Can you foresee any important experiments that would be served by Space Station as well as by rockets, balloons and satellites? Does the fact that a man could periodically revisit and attend the experiment offer any advantages? How important is long-duration for experiments you would like to plan? Are recovery or modification of the equipment important in these experiments?

Where would Canada like to be in Space Science ten years from now? Can we achieve these goals by pursuing present plans? While we can lay our plans, those of the major space powers, as they become revealed can, unfortunately, often push ours into obsolescence. In this case, however, we are being invited into a major NASA program right at the conceptual planning stage.

You are being asked, as a Canadian, who has, or might be engaged in space science whether or not this is an opportunity which should not be missed.

Only by consulting with a broad cross-section of Canadian space scientists and engineers, asking them, within their own area of expertise to project their thoughts into the future, can these questions be answered. Another question to ask yourself could be "would my international competitors in my field leave me badly behind if they had access to Space Station and I didn't?"

While it is an obvious strategy to build on strength, the possibility of using this opportunity to begin a new line of endeavour should not be ruled out. It is specific suggestions which will be sought by the interviewer when he comes and your ideas will be greatly appreciated.

3.2 Remote Sensing of Land and Sea

Through the LANDSAT program, there has been more than ten years of experimental and quasi-operational experience in land remote sensing. The present LANDSAT-4 satellite is considered to be operational and, together with its successors, will be supplying operational data to many users in most countries of the world. There is a promise of continuity of supply of data for the next ten years. The same goes for the French Satellite SPOT which is planned for launch in 1984.

While SEASAT was experimental and lasted only three months, operational and quasi-operational programs stemming from that program, such as the Canadian Radarsat and the Japanese MOS-1 and the European ERS-1 will be launched in the period 1986-1992.

Thus, any user needs for remote sensing of the land and sea proposed for the Space Station, should be beyond those expected to be met by the above satellites.

In spite of the plethora of data expected to be supplied by the above programs, those engaged in remote sensing are very aware of the fact that there will be shortcomings. For example, while visible and I.R. sensing have been very successful, users complain that they cannot get frequent and timely enough data. Is there any way Space Station could assist in this problem?

While radar methods look promising, adequate power, the need for on-board processing, the use of various frequencies and look-angles, are still problems. How could Space Station be utilized to solve these?

In the area of new and experimental sensors, many new concepts cannot be adequately tested from aircraft. Space Station offers an opportunity for the quick evaluation of 'breadboard' sensors rather than having to wait for costly design and testing of space-hardened versions which can take many years to get approved, engineered and put into space.

Remote sensing satellites are put into near-polar orbits rather than equatorial orbits in order to provide more complete global coverage. The possibility of consigning this class of satellite to be co-orbiting with a Space Station which could then serve as a base for repairing and refurbishing, should be considered. The idea of getting all space powers in future to put their remote sensing satellites in co-orbit with Space Station and constructed for panel-replacement could go a long way to achieving international compatibility and complementarity of such satellites, in an otherwise very confused situation.

SEASAT failed after producing only three months of invaluable data, due to a relatively minor fault which could probably have been easily corrected in space. Similarly, the on-board tape recorders of the LANDSAT satellites that have lasted only a few months, might have been replaced in space. Your suggestions as to how Canada might profitably contribute to Space Station, in the field of remote sensing are earnestly sought.

3.3 Atmospheric Studies

Canada occupies a strategic location in respect of the phenomena that govern the world's weather patterns. Recognizing the responsibilities and opportunities that flow therefrom, Canada has built a competent, high quality weather service, a service that is world class in its field.

Facilities for pursuing atmospheric studies have burgeoned in recent years and the next major advance may be the opportunity to take advantage of the proposed Space Station. This will move us to involvement in space activities rather than only using data provided by others.

The possibility for Canada to join in such a program will depend upon the advantages that will accrue to Canadian programs. Our national weather service is one program that may profit from our participation.

The possibilities for use of a Space Station can be grouped into two broad categories - phenomena to be measured and the techniques for measurement.

Understanding the weather involves understanding the components of the system that, interacting together, determine the resulting patterns.

What measurements do we make now that could be better made from a manned or visited Space Station? Would such a platform enable us to make better mass movement observations, for example?

The system we seek to understand is world wide. Would a Space Station provide a better base for measurements of phenomena in the Southern Hemisphere?

We can now take measurements from many altitudes. Will a low earth orbit platform provide a level from which significant additional data can be obtained?

Assuming that a Space Station does become available, what new instruments will be required to make measurements? Will a low earth orbit impose restrictions or provide opportunities?

Are there any advantages to be gained in terms of simultaneous measurements from different platforms? Will accuracy be improved? Will the presence of a human add significantly to our ability to collect data?

What advantages might be gained from the ability to service measuring instruments in space? Could we take greater risks with more sophisticated instruments if we could recover and/or service them?

The opportunities will be there if we can see how to grasp them.

3.4 Communications

While it is recognized that most present-day communications uses of space involve geostationary orbits, low earth orbit may be of use to the communications technology community, to whom we address the following questions:

1. What particular or peculiar components, subsystems or system could be developed and tested using a Space Station in LEO?

2. Could large comsats be assembled in LEO before inserting into GEO, are there advantages?

3. Could GEO comsats be benefited by services provided by an OTV for refuelling, repairing and maintenance?

4. What communications experiments could be conducted from LEO eg. propagation, ionospheric and atmospheric phenomenon, etc?

5. Could a LEO Space Station or platform be used for space qualification of comsat hardware more effectively or efficiently than the use of present chamber techniques?

6. Could a PEO (Polar Earth Orbit) communications station be used effectively in the extreme north instead of current HF with its serious outages?

7. Could a LEO communications station be used as a relay station to GEO or other location for those locations on the earth that are permanently or temporarily shielded from GEO comsats (eg. during magnetic or ionospheric storms or sun spot periods; and in unconventional locations such as down a mine, in a missile silo or among tall buildings, on a train, in a plane, in an automobile, on a person's wrist, etc.)?

8. Could a LEO communications station be used in two-way communications where the time delay using GEO comsats if unacceptable?

3.5 Materials Studies

As a country with a strong mineral base, Canada has devoted considerable effort toward the effective utilization of these resources in the development of our manufacturing industry. In the process, a cadre of expertise has been built up, and significant contributions to the understanding of metals, alloys and semi-conductors have been made from Canadian laboratories.

The advent of space programs in recent years has provided a new and unusual laboratory for pursuit of these studies. Ten years ago, the first materials investigations were undertaken in space. These have been continued on successive space flights and we now may have an opportunity to take a major step forward in the quality of space laboratories with the proposed Space Station. If we are to participate in this program, we must identify areas where the unique features will enable us to make measurements that cannot be made on earth.

Microgravity has been used in the past and is available now - but for periods of limited duration. Space Station could provide vastly extended time frames, with either permanent manning or periodic visiting. In both cases, we could extend the range of our experiments well beyond what is now at hand.

Recognizing this opportunity, the National Research Council of Canada convened a special group to consider experiments that might be undertaken and the steps that should be followed to prepare for an eventual laboratory in a micro-gravity environment. The report of this group is a reflection of Canadian interests and competence, and comes after extensive similar considerations in the U.S. and elsewhere, particularly Germany. The Canadian group concluded that two areas will be important - materials processing and biological investigations.

Evidence already collected points to an opportunity to produce better quality crystals in a microgravity environment.

What experiments should we be contemplating to provide information that will allow us to understand the faceting phenomenum that has been observed?

How can we use the high temperature gradients that can be achieved?

Heat transfer properties are different; what studies should be undertaken that will lead to an understanding of the processes?

Canada produces some of the advanced semi-conductors; can we use the space environment to improve the quality of these materials? Some of these may be key components in future space applications; should they be subjected to extensive testing in that environment before they become standard?

Will the experiments that are now performed in the short period microgravity flights be significantly improved if a Space Station were used?

Are there experiments on diffusion, solidification, vapour transport that might provide new insights on the behaviour of materials?

In addition to the metals and semi-conductors, are there opportunities for research on plastics in microgravity?

Does microgravity provide features that are of particular interest in biological cell separation? Can purity be improved? Will efficiency be greater?

Can new substances for treating or preventing human diseases be fabricated?

Is the magnitude of the microgravity and/or the quality of the vacuum an important consideration?

Current Canadian thinking in respect of these subjects can be obtained by reading the report of the NRCC and Ad Hoc Committee on Microgravity, September 1982, entitled "New Opportunities in Space: Proposed Canadian Research in Microgravity".

3.6 Department of National Defence

While it is possible that there will be direct interaction between DND and DOD, and that there may be a necessity to conduct classified interviews with DND, the following questions are intended to open up discussion and provide a basis for discovering DND uses, if any, of the Space Stations.

(a) In terms of basic DND objectives, how could a Space Station (manned or unmanned) enhance current capabilities? For example, could it be beneficial in respect of the DND role in:

i) Surveillance and protection of sovereignty, territory and coastlines,
ii) NORAD,
iii) NATO,
iv) Peace keeping missions,
v) Defence of Canada,
vi) Civil defence,
vii) EMO.

(b) Does a Space Station offer advantages to any Canadian components of a Canada/US military role - say in advanced early warning?

(c) Is there a peace keeping roles to be played from a Space Station for a non-member nation such as Canada concerning arms control and surveillance including surveillance of other satellites or Space Stations?

(d) Is the space environment a valuable asset for the development of advanced military equipment?

(e) Are there basic defence materials that can be processed better in space, such as pharmaceuticals, biochemical or chemical materials, other strategic materials including exotic metals, semi-conductors, etc.?

(f) Can DCIEM's space medicine work make use of a Space Station?

(g) What large defence-related structures could be assembled in space?

(h) Does a high-powered, space-based Laser provide a useful tool for Canadian defence?

(i) Can the search and rescue role of DND be enhanced through the use of the space platform?

(j) Could military personnel in space improve our defence capability?

3.7 Navigation, Surveillance, Search and Rescue

Position fixing for a wide variety of earth applications can be enhanced using satellites such as TRANSIT and the GPS. The high-accuracy mode of GPS will not be available to non-military users, and the question arises, "can a Space Station with relatively unlimited power and weight compared to a satellite such as GPS, provide high position-fixing accuracy for a number of applications"? The following questions should be asked:

1. What type of position-fixing accuracies are possible using a Space Station without stringent weight, size and power restrictions? To whom would such a station be useful recognizing that at LEO, its frequency of availability is limited to periods of a few minutes every 100 or so minutes, without additional stations?

2. Does a Space Station, manned or unmanned, offer special advantages over more conventional satellites (such as the earlier Aerosat design) for air traffic control and vessel traffic management - particularly in respect of costs that must be borne by the users?

3. Can man be used in a Space Station to enhance or lessen the cost of position fixing - e.g. geodetic surveying?

4. What use can be made of a metric camera on board a Space Station for mapping purposes?

5. Can a space station be used for police, customs and immigration officials to lessen the cost and improve the effectiveness of patrolling Canada's borders?

6. Can a Space Station be used for police work in general?

7. Can search and rescue missions be performed better from a Space Station than from SARSAT? Can the station be of help in the actual rescue operation by assisting in locating the disabled craft during severe conditions or in difficult locations?

3.8 Social and Cultural Applications of Space Station

By its very nature, Space Station represents an important first step in humankind's colonization of outer space. To date, most space applications have been concerned with the technological, economic, scientific or military uses of space.

There is considerable interest in the possibilities of providing services from space. It is now felt, in addition, that some of the activities of Space Station should be concerned with matters of Cultural or Social significance.

In the developed economies of the western world, services represent a significant proportion of all economic activity. It is reasonable to speculate that, in time, the activities in which humankind engages in space, will mirror those which he conducts on earth. This opens up a wide range of potential service activities which could be based in space. Space broadcasting - perhaps a weekly 10-minute science-show is a strong possibility. The use of Space Station as a backdrop for fashion photography or a platform for cinematography can also be envisaged, at some future time. Ultimately, the use of space for the provision of services, could rival the traditional applications.

In connection with Canadian and international pronouncements on the peaceful uses of outer space, Canada may wish to pioneer the cultural and artistic potential of Space Station; both as an activity worthy of pursuit in its own right, and as a demonstration of the constructive uses of space. Humankind's cultural relationship with outer space stretches back over the millenia. It is natural that we should desire to extend our culture in space and through the medium of space. Should Canada send the first dancer into space (or poet, or artist)? Space may offer new opportunities for international cultural exchange which are not so circumscribed by varying levels of technological capability as conventional space activity. Cultural and artistic activities in space may also provide for the development of new technologies and industries here on earth (e.g. the "zero-G paintbrush").

Countries which gain the first experience of the artistic and cultural uses of outer space will be best situated to exploit related commercial opportunities.

Recreational opportunities for inhabitants of Space Station are also important considerations for alleviating boredom. There may be spinoffs for ground-based recreation (e.g. "pen pals in space").

Is there a near-term demand for space tourism? What about using Space Station to create fireworks displays on national holidays? What features should be built into Space Station to promote and enable cultural and artistic activities (A picture window? A television studio?)? Should the artistic community begin planning experiments for Space Station? Which art forms would be most amenable to space experimentation? Should Canada send a poet into space? Should Canada contribute to an international (United Nations) fund to finance other nations' cultural/artistic space activities?

How should Canada demonstrate leadership in this important field?

4.0 REFERENCES

1. Architectural Options for Space Station

   In Context of the Space Infrastructure, Ivan Bekey, Director, Advanced Planning, Office of Space Flight, NASA Headquarters.

2. Briefing materials from Mission Analysis Orientation Meeting, September 13, 1982, Space Station Task Force, NASA.

3. Manned Space Platforms, Payloads and Tending

   F.C. Runge, McDonnell Douglas Astronautics Co.

4. Teleoperator Maneuvering System

   J.R. Turner (P.J. French, W.E. Agan, Vought Corporation) Space Systems Group, NASA Marshall Space Flight Center.

APPENDIX 4

INTERVIEW GUIDE

Are you now participating in a space program? yes
no

If no, go to SECTION IIE

SECTION I PRESENT ACTIVITY

1. What is your present sector of activity?

primary industry (resources)
secondary industry (manufacturing)
consumer (retail)
university
public sector

2. What is your specific field of activity?

remote sensing
communications
manufacturing
traffic control, search and rescue
social uses, remote communities
technology
science

3. Do you provide - goods
services

What are your products, services, research projects. Please elaborate.

1. Space robotics
2. Attitude control systems
3. Propulsion systems
4. Solar arrays
5. Space structures
6. Thermal systems
7. Microelectronics
8. Communications
9. Image Analysis
10. Earth Stations and Systems
11. Space Sensors
12. Space Mechanisms
13. Other - please specify

4. Are you an (end) user of space services? yes
no

5. Other information

SECTION II

This section has five subsections, each corresponding to a respondent category. Fill in the appropriate subsection.

Subsection A - active companies
B - active public sector
C - active end users
D - active university users
E - others

SECTION II A Active Companies

6. Is your organization planning for the next phase of space activity which is the space station? Please elaborate.

7. Within your industry worldwide are you aware of any space station activities? Please elaborate.

8. Are you now manufacturing any products (delivering any services) which may find a market in a space station system?

a) For the station itself

b) For associated systems

c) Could you suggest a probable timescale? 0-5, 5-10, 10-15, 15-20 20+ years.

9. Would any of your existing or planned products/services be displaced, made redundant, or enhanced by a space station system? Please elaborate.

10. Are there any planned or future "new" product/service opportunities for your company in a space station system? Please elaborate.

10A Could you suggest a probable timescale? 0-5, 5-10, 10-15, 15-20, 20+ years.

11. Current space station plans call for a range of possible configurations. Would any of these configurations be either necessary or sufficient for your expected projects?

	Sufficient (✓)	Necessary (✓)
Permanently-manned space station		
Periodically-manned space station		
Unmanned platform that can be re-visited		
Unmanned satellite (not revisited)		

12. Do you have a relevant company R&D program? Yes
No

If so, a) state the number of professional staff employed on such R&D.

b) Describe special facilities used in this R&D.

13. If you can envisage a new space product or service, are you capable of delivering it with existing

- manpower skills? yes
no
- funding levels? yes
no

14. Do any of the following constrain your projects at present? Do you have any specific requirements for your space projects in terms of the following?

	Constraint(✔)	Requirement (Please specify)
1. mission life		
2. spacecraft design (specify)		
3. payload weight		
4. payload power		
5. payload dimensions		
6. payload interfaces		
7. safety considerations		
8. pointing accuracy		
9. data retrieval problems		
10. orientation and view angle limitations		
11. thermal constraints		
12. consumables limitatations		
13. gravity		
14. temperature		
15. pressure		
16. cleanliness		
17. lighting		
18. plasma		
19. reliability		
20. accessibility		
21. orbits of existing satellites		
22. other (specify)		

15. If funding were available, are you aware of any products/ processes in your industry which would benefit from space research?

16. Is your company's present lack of technical capability an impediment to you participating in the space sation project:

a) In terms of qualified manpower?
b) In terms of physical facilities?

17. Does your organization have any foreign working associations such as licensing agreements, technical arrangements? If so, would you like them to expand? If not, would they benefit you?

18. With which federal government agency(ies) are your space activities connected, and in what way?

	NRC	ICS	DND	DOC	Other (Specify)
Grants, Loans					
Licenses					
Contracts (own)					
Contracts (gov't)					
Use of Facilities					
General Information					
Coord. function					
Technical Advice					
Other (please specify)					

19. If your organization is to realize a significant benefit from expanding space activities, what actions would be required a) on your part? b) on the part of government?

20. Finally, could you give us some indication of your organization's annual level of space effort, in round terms.

$1 - $250,000 $250-$500,000 $500,000-$1m   1 m +

$2 m + $5 m +

IIB - Active Public Sector

6. Within your own organization are you planning for the next phase of space activity; a space station?

7. Are you aware of any space station work in organizations related to your own, outside Canada?

8. Is your organization presently engaged in work which might find some application in a space station system:

a) For the station itself?

b) For associated systems?

9. Would any of your current or planned activities be displaced, made redundant, or enhanced by a space station system? Please elaborate.

10. In terms of your organization's mandate do you see any new opportunities in a space station system?

11. Do any of the following constrain your projects at present? Do you have any specific requirements for your space projects in terms of the following?

	Constraint (✓)	Requirement (Please specify)
1. mission life		
2. spacecraft design (specify)		
3. payload weight		
4. payload power		
5. payload dimensions		
6. payload interfaces		
7. safety considerations		
8. pointing accuracy		
9. data retrieval problems		
10. orientation and view angle limitations		
11. thermal constraints		

	Constraint ( )	Requirement (Please specify)
12. consumables limitations		
13. gravity		
14. temperature		
15. pressure		
16. cleanliness		
17. lighting		
18. plasma		
19. reliability		
20. accessibility		
21. orbits of existing satellites		
22. other (specify)		

12. Would you be capable of exploiting that opportunity with existing a) qualified manpower? b) facilities c) funds?

13. Are you aware of any opportunities in your field which might benefit from space research, if funds were available?

14. Current space station plans call for a range of possible configurations. Would any of these configurations be either necessary or sufficient for your expected projects?

	Sufficient ( )	Necessary ( )
Permanently-manned space station		
Periodically-manned space station		
Unmanned platform that can be re-visited		
Unmanned satellite (not revisited)		

15. Does your organization have any foreign working associations (such as technical exchange arrangements)? Will (would) they help you achieve your space projects?

16. With which federal government agency(ies) are your space activities connected, and in what way?

	NRC	ICS	DND	DOC	Other
Technical Advice					
Grants, Loans					
Licenses					
Contracts (own)					
Contracts (gov't)					
Use of Facilities					
General Information					
Coord. function					
Other (please specify)					

17. If your organization is to contribute to a Canadian space station program, what actions would be required a) on your part? b) on the part of governments?

18. Finally, could you give us some indication of your organization's level of space effort, in round terms.

$1 - 250,000 $250,000 - 500,000 $500,000-$1m
$1 m + $2 m + $5 m +

IIC - ACTIVE END USERS

6. What space platforms now or in the future will provide the information you use?

7. For which specific project(s)/services are you using the information?

Platform	Project (Title or Brief Description)
________	____
________	____
________	____

8. Would any of your current projects/services be enhanced or made redundant by a space station system? How?

9. If a space station system were in operation are there any new projects you would contemplate?

10. Current space station plans call for a range of possible configurations. Would any of these configurations be either necessary or sufficient for your expected projects?

	Sufficient ( )	Necessary ( )
Permanently-manned space station		
Periodically-manned space station		
Unmanned platform that can be revisited		
Unmanned satellite (Not revisited)		

11. Do any of the following constrain your projects at present? Do you have any specific requirements for your space projects in terms of the following?

	Constraint (✓)	Requirement (Please specify)
1. mission life		
2. spacecraft design (specify)		
3. payload weight		
4. payload power		
5. payload dimensions		
6. payload interfaces		
7. safety considerations		
8. pointing accuracy		
9. data retrieval problems		
10. orientation and view angle limitations		
11. thermal constraints		
12. consumables limitations		
13. gravity		
14. temperature		
15. pressure		
16. cleanliness		
17. lighting		
18. plasma		
19. reliability		
20. accessibility		
21. orbits of existing satellites		
22. other (specify)		

12. Does your organization have any foreign working associations such as licensing agreements, technical arrangements? If so, would you like them to expand? If not, would they benefit you?

13. With which federal government agency(ies) are your space activities connected, and in what way?

	NRC	ICS	DND	DOC	Other
Grants, Loans					
Licenses					
Contracts (own)					
Contracts (gov't)					
Use of Facilities					
General Information					
Coord. function					
Technical Advice					
Other (please specify)					

14. If your organization is to realize a significant benefit from expanding space activities, what actions would be required a) on your part? b) on the part of government?

15. Finally, could you give us some indication of your organization's annual level of space effort, in round terms.

$1 - $250,000 $250-$500,000 $500,000-$1m 1 m +

$2 m + $5 m +

IID ACTIVE UNIVERSITY USERS

6. Are you doing any planning for a space station system? Please elaborate.

7. Within your field internationally, are you aware of any space station related work? Please elaborate.

8. Is your present research relevant to the space station concept? How?

a) For the station itself

b) For associated systems

9. Would any of your current or planned research be enhanced or displaced by a space station? Please elaborate.

10. Do you see any new research opportunities in a space station system? Please elaborate.

11. Current space station plans call for a range of possible configurations. Would any of these configurations be either necessary or sufficient for your expected projects:

	Sufficient (✓)	Necessary (✓)
Permanently-manned space station		
Periodically-manned space station		
Unmanned platform that can be revisited		
Unmanned satellite (Not revisited)		

12. Are you capable of conducting your anticipated research with:

a) Your current level of funding
b) Currently available skills

13. Do any of the following constrain your projects at present? Do you have any specific requirements for your space projects in terms of the following?

	Constraint (✓)	Requirement (Please specify)
1. mission life		
2. spacecraft design (specify)		
3. payload weight		
4. payload power		
5. payload dimensions		
6. payload interfaces		
7. safety considerations		
8. pointing accuracy		
9. data retrieval problems		
10. orientation and view angle limitations		
11. thermal constraints		
12. consumables limitations		
13. gravity		
14. temperature		
15. pressure		
16. cleanliness		
17. lighting		
18. plasma		
19. reliability		
20. accessibility		
21. orbits of existing satellites		
22. other (specify)		

14. If funding were available, are there any research projects in your field you would like to see conducted?

15. Do you have any working relations with space scientists in other countries? Please specify

16. With which federal government agency(ies) are your space activities connected, and in what way?

	NRC	ICS	DND	DOC	Other
Technical Advice					
Grants, Loans					
Licenses					
Contracts (own)					
Contracts (gov't)					
Use of Facilities					
General Information					
Coord. function					
Other (please specify)					

17. Could you provide some indication of your annual level of space research effort, in round terms:

0 - $5,000, $5,000 - $10,000, $10,000 - $25,000

$25,000 - $50,000, $50,000 - $100,000, $100,000 - $250,000

over $250,000.

IIE - OTHERS

1. Could you tell us something about your present area of activity - products and services?

2. Do gravity or vacuum factors come into play in your work?

3. Could your present activities benefit from the low gravity and vacuum environment

4. Are you aware of anyone in your field who has considered transferring similar activities to outer space? Have you?

5. If funds were available, are there any space-related projects you might like to participate in?

   a) If so, could you envisage a time when there might be some economic rationale? How long? 5-10 10-20 20+ yrs.

11. Do you have a mechanism within your organization to plan for potential manned or other space activities?

12. If you were to pursue these activities what would be required a) of your organization? b) of governments?

APPENDIX 5

ASSESSMENT SUMMARY

ASSESSMENT SUMMARY

Market Sector ______________________________

End Use Application ______________________________

Proposal/Subject ______________________________

Organization ______________________________

- -

Description of Proposal/Subject:

Strategic Benefit Criteria

1. Economic Opportunity
   - o
   - o
   - o
   - o
   - o
   - o

2. National Interest
   - o
   - o
   - o
   - o
   - o
   - o

3. Regional Development
   - o
   - o
   - o
   - o
   - o
   - o

4. Advancement of Knowledge
   - o
   - o
   - o
   - o
   - o
   - o

STATE OF TECHNOLOGY DEVELOPMENT CRITERIA

1. Existing Capability

   o
   o
   o
   o
   o
   o

2. Stage of Development

   o
   o
   o
   o
   o
   o

3. Innovation Potential

   o
   o
   o
   o
   o
   o

4. Commercial Interest

   o
   o
   o
   o
   o
   o

APPENDIX 6

ADVANCED PROPOSALS

ADVANCED PROPOSALS DEALING WITH MATERIALS PROCESSING IN SPACE

Proposal	Operational use	Demonstration	Scientific use
To build a temperature gradient furnace to be placed on a space platform to measure solidification of eutectics and crystal growth	not in short term	reasonable possible in medium term	of fundamental importance in study of crystal growth
To build and supply a facility on space station for growing crystals of very high value which cannot be grown in a gravity field	not in short term	reasonably possible	expected to yield valuable fundamental data
To build a micro-gravity furnace for growing highly-refined crystals of Hg-Cd-Te, a valuable strategic compound	not in short term	reasonably possible	of fundamental scientific importance
To redesign their present furnaces used for growing Hg-Cd-Te and GaAs crystals for use on space station; their customers are requesting higher purity and fewer imperfections	not in short term	reasonably possible	of fundamental scientific importance
To design and experiment with crystal growth in space; is now designing a facility for growing the world's largest crystals of GaAs	not in short term	reasonably possible	expected to yield data of fundamental importance
To design a facility to study the effects of the space environment on structures which could not be simulated on earth, e.g. thermal vacuum cycling, uv radiation and electron bombardment; an extension of present work with NASA	could affect the design of space craft in the short and long term		
Materials processing in space	possible in long term	reasonably possible in medium term	of fundamental importance in study of crystal growth
To supply a facility for examining radiation damage (temporary or permanent) to solid state memories in space and to design protecting devices	could have an immediate effect on most space activity	immediate	–

ADVANCED PROPOSALS DEALING WITH SPACE SCIENCE

Proposal	Operational use	Demonstration	Scientific use
To design and construct a higher resolution, more sophistocated wide-angle doppler Michelson interferometer than is being made for the Shuttle	—	—	to study coupling between upper and lower atmosphere for weather prediction
To design a Canadian Science Module or sub-satellite to space station teht can be operated in an autonomous manner	—	—	multi-scientific use

ADVANCED PROPOSALS DEALING WITH SPACE TECHNOLOGY

Proposal	Operational use	Demonstration	Scientific use
To supply solar arrays for Space Station	of immediate importance for current space programs and as a basic technology for developing advanced systems		
To contribute to the construction and servicing of Space Station	of importance to the development of Space Station		
To contribute to the evaluation and control of space structures	of importance as support for construction and servicing		
To assemble in space and deploy a very large receiving antenna for radio astronomy	-	possibly could be used also for high resolution passive m/w observation of the earth	this is probably the next important technology step in the astronomical study of the universe
To design and deploy a facility in space station for testing large solar arrays and space trusses	very important in the long term	possibly of medium term importance	-
To design and build a facility in space station to test large space structures under actual space conditions and to design controls for flexible structures	very important in the long term	of medium term importance	-

ADVANCED PROPOSALS DEALING WITH SPACE MEDICINE/BIOLOGY

Proposal	Operational use	Demonstration	Scientific use
To develop a self-contained ecosystem on space station for food production and processing and for maximizing the recycling of waste	very long term use	possilbe in medium term	--
Development of automated animal habitat for space station to study biological effects of zero gravity on rats and mice	of short and long term importance	possible results in short term	will increase understanding of fundamental biological processes
Development of facilities in space station for carrying out vestibular physiology projects	of short and long term importance for future space exploration	possible results in short term	limited
Development of facilities in space station for studying the effects of variations in gravity on the blood, lungs and heart	of immediate practical and scientific importance both in the treatment of disease on earth and for space-related problems in astronauts		
To design and build a facility in space station to investigate techniques for cell separation in a micro-gravity environment	of long term importance	reasonably possible in medium term	fundamental bio-technology research

APPENDIX 7

LISTING OF CANADIAN SENSORS WITH POTENTIAL FOR USE IN SPACE

LISTING OF CANADIAN SENSORS WITH POTENTIAL FOR USE IN SPACE

	Sensor	Stage of Development
1.	Spectrometer for measuring ozone and atmospheric pollutants	Proven for airborne and ground application
2.	Spectrometer for measuring SO_2/NO_X	Proven for airborne and ground application
3.	Solid state (CCD) camera systems for aerospace	Proven for airborne application
4.	Airborne fluorescence line imager for detection and mapping of chlorophyl in sea water	Developed for airborne application
5.	U/V imaging camera	Under development for space application
6.	Wide Angle Michelson Doppler Interferometer	Developed for rocket and space application
7.	LIDAR systems for water and atmospheric pollution detection	Developed and airborne and ground application
8.	Laser radar system for altimeter and bathymetric measurements from aircraft	Proven for airborne operation
9.	Laser fluorosensor	Proven for airborne operation
10.	Synthetic aperture radar	R and D for airborne operation
11.	Real Time Photogrammetric Systems for space robots	R&D ground, qualification required space
12.	Passive Microwave Radiometer	Developed for airborne application
13.	Holographic Radar detectors for earth penetration	R and D for airborne and ground application
14.	GASPILS Gas Pipeline Leak Detector	Proven for airborne and ground application
15.	Microwave Scatterometer	Proven for airborne application
16.	Spotlight Radar	R and D for airborne operation