SURVEY

of

INSTITUTIONAL CENTERS

for the

EXPLOITATION OF LOW GRAVITY

Prepared for

Space Division

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Table of Contents

Summary

This report presents the results of an assignment to review the experiences of nineteen countries (and ESA) in dealing with the commercialization of space. The countries involved are

ESA	Italy
Australia	Japan
Austria	Netherlands
Belgium	Norway
Brazil	Peoples Republic of China
Denmark	Spain
France	Sweden
Germany	Switzerland
India	United Kingdom
Israel	USSR

The US situation was examined in a previous study.

The specific context in which commercialization is discussed relates to materials processing. Space science, as it has generally been known, and space facilities are not included.

Information was collected from a number of sources:

- External Affairs through Science Counsellors and other officials at Posts Abroad

- government officials who have worked with counterparts in foreign countries

- industrial representatives

- published documents.

Findings show that interest in space commercialization amongst countries with space programs varies from full commitment to decisions to pursue only such activities as space communications and remote sensing.

Where there is full commitment, core facilities have been established - or are being established - to provide pre-flight experiment validation, generic hardware, in-flight support, and post-flight evaluation.

In countries with extensive experience, Germany for instance, funding emphasis has shifted from long-term to support for feasibility studies. This is a recognition that considerable ground preparation is necessary to ensure optimum results from expensive and scarce space flights.

The participation of industry, spending its own money, is one characteristic of countries with committed programs.

If Canada is to join the committed group of countries, a number of actions should be taken. In order to reach this goal the following recommendations are presented.

Recommendation 1. **Canada should examine the needs for a central facility to support microgravity investigations that may eventually lead to commercial opportunities.**

Recommendation 2. **The microgravity community in Canada should be consulted regarding the most appropriate form of core support that should be established, and a report prepared for government consideration.**

Recommendation 3. **Representative members of the Canadian industrial community should be consulted in respect of willingness to provide direct support to a core facility.**

Recommendation 4. **As part of its planning to promote science and technology, the federal government should look into the possibility of establishing a centre for materials processing in space, the creation of the centre to be predicated upon industrial participation.**

During the course of this assignment results from experiments in macrogravity came to light. There are indications that this technology can yield useful results when applied to purification of intermetallics.

Recommendation 5. **A review should be undertaken of activities in macrogravity to be sure that opportunities are not missed, or that experiments planned for microgravity might not be better undertaken in macrogravity, at least in the preliminary investigative stage.**

1. INTRODUCTION

As time goes on and the costs of undertaking studies in space increase, international cooperation will become ever more important. For experiments involving microgravity, we are still anticipating a situation where commercialization is realized on a routine basis. This means that governments are the prime source of funding for microgravity projects.

International cooperation will therefore be negotiated by governments, each of whom will attempt to protect their own technology and maximize their own opportunities.

The infrastructure through which microgravity commercialization will be realized differs from country to country. Canada is in a position where the appropriate infrastructure has yet to be determined. We can therefore, take advantage of the experiences of other countries who have already decided upon a course of action.

NASA has adopted a number of measures, from joint ventures with specific companies, to the establishment of centers for commercialization of space. In the case of centers, each has a particular focus. And NASA policy is aimed at developing at least one centre in each aspect of potential space commercialization. There is also a strong in-house program which supports all space initiatives.

While the NASA infrastructure is impressive, the Challenger accident has left the US microgravity community in a position where they have fallen behind investigators in other countries. This has led to a call for more attention to US needs and less emphasis on the use of US facilities, particularly the Shuttle, for projects of other countries. If this attitude were to drive NASA policy in respect of access to microgravity, the result may have severe consequences for countries such as Canada.

The situation as far as Europe and Japan are concerned is somewhat different. Both have plans to launch their own self-contained space platforms early in the next century on which they can pursue microgravity studies. The USSR is already well advanced in this regard, and the Peoples Republic of China is establishing its own space program. Others such as India, Australia and Brazil may have aspirations in the future Canada does not plan to have its own space platform, nor is it a full partner in the ESA or Japanese programs. We are therefore, taking advantage of joint opportunities with many different partners.

This study was commissioned to assess the infrastructure our potential partners have put in place so that we will be in a better position to decide what institutional structures we should create in Canada. NASA is not included here, as the structures established by that organization were the subject of a previous assignment.

2. METHODOLOGY

Nineteen countries and ESA have been identified as potential partners for microgravity studies. These are

ESA	Italy
Australia	Japan
Austria	Netherlands
Belgium	Norway
Brazil	Peoples Republic of China
Denmark	Spain
France	Sweden
Germany	Switzerland
India	United Kingdom
Israel	USSR

In order to obtain information on the infrastructure within the above countries, as it relates to microgravity studies, External Affairs was approached to request Canadian Posts Abroad to provide answers to a series of questions.

The extent to which Canada covers science and technology matters varies from country to country. There are science counsellors in five Posts (in addition to USA and the European Communities). These are located in

Belgium
France
Germany
Japan
United Kingdom

Science and technology matters in Sweden, Norway, Finland and Denmark are dealt with by one locally engaged Technology Development Officer attached to the Canadian Embassy in Stockholm. Technology is formally handled by the Trade Commissioner in Italy and the Counsellor (Commercial) in Israel. There are no specific officers designated to deal with science and technology interests in other Posts.

In order to provide as much guidance as possible, a background paper was developed to explain the nature of the assignment. The results of the US study were included. This may be found in Appendix A, along with the questions to which answers were sought.

The information provided by Posts Abroad was used as the basis for the findings of this report, augmented by other documentation available on country programs. Government officials and members of the industrial community also provided valuable insights.

3. FINDINGS

3.1 General

As expected, the results from different countries vary considerably, largely dependent on the status of their microgravity programs.

ESA is a special case. That organization has been established to spread the risk of research in space, not to engage in commercialization activities. In fact the only acknowledgement of commercial interest has been to privatize the distribution of remote sensing data.

The development of commercial opportunities within the ESA block is left to the devices of the individual member countries. A few have focussed on microgravity applications. Others have directed their interests elsewhere.

Microgravity studies require a long term commitment to some sort of space platform. It is therefore not surprising that the countries pursuing microgravity most vigorously are those that have elected to develop a space platform, either under their own control or as part of a consortium plan.

Some countries are just beginning to develop space programs. In these cases they are following the natural progression from space science, through communications to remote sensing. Costs and accessability to microgravity often preclude the development of the infrastructure necessary to support a microgravity program.

Findings for each country (and ESA) are presented below.

3.2 ESA

ESA is an R and D organization and apart from the distribution of remote sensing data, has not engaged in any commercialization activities.

ESA does however, accept the risk associated with R and D by providing the infrastructure for experimentation that will lead eventually to commercial developments. Commercialization is left to the individual countries that participate in this infrastructure.

Spin-offs occur in member countries where hardware, software, systems integration etc. take place as a result of ESA contracts. Commercial activity as a result of this process is not the consequence of a policy of ESA to directly promote commercialization, but reflects the interest on the part of member states to develop opportunities in their own industries.

A recent report (Feb. 1987) on the Scientific Policy of ESA has recommended that more than 25% of ESA's future budget should be spent on Space/Earth and Microgravity Sciences. It has also stated that Space Station must be attractive to users in Europe. The program recommendations are that

- a microgravity support laboratory and Earth science unit should be established within ESA
- the fellowship program should be expanded
- a science data network and archiving system should be implemented
- ESA should endeavour to bring the university community and industry closer together
- ESA should finance flight facilities but not payloads.

The report further recommends that

- there should be a mandatory element (10-15%) within the microgravity program
- an interim microgravity program should be developed which uses non-shuttle-dependent flight opportunities
- ESA should establish multi-user calibration and test facilities not only in ESA but also where there is already infrastructure in place.

The ESA Council proposal for the European Long Term Space Plan 1987-2000 notes that it will take at least a decade to evaluate the usefulness of microgravity as a research tool. The first step is to develop a data base. In what appears to be an extension of the Policy report recommendations, ESA Council recommends that ESA provide 40-50% of payload facilities, the remainder of the cost to be borne by member states.

The European Retrievable Carrier (EURECA) is a free flyer, scheduled for an early launch, which will carry materials processing and life sciences experiments.

EURECA will be launched by NASA and controlled in orbit by ESA's EURECA Operations Control Centre located at ESOC in Darmstadt, West Germany. Of special interest is the concept developed by DFVLR (see Section 3.9 below) to establish a Microgravity User Support Centre (MUSC) at Porz near Cologne.

The Centre is funded by ESA and the services are free to users who have experiments on EURECA-1.

3.3 Australia

In 1984 the Commonwealth Scientific and Industrial Research Organization (CSIRO) executive created a Space Science and Technology Study Group to advise CSIRO on steps it should take in respect of space R and D. At that time, Australia was spending 0.003% of its GDP on space R and D.

As a result of this study, the Office of Space Science and Applications (COSSA) was established within CSIRO in December 1984. Its responsibilities are to coordinate space research and development across CSIRO and to ensure that

- 70% of new funds are spent in industry
- 80% of CSIRO R and D is directed to applied science

COSSA commissioned a consulting study to determine the country's strengths in space. About 38 industries who have work in space were contacted. The main areas of strength were determined as

- remote sensing
- value added services
- equipment and software
- use of remote sensing data in business decisions

Australia's interests lie in remote sensing and weather satellites for resource management. Data obtained by read-out stations for US satellites are used in crop monitoring and mineral exploration.

Aussat PTY Ltd. has been created to

- foster technology transfer to Australia
- develop ability of Australian industry to supply and manufacture satellite-related equipment
- develop relevant skills

3.4 Austria

Most of the government spending on R and D is directed to universities and government laboratories. There are however, two programs for industrial support, offering grants and 50% cost sharing. Individuals may also receive 100% funding.

The programs are for support of advanced technologies, but there is no breakdown with respect to individual fields.

There are also a large number (98) of small programs aimed at universities and individuals. Some of these have regional aspects.

3.5 Belgium

At the present time Belgium has no formal program aimed at supporting studies in microgravity, although a number of investigators in universities have participated in ESA projects in the subject area.

The Belgium program is funded mainly by public money. It is coordinated by three bodies. The Space Research and Technology Section of the Space Policy Office (SPO) manages the budget, activities and cooperation. The Belgospace Association acts as the voice of industry. And the Regie des Telegraphes & Telephones (RTT) is a user of communications satellites.

Research in microgravity has focussed on

- metallurgy and composites
- fluid physics
- crystal growth
- space medicine and human physiology
- in vitro fertilization

Experiments have flown in Skylab (1973), Spacelab 1 and Spacelab D1, Texus rockets and the KC 135. Preparations are being made to participate in Spacelab D2 and the ESA EURECA project. Hardware is being provided by private sector firms.

A private firm, Biospace Technology, was established in 1986 to promote applications, services and products for development and processing of materials in microgravity. This company will commercialize and market new technologies developed by universities, institutes and small and medium sized enterprises.

Biospace Technology works with the Ministry of National Defence and the Belgium Air Force using parabolic flights of training planes. The company also has contacts with ESA and NASA. It is involved in EURECA, specifically with electrophoresis studies.

3.6 Brazil

The Brazilian space program is organized under the Ministry of Science and Technology (MCT) which operates the National Institute of Space Research (INPE).

INPE's program is focussed on

- space and atmospheric research
- engineering and technology research for space
- ground segments

Brazil has engaged in one experiment to investigate the growth of semiconductor crystals on board the USSR space station MIR.

Although there is no formal program at the moment, Brazil would like to participate in joint projects with other countries in this field.

Launch vehicles are developed by the Institute of Space Activities (IAE) which is part of the Aerospace Technology Centre (CTA) belonging to the airforce.

Brazil is constructing a 520 square kilometre launch base at Alcantera outside San Luiz - almost exactly on the equator. Vehicles launched from this site will enjoy a 25% fuel saving over a similar vehicle launched by NASA.

The Complete Brazilian Space Mission (MECB) is a program developed by three state agencies in Sao Paulo. The plan is to launch 4 locally developed satellites using Brazilian launchers in the time period 1989 to 1993. The first satellites will gather data on rainfall, temperature, atmospheric processes, humidity and water levels. These will be followed by remote sensing satellites.

3.7 Denmark

Denmark participates in ESA projects through industry and institutions. However, there is little effort in the field of microgravity, and no program to develop commercial applications. Advanced technological developments are funded by the government and administered by the National Agency of Technology.

3.8 France

The Centre Nationale d'Etude Spatiale (CNES) is the organization responsible for France's space program. It is the French equivalent of the US NASA.

CNES operates its own laboratories, both for carrying out fundamental investigations and for providing support to industry on a fee-for-service basis. This latter takes the form of systems integration and testing for such projects as communication satellite systems.

In addition to its laboratory work, CNES takes a position in private corporations formed to commercialize specific aspects of space. These corporations, of which there are 12 at present, comprise individual companies, financial institutions and CNES. They are thus broadly based and have all the tools to develop commercial opportunities. The functions of the organizations in which CNES participates are summarized as follows.

Intespace This organization was formed in 1983 out of the French Space Testing Laboratories. It deals with the study, simulation and interpretation of the environmental conditions in space. Its clients are both national and international.

Spot Image Spot Image was created in 1986 to sell remote sensing data obtained by the French Spot 1 satellite. It has entered into agreements with a number of other countries, including Canada, to read and distribute Spot 1 data.

SAT Control SAT Control was established in 1986 to develop and market space vehicle control centres and associated services.

Novespace This company was formed in 1986 to encourage the transfer of space-related technologies into industries not directly connected with space. It also acts in a consultative capacity, offering advice on the applicability and value of space technologies. This organization will probably emerge as the main French vehicle for commercialization of microgravity opportunities in the fields of metallurgy and medicine.

SIMKO This company looks after housing in French Guiana at the Kourou launch centre.

GDTA The Groupment pour le Developpment de la Teledetection Aerospaciale deals with training, international projects and work abroad, distribution of satellite data and space oceanography, including the development of new on-board remote sensors.

Prospace Prospace is one of the older consortia, formed in 1974. Its operations include provision of foreign promotion for space-related activities and products of its members, market surveys and marketing of products. Some of these latter involve equipment that was used on Spacelab.

Satel Conseil This organization was created in 1978 to act as international consultants in the field of satellite-aided communications.

Arianespace This is the launching agency for French rockets carrying satellite payloads.

CLS Collecte Localisation Satellites is responsible for promoting the Argos system and handling the world-wide processing and distribution of Argos data. Argos is a satellite that collects data from various platforms such as buoys, icebergs, drill platforms and ships. The data are used for oceanographic and atmospheric studies.

LOCSTAR This recently formed company will be responsible for the program involving position determination and message service by satellite. This is a European company, not just French, with CNES holding less than 34%. The technology will be Geostar, which may restart in the near future.

There is some dispute over the service, as the EEC favours Inmarsat for messaging.

SCOT The Service de Consultance en Observation de la Terre is a wholly owned subsidiary of CNES. It has been created to promote the products of remote sensing. There are indications that partners may join the enterprise.

CNES has developed various facilities such as drop towers at various laboratories. It also arranges for KC 135 flights. In anticipation of long term manned space flights, CNES has proposed the creation of an Institute of Space Medicine. This organization will include universities, hospitals, the Toulouse Space Centre and some participation by the French Army. It is expected that in time, it will evolve into an operational entity handling all aspects of space medicine.

A study has recently been undertaken of the French organization for space. It is expected to recommend that

- prime contracts should go to industry rather than to CNES

- commercial management of CNES subsidiaries should be entrusted to a holding company

If these recommendations are accepted and implemented, they will have an impact on the role of CNES in space commercialization.

3.9 Germany

The Federal Republic of Germany (FRG) has supported space research and technology since 1962. There is a well integrated program in place that spans all space interests including the commercialization of space technologies.

The aim of the German program is to position that country to take a leading role in space activities in order to secure future employment in innovative industries.

Germany was one of the first European countries to recognize the potential importance of materials processing in space. A sounding rocket program, Texus, was created to carry out the first tests in microgravity. This was followed by the development of Spacelab, in which Germany took the leading role.

The German government, through the Federal Ministry for Research and Technology (BMFT), provides funding and policy guidance for the FRG space program. Project management and coordination activities are delegated to the Deutsche Forschungs- und Versuchsanstalt fur Luft- und Raumfahrt e.V. (DFVLR).

DFVLR areas of operation cover

- preparatory technological research
- project plans for ESA and other international cooperative projects
- planning and executing space missions
- developing applications and providing user support

The FRG space program has three components

- scientific program for experiments requiring microgravity
- support facilities to develop hardware for ground- and space-based activities
- flight program.

Centers of Excellence have been established corresponding generally to the program elements, namely,

- interface and transport phenomena
- metals and compound materials
- crystals
- physical chemistry and process technology
- biotechnology
- biology
- medicine/human physiology.

Funding for the Centers comes from federal/state sources. Project support is provided by federal/state, universities, industry.

There is no standard format for the administrative structure of the Centers. Each is determined by location and its relationships to neighbouring research institutes, universities and industry.

Any scientist can use the centre appropriate to his/her project for support within the microgravity research program.

Space projects are approved by a selection committee composed of experts, of whom 50% must not be actively involved in space research. The chairman receives an honorarium from BMFT; secretariat support is provided by DFVLR.

FRG has a wide range of microgravity facilities:

- drop tower (under construction, 4-5 sec.)
- MICROBA (balloon lift and drop)
- parabolic flights
- rocket flights (superTexus planned for 15-18 min.)

The program also participates in

- Spacelab flights
- DOM, orbital research facility
- MAUS, similar to Get-Away-Special
- EURECA
- Space Station.

DFVLR is establishing a Microgravity User Support Centre (MUSC) at its main facility at Porz, near Cologne. This is scheduled for completion in 1993.

MUSC will provide integrated user support tailored to the needs of microgravity experimenters in long duration missions. MUSC will support scientific and commercial activities during the

- preparation
- operation
- evaluation

of the EURECA-1 mission.

Operational systems are run by the user organizations. These systems are supported and monitored by DFVLR on request. Industry is expected to undertake commercial projects.

In addition to DFVLR, the aerospace industry, equipment suppliers, scientific institutions, technical universities, and the Max Planck Institute all participate in the national space program.

Germany's Messerschmitt-Boelkow-Blohm and Italy's Aeritalia have taken the leadership in Europe in respect of commercialization of space activities in microgravity by establishing, in 1985, the marketing firm Intospace GmbH. This is a German-registered company based in Hanover.

Intospace was created as a result of a consultant's study funded by the German government (BMFT) and DFVLR. The consulting company evaluated the market requirements and recommended that a non-aerospace marketing company should be formed to promote commercialization of microgravity activities. Participation by

European aerospace companies is limited to 38%.

The shareholders of Intospace comprise a variety of private companies resident in a number of European countries. The range of investors include financial institutions, insurance companies, aerospace companies, chemical companies, venture management companies, resource companies and automotive companies. Some banks have also acquired shares.

Participation by country is as follows:

- Germany - 44 firms
- Italy - 15 firms
- France - 10 firms
- UK - 8 firms
- Switzerland - 12 firms
- Netherlands, Sweden, Spain - 1 each
- Belgium - 1 firm

Particular interests amongst the industries lie in the following fields

- chemical
- glass
- ceramics
- porcelain
- electric and electronic engineering
- precision engineering
- optics
- metallurgy

Intospace's main activity at present is to act as the German working group on the utilization of Spacelab. The organization has documented 400 flights (experiments) already flown in space. It has signed a cooperative MOU with the Space Technology Corporation of Japan (STC) for STC payloads aboard Spacelab D-2 and subsequent flights.

The original expectation was that the company would lose money for the first five years of operation, such losses to be covered by the founding shareholders.

3.10 India

India's space program began in 1962 with the creation of the Indian National Committee for Space Research (INCOSPAR). A rocket launching facility was established at Thumba in 1963.

In 1972 a space program was formally organized with the creation of the Space Commission. The responsibility of this body is to

- develop space technology and science

- develop policy for the Department of Space (DOS)

The Department of Space executes space activities through the Indian Space Research Organization (ISRO).

The Indian program focusses on

- satellite communications
- TV broadcasting
- remote sensing

In the case of remote sensing, India has developed some unique features in its satellites which have the capability to 3-axis and spin stabilize.

3.11 Israel

Israel has no official program to exploit materials processing in space at the present time. One scientist is engaged in research in this field.

3.12 Italy

Italy's space plan calls for a 40/60 split between funding for domestic projects and support of ESA. Both components are theoretically under the purview of an Interministerial Committee on Economic Planning (CIPE).

However, the ESA program is led by the Ministry for the Coordination of Scientific Research and Technology. And the National Space Plan is managed by the National Research Council, with inputs from the Centre for Aerospace Research which is part of Rome University.

This divided responsibility is perceived to cause problems in respect of coordination.

Italy has a plan to establish an Agenzia Spaziale Italiana. This organization is expected to assist in commercialization and will be a policy and planning agency patterned after the British National Space Centre.

In the industrial sector, Aeritalia has been a strong participant in the provision of space hardware. Its accomplishments include

- building the shell for ESA's Spacelab
- participation in Columbus
- participation in Spacelab
- tethered satellite project
- participation in EURECA

3.13 Japan

The Space Activities Commission (SAC) establishes and oversees Japanese government policy for space. SAC is supported by the Science and Technology Agency (STA) which acts as the secretariat. The National Aeronautical Laboratory reports to STA.

SAC has three groups reporting to it, in addition to STA, that carry out the government programs in space. The National Space Development Agency of Japan (NASDA) was established by the NASDA Law. It is an R and D agency whose main tasks are

- R and D in connection with satellites and their launch vehicles, excluding those for scientific purposes
- launching of satellites, including tracking and control
- receiving and processing of satellite remote sensing data
- promotion of materials processing in space

NASDA funding comes primarily from government, although it can receive contributions from non-governmental sources. It cannot join with industry in joint ventures since its governing law prohibits financial contributions to other organizations.

The other agencies under SAC are the Institute for Space and Astronautical Sciences (ISAS) and the Japan Space Utilization Promotion Centre (JSUP). SAC, through STA, also coordinates the space activities of the national laboratories that are located in various ministries.

ISAS is concerned with space research, and is the link between universities and STA. JSUP was established in 1985 by 42 independent corporations representing various space related fields such as materials processing and pharmaceutical technology.

JSUP's main program areas are

- training of people
- supplying of experimental equipment
- designing a space data base
- surveying space experimental themes
- surveying requests for use of space station
- holding international symposia

It is establishing a system for support and coordination of the user community.

Various other organizations have been created to deal with space matters.

- The Japan Key Technology Centre joined with six private firms to form the Space Technology Corporation in 1986. This corporation will carry out R and D on materials processing technology focussed on crystal growth of compound semiconductors, and also will explore opportunities in biotechnology. The aim is to improve land-based processes. The corporation will cooperate with Germany in Spacelab D-2.

- In 1986 also, thirteen private companies formed the Institute for Unmanned Space Experiments Free Flyer to develop a Japanese free flyer. It is a non-profit institute, managed under the direction of the Ministry of International Trade and Industry (MITI), and cooperates with ISAS and NASDA.

- STA established an office of Space Utilization Promotion within its Research Development Bureau in 1987. This office will promote the use of the First Materials Processing Test (FMPT) module (a joint NASDA-NASA project), the International Microgravity Laboratory (IML), remote sensing projects using MOS-1, and the space station program.

- Also in 1987, MITI created the space Industry Division to promote industrial use of space and to strengthen space-related equipment manufacturers.

In addition to the above institutional initiatives, in 1987 Japan introduced a new tax system for promoting the development and use of space. Under its provisions, purchasers of testing and research equipment specified in a Ministry of Finance Ordinance will be eligible for tax credits.

Japan has been active in materials processing in space for a number of years, supported in part by STA through its National Aerospace Laboratory, by NASDA, and also by individual companies. Experiments have taken place with rockets and parabolic-flight aircraft. STA has provided test equipment for the latter experiments.

NASDA started to develop facilities for materials processing in space as early as 1979. Current activities are focussed on FMPT, for which 34 experiments on materials processing and life sciences are planned.

Investigations using aircraft and reported on to date are listed below, along with the sponsoring agency.

- Marangoni convection by industry
- optical materials in the non-visible region by a MITI agency
- gas evaporation by a university
- bubble behaviour by NAL
- acoustic levitation by NAL
- human dexterity by NAL

These are likely to be continued in FMPT.

Japan has a strong space science program based on rockets and satellites. It is also participating in space station by providing the Japanese Experimental Module, consisting of a pressurized module, an experiment logistics module, and an exposed facility. There may also be a free flyer.

At the present time, Japan does not believe that space technology is at the commercial stage because the size of the market is too small.

3.14 Netherlands

At the governmental level, a number of ministries are involved in space related activities, the Ministry of Economic Affairs, the Ministry of Science and Education, the Ministry of Transport and the Ministry of Public Works. The main organizations for support and promotion of microgravity research and applications are the Netherlands Agency for Aerospace Programs (NIVR) and the Space Research Organization Netherlands (SRON).

NIVR is a semi-governmental agency founded in 1946. Funding is provided by the Ministry of Economic Affairs. It initiates, promotes and monitors industrial activities associated with space.

SRON coordinates all Dutch space research and is part of the Organization for Pure Scientific Research (ZWO), which comes under the Ministry of Education and Science. It initiates and performs scientific space activities and maintains the National Institute for Scientific Space Research, which has three laboratories in Leiden, Utrecht and Groningen. Collectively, these institutes employ about 150 people. SRON's budget is provided by the Ministry of Education and Science through ZWO. Until recent years, SRON has focussed on space sciences in the fields of astronomy, astrophysics and geodesy. Microgravity has now been added to the list.

SRON maintains close links with the university community, while NIVR deals with industry and scientific/technological research establishments.

There is a solid base of expertise for microgravity studies, as about 20 universities have been involved in Spacelab, Texus and EURECA. The research focus is now directed toward Columbus, where the Netherlands has a 4 to 5% participation. Industry is also involved, having participated in Spacelab, and now has undertaken a number of studies for the Columbus project.

There are no formal structures at present to promote commercialization of space. Cooperation between NIVR and SRON is good, but is dependent upon individual people in each organization. Universities, industry and government work well together but on an ad hoc basis.

3.15 Norway

The Norwegian economy relies to a large extent on natural resources, oil, minerals and the fishery. It has a negative balance of payments in the advanced technology sector.

Industry receives about 50% of the government R and D funding with the rest going to government laboratories and universities. Government funding provides about 20% of industry's expenditures.

There are no specific programs for support of commercial activities related to applications arising from microgravity investigations.

3.16 Peoples Republic of China

The Peoples Republic of China (PRC) created the Chinese Academy of Space Technology in 1968 to do research and to manufacture satellite systems. The Shanghai Astronautics Bureau, and some other institutes, develop and manufacture launch vehicles. The Ministry of Astronautics (MOA), under the State Council is responsible for

- electronics
- computer research
- ground control

3.17 Spain

There is no national program on microgravity at present, although one is in the planning stages. Industry is expected to participate in any future program.

The Instituto Nacional de Tecnica Aerospacial (INTA) is studying combustion in microgravity, and has recently completed an ESA contract on "Preparatory Study on Heterogeneous Combustion Processes under Microgravity Conditions". INTA has a free-fall tower, 25m high, which is fully instrumented for combustion research in microgravity.

There are also some facilities for research on the stability of fluid bridges in microgravity at the Escuela Tecnica Superior de Ingenieros Aeronauticos.

3.18 Sweden

The Swedish Space Corporation (SSC) is a state owned corporation under the Ministry of Industry. It is the focus for the Swedish space program, and is responsible for the technical implementation of the Swedish space and remote sensing programs. As a result of a policy decision in 1979, the main thrust of the Swedish space program is aimed at satellite communications.

At the same time, SSC has been involved in microgravity studies since 1975. The aim has been to gain an understanding of promising research and development areas, and to develop processes for materials fabrication in low gravity. The Corporation has built experimental equipment for a variety of space vehicles including rockets, get-away-specials for the shuttle, parabolic flight aircraft and EURECA.

SSC offers its expertise at home and internationally on a fee-for-service basis. It has made an effort to broadly promote its services in the field of microgravity, but without much success. It is now concentrating on universities and other researchers.

SSC is in the interesting position of on the one hand being the operating arm for the Swedish space program, and on the other a commercial operation offering everything from consulting services to turn-key facilities on a world wide basis.

3.19 Switzerland

Government in Switzerland provides very little funding assistance to industry, leaving that sector to find R and D funds from its own resources. The Commission for Scientific Research Encouragement (CERS), an agency of the Federal Department of Economy, does provide financial support for industrial R and D projects focussed on practical applications. Industry must provide at least 50% of the project funding itself. Most projects that are supported are performed in collaboration with universities or scientific institutes.

Projects at public institutions can receive funding from the National Fund. Since these are often undertaken cooperatively with industry, there is an indirect support for industrial R and D.

A new centre, the Research Centre for Electronics and Microelectronics (CSEM), has been established with a strong industrial focus. Projects are funded by CERS and the National Fund, but there is provision for industrial participation.

3.20 United Kingdom

The UK microgravity program is coordinated by the British National Space Centre (BNSC), the organization established in 1985 to

- plan the UK activity in space
- direct UK civil space activities
- develop future policy

The BNSC was created by combining facilities and budget from

- the Department of Industry and Trade (DIT)
- the Ministry of Defence (MOD)
- the Science and Engineering Research Council (SERC)
- the Natural Environment Research Council (NERC)

UK support for ESA flows through the BNSC, accounting for about 80% of its funds. The remainder supports research and development at universities, research establishments, and industry.

The BNSC is structured into a Projects and Technology Directorate and a Policy and Programmes Directorate. Microgravity research is combined with science under the latter directorate. BNSC laboratory facilities are located primarily at the Royal Aeronautical Establishment (MOD) and the Rutherford Appleton Laboratory (SERC).

These laboratories provide central facilities for user groups. The Royal Aeronautical Establishment is concerned with space craft and remote sensing. The Rutherford Appleton Laboratory provides assembly, integration and test facilities, as well as the Geophysical Data Facility.

The main user programmes are in the fields of

- satellite communications
- Earth observation
- space science

The Columbus program has stirred interest in materials processing in space, and a tentative UK program has been put forward. The recently tabled space plan (not approved as yet) calls for about 3% of the budget to be allocated to microgravity investigations.

The BNSC has not established any special institutional structures to deal with microgravity. Failure to secure approval for the proposed space plan has curtailed planned activities in microgravity, and probably the creation of organizational structures to deal with this subject. Research will continue however, at the universities and institutes where it has been pursued to date.

3.21 USSR

The USSR program in microgravity research is directed by the Materials Sciences Laboratory of the Institute for Space Research, an institute of the Academy of Science. The Institute has a staff of about 1500 located in Moscow, with an equivalent number of collaborators elsewhere in the Soviet Union.

The USSR has been active in microgravity for many years and has flown more than 1500 microgravity experiments. The subjects of interest correspond to those identified in the western world in general and Canada in particular. These are

- semiconductors
- ceramics
- glasses
- metals
- non-metals
- alloys
- pharmaceuticals

The Institute plans to develop a space station, MIR variety, solely for materials research, with production taking place on an automated free flyer.

Technical and commercial aspects of the USSR space program come under Glavkosmos, an agency created to sell launches and develop space hardware. This agency controls launches and provides services of the following nature

- materials processing with proven equipment
- experimental facilities on MIR using Glavkosmos equipment
- launch facilities

The USSR has also performed materials experiments in high gravity. Results suggest that materials can be purified to a higher degree using this technology than is the case in microgravity.

4. CONCLUSIONS AND RECOMMENDATIONS

Our survey shows that in respect of the microgravity user community, interest spans the spectrum from committed readiness programs, to decisions to eschew this field for the time being. Notwithstanding this general observation, the countries with space programs can be divided into three groups. The segmentation is arbitrary, but is useful for focussing attention on countries where there are patterns that may have applicability to the Canadian situation.

a) countries with committed programs/core facilities/industrial involvement in this field,

ESA
Belgium
France
Germany
Italy
Japan
Netherlands
Spain
Sweden
USSR

b) countries with programs at the investigative stage only,

Denmark
Israel
Switzerland
United Kingdom

c) countries that are concentrating on space communications, or remote sensing as a means of improving resource management.

Australia
Austria
Brazil
India
Norway

Information on the PRC is not sufficient to make a determination of that country's microgravity program. It is however, becoming a very important element of international space activities.

Canada's microgravity program falls within category a) above; and within this category there are two distinct groups

- countries with extensive programs and facilities
- countries where the microgravity program is at the R and D stage.

Canada belongs to this latter group.

Where the microgravity program is at the R and D stage, project support falls under the country's normal funding and institutional structures for science and technology. No special centers have been established.

Category b) countries, with the exception of Israel, are members of ESA, and could move to category a) if the results of experiments undertaken by that agency show commercial promise in respect of their native industries.

Category c) countries are unlikely to develop programs in microgravity in the near future.

We have most to learn as far as organization is concerned by examining category a) countries, and in particular those that have well-developed programs or facilities. ESA is a special case, as that organization concentrates on R and D. Canada's relationship with ESA will remain at the R and D level, with Canadian industry participating in hardware supply and consulting studies.

Program commitment is the key factor that positions countries to capitalize on space expenditures. Industrial involvement follows this commitment.

Each of the countries with extensive committed programs have developed government-funded core support facilities to

- permit assessment of experiments on Earth before committing to large expenditures for space
- assist in the design and testing of space experimental hardware
- develop generic hardware
- provide post-flight experimentation.

There are also some facilities to control experiments in flight, although this aspect is not well developed at present.

If Canada is to realize the economic potential of investments in space activities, there will have to be adequate ground support. In the case of materials processing, this was recognized many years ago by the interested scientific community and relevant recommendations were made to move in this direction. Given the effort being made by other countries with materials processing programs, it is appropriate that Canada pay attention to our own needs in this area. This observation leads to

Recommendation 1. Canada should examine the needs for a central facility to support microgravity investigations that may eventually lead to commercial opportunities.

Economies of scale suggest that if such support is warranted, there should only be one facility. The David Florida Laboratory, which supports the space communications program, might be a logical facility upon which to build.

There are a number of Canadian scientists, engineers and industrial firms interested in investigating processes in microgravity. The nature of core facilities chosen should be tailored to the needs of this community. If the microgravity program creates and supports such a facility, other investigators will be attracted to this field. In order to determine the perceived needs, steps should be taken to ascertain the views of the microgravity community. This suggests

Recommendation 2. The microgravity community in Canada should be consulted regarding the most appropriate form of core support that should be established, and a report prepared for government consideration.

The results of this assignment, together with those of the NASA Centers study, should be used as background material.

It is generally acknowledged that commercial developments arising from investigations of materials processing in microgravity will only take place some time in the future. Notwithstanding this situation, industry in France, FRG and Japan is prepared to put up its own money in expectation of returns in the longer term. This suggests that with a commitment to the program and the right institutional structures, Canadian industry might also become a more visible partner. To test this hypothesis,

Recommendation 3. Representative members of the Canadian industrial community should be consulted in respect of willingness to provide direct support to a core facility.

The situation has changed since the last study on industrial participation. Other countries are making large commitments to space. Intospace has been created in Europe. The consultants' study that gave rise to its creation could serve as a background document with which to approach Canadian industry. Experience with the NASA Centers is also relevant.

The microgravity program in Canada could benefit from a more visible focus. The establishment of the Centre of Excellence in Space and Terrestrial Sciences at York University has provided this focus for that subject area. Materials processing in microgravity has not been included in that centre. This observation leads to

Recommendation 4. **As part of its planning to promote science and technology, the federal government should look into the possibility of establishing a centre for materials processing in space, the creation of the centre to be predicated upon industrial participation.**

An interesting observation that arose from a visit of federal officials to the USSR relates to the possibilities of macrogravity for improving materials processing technology. This activity takes place on Earth, and is complementary to investigations in microgravity.

Recommendation 5. **A review should be undertaken of activities in macrogravity to be sure that opportunities are not missed, or that experiments planned for microgravity might not be better undertaken in macrogravity, at least in the preliminary investigative stage.**

5. ACKNOWLEDGEMENTS

This study would not have been possible without the cooperation of many individuals. While it would be unfair to single out individuals by name, Science Counsellors, officials of Posts Abroad, federal officials and members of the industrial community all played key roles.

The cooperation of External Affairs is particularly acknowledged, as officials in that department acted as the communication link between Canada and our representatives overseas who provided much of the information upon which this report is based.

Appendix A

Background Paper

INTERNATIONAL STRUCTURES FOR PROMOTING EXPERIMENTATION IN THE LOW GRAVITY ENVIRONMENT

The government has recently announced its intention to participate in the US Space Station Program, and has allocated significant resources to this activity. Part of the Canadian effort is devoted to developing a user community that can take advantage of the long-duration low gravity environment that will be available through Space Station. Cooperative programs with other countries, particularly those within the ESA community, also present opportunities for low gravity studies.

Experimentation in low gravity is expensive. Resources allocated to this program will be used best if all sectors - government, industry, university - can be brought together to focus their work in cooperation. As has been our custom, we will also engage in international projects.

For these reasons, we wish to establish institutional arrangements in Canada that fit our own requirements and also allow us easy access to foreign programs. We are relatively early in our program development, with a Space Agency yet to be formally announced. It will be useful therefore, to learn how other countries are approaching the institutional issue so that we can take advantage of their experiences.

To this end, NRC has commissioned a study of the NASA experience. A summary of that assignment is attached. We would now like to obtain information on the experiences of other countries with whom we have, or are likely to have, joint projects. These are

ESA
UK
France
Germany
Belgium
Sweden
Norway
Spain
Italy
Austria
Switzerland
Denmark
Netherlands
Brazil
Israel
Australia
India
Japan
Peoples Republic of China
USSR

A guide to the information requested is given below.

INTERVIEW GUIDE

The first step will be to describe the structures that have been put in place, and to determine the motivation that led to their establishment. In particular to ascertain

1. What type of institutional arrangements have been established to promote the integration of effort to study the low gravity environment.

2. Why was this route followed.

3. Were any studies undertaken to support the decision. Are they available.

4. Were there any guidelines to direct either the studies or the establishment of institutional arrangements.

5. If yes, how were they developed.

6. What are the funding arrangements.

7. Are there sunset provisions.

8. What management control is exercised, and by whom.

9. Are there any provisions for dealing with proprietary interests.

10. Would foreign participation be permitted.

Assess the experience of the institutional structures in meeting their objectives; this will include

11. How did they become established - by competitive process, selection without competition, unsolicited proposal, etc.

12. Was there a strong technical base present upon which to build.

13. What facilities are available - drop tubes, rockets, aircraft, etc.

14. What type of cooperative arrangements have developed between academic interests, industry and government laboratories.

15. How do the various participants in an institution participate - provide funds, provide facilities, act on advisory boards, etc.

16. Has a data base been established.

17. Is the current plan being met.

18. What are relations with the sponsor(s).

19. What are plans for the future.

20. What improvements in the arrangements could be made.

The information gathered will be collated and conclusions drawn. The results of this assignment will be combined with those of the NASA study to form a basis for discussion in respect of the approach Canada might take.

Dr. J. D. Keys of Philip A. Lapp Limited, Toronto, has been retained to prepare a report on the findings of this project, and he may want to contact individual interviewers for clarification once the summaries have been received.

SUMMARY OF NASA ASSIGNMENT

BACKGROUND

NASA has established a number of centres to investigate opportunities for research in low gravity. These centres fall into two categories - Centres of Excellence (CE) sponsored by the Office of Space Science and Applications (Code E) and Centres for Commercial Development of Space (CCDS) funded by the Office of Commercial Programs (Code I). Both programs require that there be industrial partners as part of the Centre, but in the case of the CCDS, there is the added condition that the industrial partners be American owned and American controlled.

Canada will have a significant stake in the US space station project, and will also participate with ESA and possible other foreign programs. Therefore we should take appropriate steps to develop a user community that can take advantage of our investments in these cooperative programs. As a minimum we should understand the institutional structures our partners and potential partners have established to promote investigation in the low gravity environment.

As a first stage in the assessment of structures in foreign countries the NASA experience has been examined. The findings are summarized below. We now wish to broaden the study to encompass our other partners (and potential partners) to gain assessments of their approaches. The final stage will be to consult within the Canadian community, with the foreign experience as background, to see what steps we should take to promote Canadian interests in this field.

THE NASA FINDINGS

In order to assess the US experience in establishing Centers for the Commercial Development of Space (CCDS) supported by NASA Office of Commercial Programs and Centers of Excellence (CE) supported by the Office of Space Science and Applications, NASA Headquarters (Office of Commercial Programs), and eight centers have been visited. Of these, six are located in universities, one in a non-profit organization, and one within a NASA research centre (funded by the Office of Space Science and Applications).

The Centers' programs are relatively new, having come into being about two years ago, and are still being expanded. With one exception, the university Centers visited were created as a result of the first solicitation for proposals. The exception resulted from an unsolicited proposal.

All centers have industrial affiliates. In the case of CCDS, these must be US owned and US controlled; no such restrictions apply to CE. Industrial participation takes several forms, including in-kind contributions, cash, and on a no-exchange-of-funds basis, with the former predominating. NASA estimates that in the case of CCDS, industrial contributions outweigh NASA grants by as much as 1.5 to 1.

Centers are funded by block grants. CCDS are funded on a five year basis (on average about $750K annually), and are expected to be self-supporting at the end of that time, but this is likely to be extended as a result of the shuttle disaster. CE are funded for three years. All centers are reviewed annually, with continued support subject to satisfactory performance.

All centers have been established where existing strong ground-based programs have been in place, and where a recognized reputation in a particular field has been achieved. NASA funding is used to shift the particular focus from ground-based to space-based.

Of the centers visited, NASA support has resulted in some successes, not all directly related to space, and none with immediate commercial applications. There is a common view in the centers that the need is for a data base, from which experiments leading toward commercialization will develop in the future; the promise of early commercial returns may have been oversold.

In most cases, the centers are pursuing a relatively few number of projects, reflecting the level of funding available. There is direct industrial involvement in the projects, and for the most part with industrial co-investigators. NASA facilities are made available free of charge; this includes not only hardware such as drop tubes, but also research personnel.

Frequently, institute investigators participating in the program of a CCDS receive support from the Office of Space Science and Applications for projects outside the centre. The leads to a perception that NASA is two-headed, and that coordination of support could be improved. There are also implications for foreign participation, since there are restrictions only on the programs of CCDS.

From discussions with NASA and with CCDS and Centers of Excellence (CE), we have concluded the following in respect of the motivation that led NASA to adopt this strategy.

1. The authority resides in the Act, no special submissions were required, and no special studies were commissioned.
2. There is one view that the CE concept was a creature of Congress. The CCDS, probably patterned after NSF programs, originated in Code I.
3. For CE, it appears that competence in a technology that might have space applications is the main criterion. In the case of CCDS, there is an additional requirement that written evidence of industrial participation and commitment

must also be obtained.

4. Funding for CE is on a three year basis with annual funding reviews. CCDS are supported for five years, subject to annual funding reviews, which also include a review of industrial support.

5. There is no clear policy in the matter of sunset provisions for CE. In the case of CCDS however, Code I block funding will cease after five years, at which time they should be self-supporting, presumably mainly by industry. There is speculation that the five year period may be extended.

6. Each centre is required to have a Board of Directors, the exact shape of which is left to the discretion of the centre. Boards of CCDS must be composed of mainly industrial representatives. Code I has a peer review system in which the industrial membership is 75%

7. Proprietary issues appear to be creating some problems. As long as the work of the centre is generic, all industrial partners benefit. When a particular project shows commercial potential, there does not appear to be a clear path by which the work is removed from the purview of the Board. As a general policy, there is a two year patent protection period, but even this runs afoul of academic freedom in some cases.

8. Foreign participation is a sticky issue. CE have no restrictions, but CCDS bar foreign owned or controlled companies. Although the matter does not appear to have arisen in practice, engagement on foreign nationals in the programs of CCDS does not appear possible. It should be borne in mind however, that PI's working in CCDS are eligible for support from Code E, and foreign nationals are permitted to work under that program.

The experiences of the centers can be summarized as follows.

1. Most became a centre by responding to a solicitation. At least one submitted an unsolicited proposal that was accepted.

2. Every centre has cooperative projects with industry. In most cases there is a co-investigation team, and there is an obvious commitment to seek commercial applications. This is equally true for both CE and CCDS.

3. In each case there was a strong technical base upon which to build, at least in respect of people. Most centers have

their own facilities, developed to some extent by industrial partners. One or two rely on the facilities of the PI's home department or institute.

4. The data base in most cases is weak, and the need to augment it is recognized by everyone. In fact, this appears to be the main goal at present.

5. A variety of cooperative arrangements are in place. NASA laboratories are open to PI's from centers, without fee. In nearly all cases, centre projects have an industrial PI participating. One centre appears to be focussing on an educational program, in order to attract investigators to the low-gravity field.

6. Industrial support is almost exclusively of the in-kind variety, and this has implications for the self-sufficiency targets. There is difficulty in acquiring additional industrial partners in the absence of demonstrated commercial pay-off. One centre has been fortunate, and industrial support is formidable. CE do not appear to attach quite the same importance to the type of industrial involvement, and the funding arrangements are less formal.

7. Since the centers are relatively young, and no formal targets appear to have been set, not much of a definitive nature can be concluded regarding progress against expectation.

8. Relations with the sponsor are good. There are some complaints about the frequency of reporting (quarterly), and a feeling that coordination within NASA and also amongst the centers could be improved. The most significant comments relate to the projects. These fall into two categories, quality and expectation. In regard to the former, there is some concern that the experiments flown at great expense may not have been carefully evaluated in advance. As for expectations, there is universal belief that commercialization in beyond the horizon.