NASA CENTERS

FOR THE

COMMERCIAL DEVELOPMENT OF SPACE

AND

CENTERS OF EXCELLENCE

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Executive Summary

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 center (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 center. 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 center is required to have a Board of Directors, the exact shape of which is left to the discretion of the center. 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 center 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 center by responding to a solicitation. At least one submitted an unsolicited proposal that was accepted.

2. Every center 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, center projects have an industrial PI participating. One center 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 center 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.

The situation is still evolving in the US, and with this in mind, the following recommendations have been developed.

Recommendation 1. **The Canadian program to support commercialization of space should concentrate mainly on the development of a non-proprietary data base in subject areas of interest.**

Recommendation 2. If Canadian centers are established, they should be located at universities, involve industrial participation, with the requirement that affiliate companies undertake a formal commitment to support the work of the center.

Recommendation 3. Given that the focus at centers will be on acquisition of generic data, there should be no restriction on ownership or control of participating companies.

Recommendation 4. Canada should be selective in establishing centers for the commercial development of space, and should concentrate on those subject areas that coincide with Canadian industrial strength.

Recommendation 5. Future symposia, workshops or similar gatherings should have guest speakers from US centers who would describe their operations in the context of Canadian participation.

Recommendation 6. Consideration should be given to establishing a program to support Canadian doctorate and post-doctorate studies at appropriate US centers.

Recommendation 7. The experience of European countries, Japan, and other countries pursuing commercial development of space should be determined and assessed before a decision on the establishment of centers in Canada is taken.

1.0 INTRODUCTION

1.1 Background

NASA received its mandate following the Russian flight of Sputnik, and the breadth of that mandate reflects the determination of the government of the time to ensure that the USA would establish and maintain a position of pre-eminence in space. Not only does NASA have wide powers, but it is charged with developing competence in all fields associated with space. This is both a blessing and a curse, since the door is open as far as programs are concerned, but so wide open that specialization is not an option. This responsibility has governed the NASA approach to space, and continues with Space Station.

One of the key clauses in NASA's act directs the agency to take steps to "enable small-business concerns to participate equitably and proportionally in the conduct of the work of the Administration". Furthermore, NASA has almost a free hand to enter into cooperative agreements. And the combination of these two have set the stage for a program to develop commercial opportunities in space. It should also be noted, as will be discussed later, that NASA has a responsibility to support space science. This has implications for the program to establish Centers for the Commercial Development of Space.

Canada has undertaken to become a partner with NASA (and others) in the Space Station Program. While a large part of our contribution will be taken up with the provision of a servicing facility, there will also be opportunities for space science, and beyond that to possible commercial developments. With the advent of the Canadian Space Agency, the institutional structures that Canada might put in place become of increasing importance, and in this connection the steps taken by our partners should be investigated so that we can adopt the successes and eschew the failures.

It is in the context of developing cooperative arrangements between government, industry and universities that the present assignment has been commissioned, and in particular, to assess the NASA program to establish Centers for the Commercial Development of Space (CCDS) sponsored by the Office of Commercial Programs (Code I).

Although the focus of this study is on the commercial aspects, NASA has a further program to establish Centers of Excellence, operated from within the Office of Space Science and Applications (Code E). There are some significant differences in the approach of the two branches of the agency, but there are also areas of overlapping interest. For instance, many Principal Investigators (PI) participating in CCDS are also receiving funding from Code E.

1.2 Terms of Reference

The terms of reference of this assignment are aimed at gathering information on the process by which NASA establishes Centers for the Commercial Development of Space and Centers of Excellence, and also on the experience with those programs. This information should be helpful in deciding what directions Canada should take to develop a user community in this country.

The Terms of Reference are:

1. To determine the motivation that led NASA to embark on a program to establish specialized Centers for the Commercial Development of Space and Centers of Excellence.
2. To assess the results of the NASA programs, and in particular learn what has been successful and what problems have been encountered in CCDS and Centers of Excellence.
3. To recommend what, if anything, Canada should do in the line of Centers to promote the use of microgravity.

1.3 Methodology

The information has been collected by personal interviews, augmented by documentation provided by the Centers visited. Visits to NASA Headquarters, and to Lewis Research Center (LeRC) were made early in the process, in order to gain insight into the reasons why the CCDS program was instituted. Although, as mentioned above, there are two such programs operating from NASA Headquarters, the focus of this assignment is on commercialization of space, and only the Office of Commercial Programs (Code I) in Washington was contacted. Three Centers of Excellence were, however, visited to gain an assessment of that program.

The initial NASA visits were followed by interviews with directors or representatives of a number of Centers operating within non-profit institutes, mainly located in universities, to learn how the program operates from their point of view. Two aspects are of particular interest; how "excellence" is assessed and maintained; and the process by which industrial partners are brought into the operation of the Center and how they are retained. The history of the program is short, as the first institutes were formed as part of a recognized program only two years ago. We thus are looking at what is taking place at the very early stages, when all are feeling their respective ways.

In all, nine visits were made. The list of individuals, and their institutes, with whom personal interviews were held can be found in Appendix A.

2.0 FINDINGS

2.1 The NASA Perspective

The NASA approach to developing a space user community has three components, a set of funding programs operated from NASA Headquarters, an in-house program in NASA centers, and the provision of space-related facilities located in various centers. The centers themselves will provide funding support for work in industry or university that forms part of the center program.

The component of the program in NASA centers that deals with experiments in low gravity falls under the administrative authority of Code E. At the same time, particular experiments may be funded by Code I. There are thus two potential sources of financial support from within NASA, Code E and Code I. The distinction lies in the extent to which information on results can be made public, and Code I restrictions on industrial participation to companies that are American owned and American controlled. The NASA administrative structure as it relates to the establishment of non-profit centers is shown in Table 1 below.

Table 1

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                              |Administrator|
                              -------------
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   --------------------------------------------------------------------
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|Office |     |Office |         |Office |        | Space |       | OAST  |
|Space  |     |Commerc|         | Space |        |Science|       |       |
|Flight |     |Program|         |Station|        |Applic.|       |       |
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            ------------                     ---------------
           | Commercial |                   | Microgravity  |
           |Development |                   | Sci.& Applic. |
            ------------                     ---------------
                  |                                  |
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            |  Centers  |                      |  Centers  |
            |  for the  |                      |    of     |
            |Comm.Dev.Sp|                      |Excellence |
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2.1.1 Office of Commercial Programs

The Office of Commercial Programs, NASA Headquarters, has instituted a program to establish Centers for the Commercial Development of Space (CCDS). The purpose of the program is to develop non-profit/commercial partnerships that will undertake focussed R & D leading to commercial products or processes.

The authority to carry out the program lies in the National Aeronautics and Space Act of 1958, which essentially gives NASA powers to undertake whatever actions it deems necessary to ensure that the US retains leadership in space. This Act was approved in the post-Sputnik era when urgency was paramount, and there was no intention to restrict areas of interest.
The CCDS program was inaugurated in 1985 with the selection of five centers, followed by the addition of a further four in 1986. A third group will be established in 1987, with a fourth to follow in 1988.

The CCDS concept is patterned after the Centers of Excellence program of the National Science Foundation. However, CCDS must not only meet excellence criteria, but also must be able to lever funds from the private sector in order to be eligible for continued NASA support. Furthermore, the focus must be clearly on R & D that relates to commercial opportunities which depend upon space for realization. All private sector participants must be American owned and controlled, and letters of commitment are required. State and local development funds can be contributed and counted as matching funds.

CCDS are established by a process of solicitation. The Center making the proposal must be non-profit, and must show evidence that there is private sector support - direct funds or in-kind support. Proposals meeting the basic criteria are reviewed by a group of peers, about 75% of whom are from the private sector. NASA will provide between $750K and $1M per year for five years to a successful proposer. The usual ratio of private to NASA funding is 1.5 to 1. NASA funding is considered to be seed money, and the Centers are expected to be self-sufficient after five years. It is likely that this time limit will be extended, since access to extended periods in space will not be possible until 1988. The Center must establish a Board of Directors; the exact form to be determined by the Center. There is a period of two years patent protection for inventions arising from work at CCDS.

Project funding is expected to come from other federal departments. NASA funding is in the form of grants, and may not be used for construction of plant. CCDS (and Centers of Excellence) are required to submit quarterly reports of work accomplished, and are peer reviewed annually. The annual reviews assess the technical work, determine that the work in driven by space, and ensure that non-NASA support is being provided. CCDS maintain focus by working on a limited number of projects, in some cases only one or two; in others as many as seven or eight.

The program is new, but already there have been private sector drop-outs, possibly due to the Challenger accident. There has also been one case where a company has been purchased by foreign interests (German), and has therefore been forced to withdraw from the CCDS program. As a general comment, the foreign non-aerospace community has been much more interested in investing in space than has the domestic non-aerospace community.

NASA is considering setting up a Council of CCDS Directors to

- set rules for CCDS directors
- make sure there is no stealing of customers
- be a self-policing body.

There is optimism about the number of flights that will take sector. NASA will provide between $750K and $1M per year for five years to a successful proposer. The usual ratio of private to NASA funding is 1.5 to 1. NASA funding is considered to be seed money, and the Centers are expected to be self-sufficient after five years. It is likely that this time limit will be extended, since access to extended periods in space will not be possible until 1988. The Center must establish a Board of Directors; the exact form to be determined by the Center. There is a period of two years patent protection for inventions arising from work at CCDS.

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There is optimism about the number of flights that will take place annually once the shuttle is back in operation - between 12 and 16 are forecast. Considerable space will likely be available, since the DOD requirements are to be met by ELV's. Already 450 GAS cans have been reserved.

On the matter of information, all the unclassified information, including that pertaining to non-proprietary commercial applications, is available on the NASA RECON data base, accessible through the NASA field centers. Individuals cannot access RECON, but some universities and aerospace companies do have access rights.

The present (April 1987) status of the Code I program to establish CCDS is given in Table 2 below.

Table 2

Centers for the Commercial Development of Space

April 1987

	University Alabama Huntsville	University Alabama Birmingham	Vanderbilt University	Battelle Columbus	IDT Space RS Center	Ohio State University	University of Wisconsin	University of Houston	Clarkson University
Controls & Guidance									
Earth & Ocean Observation					X	X			
Fluid Behaviour & Management									
Glasses & Ceramics				X					
Electronic Materials	X			X				X	X
Space Power									
Space Propulsion									
Combustion Science									
Remote Sensing					X	X			
Communications & Data Systems									
Space Materials & Structures	X								
Metals & Alloys			X	X					
Automation & Robotics							X		
Life Sciences & Human Factors							X		
Biotechnology		X							

2.1.2 Microgravity Materials Science Laboratory
Lewis Research Center, Cleveland, Ohio

The Lewis Research Center (LeRC) is one of three NASA in-house centers investigating materials behaviour in microgravity. The other two are Marshall Space Flight Center, Huntsville AL and the Jet Propulsion Laboratory, Pasadena CAL.

There are about 100 professionals working on materials studies in microgravity at LeRC, not all on a full-time basis. They are located in two divisions, the Space Experiments Office (SEO) and the Materials Division. The latter division has two sections, Ground-based Science Discipline Areas (GSDA) and the Microgravity Materials Science Laboratory (MMSL).

The in-house microgravity program is operated on the matrix principle. The Microgravity Materials Science Laboratory develops projects and experimental equipment. The actual work is performed by investigators located in the Space Experiments Office and the Ground-based Science Discipline Areas. This arrangement has been recently established (1985), and is still evolving. One benefit from the focussed approach on microgravity investigations at LeRC appears to be the development of a sense of competitiveness that has resulted amongst the three NASA centers, leading to better selection of subjects for investigation.

MMSL has a range of experimental equipment available to qualified users, including external users.

- general purpose furnace
- electromagnetic levitator
- instrumented drop tube (1 sec)
- undercooling furnace
- bulk undercooling furnace
- transparent directional solidification furnace

- high temperature directional solidification furnace
- isothermal dendrite growth apparatus
- crystal growth furnace
- single axis acoustic levitator furnace

LeRC has a drop tube (30m), two drop towers (145m and 30m), and a Lear Jet for parabolic flights. This latter came to the Center as a gift from the IRS, who had confiscated the aircraft from a fugitive tax evader. Sounding rockets are also available.

At present there are 30 customers for the facilities - 12 within LeRC, 10 in universities and other NASA laboratories, and 8 in industry.

MMSL receives funding from NASA Lewis and also from Code I. Proposals are made to the two sources of funds and those that are accepted become projects. Since MMSL relies on investigators working in the general field of materials to carry out the projects, people are co-opted from the SEO and GSDA to physically work in the MMSL laboratories. Thus MMSL at any given time can be full of investigators or empty, depending on what projects PI's are working on at that particular time.

MMSL has established a program to bring in university professors, graduate students (who may work toward advanced degrees in MMSL), summer students, students studying in cooperative programs, and high school students. It has been noted that once a scientist has spent more than three years in a field of study, it is almost impossible for that person to change his field of interest to that of microgravity research. Thus the emphasis is on bringing new people into the field at an early stage of their careers.

There is difficulty in attracting private sector financing when commercial prospects are in the distant future. There is a belief in MMSL that the most likely use of space processing will be to fabricate structures that will actually be used in space.

The view is held that a great deal of work must be done on earth before any experiments are flown, and that much can be learned by experiments conducted in drop tubes, aircraft etc. This aspect is recognized by the Germans (DFVLR) who are apparently considering constructing a drop tube identical to the one at LeRC, but to be located above ground. They are also contemplating a balloon drop facility using down-thrusting rockets to overcome drag.

The opportunity is present for cooperative projects with Canadian investigators. It is also possible to rent the facilities, but the joint approach is preferred if there are no proprietary interests, since the facilities are provided free of charge for approved joint projects.

There is an ever-present fear that within a few years MMSL will be instructed to greatly expand the microgravity program, and there will be insufficient people to respond. Hence the emphasis on encouraging young scientists from universities into the program.

2.2 Centers for the Commercial Development of Space (CCDS)

Nine CCDS have been established to date (April 1987); four of the five established as a result of the first NASA solicitation were visited. These were selected on the basis of the subjects of major development focus. The nine CCDS involve more than 100 companies, institutions and government organizations, and represent an estimated commitment of over $100 million in resources.

2.2.1 Center for Macromolecular Crystallography
University of Alabama, Birmingham, Alabama

The Center for Macromolecular Crystallography (CMC) is focussed on the study of protein crystallography. It is in its second year of operation and has attracted the interest of 12 companies each of which has provided guest Principal Investigators to work with the Center. The initial effort to find commercial applications from studies in microgravity is in the process of re-evaluation, as it is agreed by all concerned that what is needed now is a data base resulting from fundamental non-proprietary investigations. The Executive Advisory Board has taken the position that the CMC should foster the scientific aspects of the program rather than the commercial.

The CMC has a staff of 20 - 12 with Ph.D.'s. There are five faculty members from five different departments. The Center concept has been easy to implement, since the University of Alabama, Birmingham (UAB) is itself based on institutes, to which discipline faculty members affiliate. There are also co-investigators located in 8 other universities, the Naval Research Laboratory, as well as a number working in the Marshall Space Flight Center.

Funding from NASA Code I amounts to about $700K annually, with an additional $400K from Code E. Industrial contributions are largely in-kind, but some of this is in the form extremely valuable materials such as those formed by recombinant DNA technology. There is also about $1M from NSF, with another $200K from non-profit organizations and the State of Alabama.

The CMC has flown four missions on the shuttle within a span of one year. The presence of a human was critical since many adjustments to the apparatus were necessary. Enough was learned to keep the Center occupied for at least six months. They plan to be on two spacelab missions in the future.

The first priority for the CMC is to develop micromethods that will permit co-investigators to fly their protein crystallization experiments using techniques and conditions that closely parallel those developed in laboratory experiments. The techniques selected are vapour diffusion and dialysis.

The usual way to grow protein crystals is from solution. The problem in the laboratory relates to the formation of the crystals on the bottom of the container, and the presence of convection as a result of the growth process itself. These may be overcome in low gravity, and lead to the growth of crystals at accelerated rates. The purpose is to grow crystals whose structure can be studied to determine the relationship between structure and biological activity, thus leading to the production of targeted proteins to fulfill specific functions.

The issue of Code I support for US interests only has caused some problems, since at least two large pharmaceutical companies who could contribute are barred because of ownership. CMC has worked around this to some extent by keeping its Code I and Code E support under separate financial administration. Code E has no restrictions on ownership. The situation is considered a bit messy, and there is a view that NASA will have to re-evaluate its policy in this area.

The CCDS concept can do three things

1. Facilitate the involvement of industrial groups in space research who would not otherwise be interested. They provide an easy mechanism that avoids dealing directly with NASA - which is considered very difficult.

2. Provide industry with a data base dealing with the types of materials that are suitable for study, and the type of instrumentation required.

3. Pursue basic research and relate technologies to the long term use of space.

An interesting organizational feature of the CMC is the employment on a half-time basis of a McDonnell Douglas Astronautics Company (MDAC) scientist to act as the associate director responsible for commercialization, design and engineering, and flight operations. Since MDAC is not in the pharmaceutical business itself, there is no problem with this arrangement as far as the affiliate companies are concerned. Furthermore, this arrangement provides a good link between the experiment and the hardware.

2.2.2 <u>Consortium for Materials Development in Space</u> **University of Alabama, Huntsville, Alabama**

The Director of this Consortium has been associated with the US space program since the 50's and has worked in a variety of occupations including the Marshall Space Flight Center (MSFC) in Huntsville. He holds two positions at the University of Alabama, Huntsville (UAH) - Director of Research and Director of the Consortium for Materials Development in Space (CMDS).

The CMDS is barely a year old, the Consortium Council having held its organizational meeting in March 1986. The Center itself is an administrative organization, with no research staff of its own. The university PI's come from the discipline departments or other centers within UAH, such as the Center for Microgravity Research, of which there are four affiliated with CMDS.

CCDS are viewed as vehicles for forming joint university-industry-government teams which are deemed necessary for the US to compete with the Japanese and Europeans. This consortium had a good start since many of the PI's at the university have been involved in the space program for years because of the proximity of the MSFC and the US Army Space Center at Huntsville. This situation made UAH a natural setting for the establishment of a CCDS.

The CMDS is funded through the university, which provides all administrative support. The Center is an initiator and coordinator, developing projects in cooperation with faculty members from UAH departments and research centers. Proposed projects are presented to the Consortium Council for approval. This body is composed of industrial representatives - usually at the V-P level - of firms who make a significant financial contribution to the CMDS. Significant in this context is taken to be 2 py of effort, which is equivalent to about $250K per year. NASA participates with observer status. In addition to the Council, there is a working committee whose membership is drawn from working-level scientists in the firms represented on the Council. This committee provides the forum for preparing recommendations on projects that go to the Council for approval.

The work of the CMDS is structured around projects, tasks and mutual support tasks. The former are active projects with specific goals and planned flight in space; tasks are at the formative stage where work must be done to develop a project or determine that the idea should be dropped; mutual support tasks include flight operations, the developed data base, core facilities.

As with other CCDS, CMDS receives about $750K annually from NASA Code I. Code E support goes to the Research Centers and to PI's within departments. There is thus funding with US ownership contracts (Code I) and funding with no restrictions (Code E). Projects are separated, and the Code E support permits cooperative work with foreign PI's. One example is Don Brooks, who apparently works with PI's who are also associated with the CMDS, but whose projects fall under Code E.

CMDS has six active projects at present and three tasks. The projects are all in the preflight stage, and with the Challenger disaster, there is not much hope of getting into low gravity for another year or so. The ISF is being considered for the early 90's, and application has been made for GAS space on the early shuttle flights.

The initial work on the new superconductors was completed at UAH - partially funded by NASA. The PI for that project is currently working as a member of the co-investigation team studying vapour transport crystal growth. (As an aside, it appears that SDI is interested in these superconductors, and there is a move to establish a new consortium, funded by SDI, to study the fabrication and properties of these materials).

The development of a data base is considered necessary, but industry must be involved in the process so that if commercial opportunities appear, they can be developed with industrial in-house expertise. Although there does not appear to be any proprietary problems at the moment, the US anti-trust laws may work to the detriment of technological development in the country.

There is a problem with the volatile ownership of industry - sell-off of units with research laboratories, buy-outs by foreign interests. This leads to the break-up of teams under the present rules and is counter-productive from the national perspective.

UAH is perhaps in a unique position. It is adjacent to MSFC and many of the companies that support the US space program - and are supported by it in return. The US Army has its space effort located here also - it is larger than MSFC. There if thus a very significant concentration of talent and effort devoted to all aspects of space in the immediate area.

2.2.3 Center for the Space Processing of Engineering Materials
Vanderbilt University, Nashville, TN

The Center for the Space Processing of Engineering Materials (CSPEM) is located within the Department of Mechanical and Materials Engineering, School of Engineering.

The primary objective of the CSPEM is to stimulate new industrial concepts for engineering materials through the utilization of low gravity experimentation, and to promote the orderly transition from research and development to full commercialization. The concept adopted to achieve these goals is the development of a team approach to projects of corporate interest. The projects arise in well-defined areas where a company has identified potential profitable markets.

There are at present 12 industrial members of the Center, who are termed Charter Members. There are two additional categories of membership; Member, not a charter member but later accepted for membership on payment of an entry fee and provision of an agreed level of services annually; and a Small Business Member, intended for small companies such as start-ups who normally lack adequate in-house R & D facilities. In this latter case, a minimum entry fee is levied. The Center is negotiating with the first two companies who wish to become Members.

The work of the Center is approved by a Management Advisory Group which draws its membership from industry, and has a NASA observer. This Advisory Group has four committees

- Executive Committee
- Policy Committee
- Marketing Committee
- Project Viability Committee

Each committee has its own terms of reference and all except the Policy Committee are composed of technical people. The Policy

Committee is a committee of lawyers. The Marketing Committee is responsible for the long-term viability of the Center.

There is an active program to acquire new members. This is carried out primarily through a dog-and-pony show for executives in target companies. It is not clear that there is a two pronged approach involving both the executives and the PI's in the target companies.

While the Center is a creature of Vanderbilt University, University of Alabama at Tuscaloosa (UAT), University of Florida, Oak Ridge National Laboratory are supporting organizations, mainly through the provision of facilities, but there are also projects underway at UAT and the University of Florida. In addition, as a CCDS the Center has access to NASA facilities at MSFC, JPL and LeRC.

Funding for the Center comes through the university which provides the financial management services. NASA is providing about $1.1M annually for five years from Code I. There is one Code E project within the department but outside the Center. Industrial support falls within three categories, direct contributions, direct in-kind, and direct in-kind collaboration. While industrial contributions are estimated to equal the NASA funding, it is almost entirely of the in-kind variety, about equally split between these two categories.

The focus of the CSPEM is on the production and commercialization of metals, alloys, ceramics, and glasses with superior mechanical, chemical, electrical, magnetic, and optical properties. Specific technologies around which the program is organized are containerless processing and containered processing.

Containerless processing involves three principal activities, deep undercooling, ultra high purity materials, and thermo physical property measurements. Containered processing also involves three activities, directional solidification, "uniform" solidification, and casting.

Projects are joint efforts between Vanderbilt University and industry. There are eleven underway at present, each with a team staffed from both the Center and industry.

There is optimism that some of the high value-added specialty alloys may in fact be fabricated in space. Alloys using platinum group metals are already expensive on earth, and if the flight costs can be reduced to about $500 per pound, microgravity processing can be commercially competitive.

On the matter of how such a center might be established, from a PI point of view it would be preferable to fund a center devoted to the study of solidification, with microgravity research as one element of the program. What may have happened at the Center, is that some projects underway at the time the Center was formed were force-fitted to meet NASA requirements; others may not have been well thought-out, and were developed only to use microgravity - a technology push. There is evidence however, that some investigators who were skeptical at the beginning are now seeing some potential. What is really needed is a success.

On the administrative side, quarterly reports are considered to be too frequent, since they are out of date before submitted. Also, the policies regarding reporting relationships amongst the various participants, and matters such as patent rights, proprietary information etc. should be addressed when the center is established. Some problems have apparently arisen, attributed to the fact that the Center was established by researchers without benefit of legal advice.

2.2.4 The Advanced Materials Center for the Commercial Development of Space Battelle, Columbus Division, Columbus, Ohio

After much careful thought and some misgivings, Battelle applied for, and was accepted as a CCDS. The administrative situation looked complicated. Battelle uses universities to perform some of its contract research, and the acceptance of a CCDS placed the organization in a position of acting as a contractor for NASA and a client for universities, while doing some of the work in-house itself. The potential for conflict and dissatisfaction appeared great.

The above notwithstanding, Battelle did become a CCDS and has developed a program. The problems that were foreseen appear to have come to pass, and administratively there is a continual struggle between the funders and the performers.

The Center has been established as a coordinating and administrative office. Participants from within Battelle who are drawn into the program come from discipline groups, and while their participation is funded from the CCDS, they belong to their discipline areas.

The technical monitoring of the program is carried out by the Lewis Research Center (LeRC) on behalf of NASA. The program itself is industry-driven. This is achieved through a Technical Group composed of representatives from industrial affiliates, Battelle, university and LeRC, that meets once or twice a year and works out the program for approval by the Center Advisory Board. Projects are selected on the basis of their commercial interest and also technical merit. It appears that there is considerable debate within the group regarding the merit of proposals that come forward, and the review process will probably result in the termination of some of the present projects. There are six projects at the moment, each with one or two people from

LeRC associated with it. There are 3 or 4 PI's at Battelle working in the Center program.

For projects that involve a university as a sub-contractor, the work to be done by the PI in university is self-contained so that a contractual relationship can be established and maintained. In some circumstances where there is a requirement for a small project, about $10K, a consulting contract may be awarded to the university investigator. This has some attractions, as it avoids university overheads.

As a CCDS, all participants have free access to NASA facilities and personnel, and since LeRC is nearby, there is a close relationship with that Center, although the drop tube at MSFC has also been used. The cooperation of NASA in regard to use of facilities is considered to be an excellent feature of the program.

A continuous effort is made to enlist industrial affiliates. This takes the form of a dog and pony show aimed at company management. Although it is acknowledged that a two level approach - PI to potential PI, and manager to manager - is desirable, it appears that this is not followed in all cases. The attractions to industry are presented as

- large say in the projects to be undertaken
- access to extensive Battelle facilities and personnel
- inexpensive way to get into space R & D
- results from all projects

The projects have been established at two levels. Tier 1 are those that are non-proprietary and open to all members of the Center as far as conduct and results are concerned. Tier 2 are proprietary projects, fully funded by the sponsoring company. There are no tier 2 projects underway at present.

At the end of 1986 there were 5 industrial and 7 university and non-profit affiliates. There has been some change in membership; two companies have withdrawn due to changing priorities. This is likely to be dynamic situation, with comings and goings depending on company interests and perhaps results from the CCDS.

Funding comes largely from NASA, about $850K in 1986. Industrial affiliates contributed about $100K cash, which represents an annual membership fee, and $150K worth of in-kind services. The state of Ohio contributed $60K, and for this has a seat on the Advisory Board. As with all CCDS, the intent is for the Center to become self-sufficient, free of NASA subsidies, in five years. As with the other CCDS, and in fact NASA itself, this does not appear to be a realistic expectation. Some funds come in to PI's in Battelle associated with the Center from Code E, but these are accounted for outside the CCDS. In at least one case, a Battelle PI receives funding from NSF.

It is interesting to learn why an organization such as Battelle should be awarded a CCDS when much of the work is sub-contracted to universities. It is acknowledged that this arrangement adds considerably to overhead costs. As an example, with funding at a level of about $1.1M and six projects, the average project consumes $160K annually. With university and Battelle overheads, only about $60K goes to support actual research. A case in point is the situation where the work is divided between two universities, each PI receiving about $30K. It is worth noting that one of the PI's involved in this particular project applied to NASA to become a CCDS and was accepted. There is now a administrative situation where the work of the new Center must be separated from its participation with Battelle, not only for NASA purposes but also to protect the interests of the industrial affiliates.

As mentioned above, the situation of Battelle acting as manager between NASA and the university PI's causes problems. PI's seek additional funds from the Battelle project manager, who in turn makes demands on the Center Director. In the early days, there were problems with university PI's spending beyond the agreed funding limits. As a result, Battelle now enters into a firm contract with the university and calls for quarterly reports. This is considered essential in order to maintain control.

There is also a potential problem for the universities in the event that the project is terminated, which can happen with the technical group selection procedures. This is further aggravated by the funding level which remains constant with the result that new projects cannot be started without terminating existing ones. Universities use graduate students who must present results for a thesis. Of the six projects, one is carried out completely in Battelle, one completely in a university, and the other four joint.

The technical program has four components

- Catalysts
  - 1A. Mixed-chloride catalysts
  - 1B. Zeolite catalysts
  - 1C. Mixed-oxide catalysts
- Multiphase-polymer component systems
- Electronic materials (II-VI compounds)
- Controlled porosity glass.

The work is at the fundamental stages at present and there is no need for long periods of low gravity, hence the absence of shuttle space is not hindering the program. Use has been made of drop tubes and the KC 135 is being considered. They have found that for rapid solidification experiments 2 seconds of microgravity are adequate, and consideration is being given to constructing a drop tube to meet this time requirement at Battelle.

2.3 Centers of Excellence

The Centers of Excellence are supported by block grants from the NASA Office of Space Science and Applications (OSSA), and are similar in concept to the CCDS, except that there are no restrictions on the ownership or control of the industrial affiliates. Six centers have been established. There is no direct commercial implication in the work of the Centers, although applications are certainly sought and expected.

The OSSA also supports work in the NASA in-house centers, as well as basic and applied work in universities, the latter for specific projects. This Office also supports industry sponsored investigations in low gravity through Technical Exchange Agreements and Joint Endeavour Agreements.

Centers of Excellence have been established through a process of solicitation and also as a result of proposals from universities. Projects funded arise from proposals received from all communities. The proposal is tested for concept feasibility, subjected to detailed laboratory investigation, assessed to confirm the need for low gravity, and reviewed to ensure that the key experiment is being carried out. The philosophy is to encourage joint university-industry studies in basic research, and when a commercial opportunity is identified, to negotiate a joint endeavour agreement.

2.3.1 Bioprocessing and Pharmaceutical Research Center
University City Science Center, Philadelphia, PA

The Bioprocessing and Pharmaceutical Research Center (BPRC) is a research institute within the Space Division of the University City Science Center (Philadelphia), a regional not-for-profit organization owned by 28 member universities and health professional institutions in the Delaware Valley. The University

City Science Center has a number of divisions including a Research Institutes Division, a Research Park Division, and The Advanced Technology Center of Southeastern Pennsylvania (ATC).

The BPRC has been accepted as a Center of Excellence supported in part by the Microgravity Science Application Division of the Office of Space Science Applications (OSSA). It was founded in 1985 in response to a solicitation from OSSA issued in 1984, and is one of two successful applicants at that time, the second being in Tucson.

There is a Board of Directors with a limit of nine, of which five positions are occupied. The Board advises the Director of the Center, but since the latter is part of the University Science Center, it also advises the Board to that body. Less than half the members of the Board are from industry, although the payload specialist from McDonnell Douglas has been a Director from the beginning.

The BPRC receives funds from five sources, the ATC, the Greater Philadelphia First Corporation (GPFC), NASA, affiliates, and user fees. The breakdown of the minimum projected contributions for the year 1 July 1986 through 30 June 1987 is as follows:

	Amount (000 $)	Percent
ATC	244	23
GPFC	326	30
NASA	508	46
Affiliates	15	1
User fees	3	-

The Greater Philadelphia First Corporation (GPFC) is a form of community chest that obtains subscriptions from companies in the area, and uses the funds to promote the development of industry. Companies subscribe on the average $20K per year, and at the moment about 20% of the total contributed goes to the BPRC.

Funding from NASA is for a three year period at the end of which there is a review. This can lead either to an extension of the funding or termination of support. The State funding is limited to three years by statute. In response to an affiliates campaign in the first two years, 17 companies contributed either cash or in-kind to the BPRC, but that number has since dwindled to 9. Proprietary interests are protected. If a company pays the entire cost of an investigation, the intellectual rights remain with that sponsor. If there is cost sharing, the Center receives a small percentage of the royalties, about 5%. This will change to about 20% in the near future.

BPRC has four tasks:

- to build a physical center
- to acquire staff
- to develop research programs in separation science and cell growth
- to develop an outreach program

It has been successful in the first three tasks, although the Challenger disaster has had a detrimental effect on staff and they are now down to two professionals and two technicians. There is an annual peer review of the work of the Center, but the Board does not take an active role in this process.
The Center is well equipped for research in the two selected fields. It occupies about six offices in one building of the Science Center, and appears to have established a unique facility. They have a Continuous Flow Electrophoresis System (CFES) and a Pen Kem System Electrokinetic Analyzer for use in the Free Fluid Separation Program. The former is similar to the unit flown by McDonnell Douglas in the Shuttle, although the throughput is much less.

They also have modern and sophisticated equipment for studies in Cell Science, including a conventional reactor, a hollow fiber flow-through culture system and a Horizontal Rotational Device.

The development of an industrial constituency has been difficult, and it seems as though the Center is not developing as planned, although there is plenty of evidence that they have made significant contributions to science. They have reserved three GAS cans, but only one is likely to fly in the foreseeable future, so the ability to actually experiment in space is limited.

A site visit is important when Centers are being selected. A Board should be established at the outset, even if its terms of reference are only to set up the mechanics of a permanent Board. Funding should not be provided for bricks and mortar, and it is essential to support excellence not greed. Finally, there is no sure way to ensure that the center established will in fact be excellent.

2.3.2 Center for Separation Science
University of Arizona, Tucson AR

The Center for Separation Science (CSS) is focussed on the study of electrophoresis (EP) as a technology, as it has been for many years before NASA became interested in possible microgravity applications. The Director has had a life-long interest in the subject with particular emphasis on water purification and the removal of undesirable elements from blood plasma.

About 15 years ago NASA invited the laboratory to participate in the space program. It has been supported by NASA since that time, and two years ago became one of two Centers of Excellence funded by the Office of Space Science Applications (Code E). The other is the Bioprocessing and Pharmaceutical Center in

Philadelphia.

The CSS was established to cover all aspects of EP, and in this it has succeeded. There are now 7 or 8 permanent staff (Ph.D. level) with post-doctorate fellows and graduate students - some from Europe. This Center is recognized as the leading institute that covers the full EP field of study, although in specific areas others are more expert.

It is acknowledged that the Center has failed to attract funding from industry. There is neither surprise nor dismay at this situation, as there are no obvious commercial opportunities for EP in low gravity. However, because of the significance of the work, the Center has received donations of specialized equipment - some from as far away as Germany.

The Center's work deals with the preparatory aspects of EP. Until the last few years there were only four laboratories in the world investigating this aspect of EP, one in each of Germany, UK, South Africa and the USA (Arizona). On the other hand, there are between 20 and 40 thousand laboratories in the world equipped with EP apparatus, which is now as common as pH meters. Thirty companies in the US alone sell EP equipment.

The work of the Center is not dependent on the availability of low gravity, an environment that is considered to provide only a marginal degree of improvement beyond what is available on earth. However, four experiments have been carried out in low gravity, three on Apollo missions and one in the shuttle. Unpredicted results were obtained on one flight, which led to investigations in a new direction. While the exact results have not been reproduced on earth, the particular phenomenon has been explained, and in fact, had been observed in a different set of experiments where its presence was not significant and had therefore been overlooked. This example was cited to show that low gravity is not essential for the study of EP.

Low gravity EP experiments can be done in one hour, thus a seven day shuttle flight is wasted unless there are a number of experiments performed. Each experiment gives one point on a graph, and many points are needed. The view was expressed that in spite of the strong programs in EP pursued by the USSR, Germany, France, US and Japan, there is no evidence that much is to be gained from low gravity experiments. McDonnell Douglas are held to have done a service in promoting the use of low gravity, but a disservice in overselling the virtues of EP in that environment.

The NASA approach is welcome, and is considered to be of the right form, since it supports science without the need to identify a particular potential application, as is the case with National Institutes of Health funding, for example. However, NASA is perceived to have two shortcomings

- lack of coordination between various offices dealing with the same technology
- overselling commercial pay-offs

The former results in a lack of focus by the best practitioners, and the latter may cause a political problem when Congress eventually becomes disenchanted with the lack of commercial results.

The view was expressed that the joint university-industry programs will soon disappear. As an example, the drug companies will spend their own money when they see a potential profit. The major ones have R & D budgets in the region of $300M annually, and generally don't want to be bothered with government programs, particularly when they view government regulation as one of their own main problems.

There is a suspicion that NASA was forced into the Center of

Excellence program by Congress, who provided an unasked-for $2M in the NASA budget, and directed that it be used for this purpose. When the program started it was argued that only one center be established to combine the talents of all who work in the field. NASA opted for two.

NASA is not perceived to have any firm idea of what a center should do. No specific charge is given to provide a special service, and its actions are purely responsive. Furthermore, there is a perceived danger in accepting NASA support, as it may make it more difficult to obtain funding from other sources, who don't want to fund "NASA programs".

This Center receives $450K annually from NASA and $180K annually from the University of Arizona. Industry has provided about $250K worth of equipment outright, another $100K on long term loan and about $80K-$90K in cash.

The CSS can award its own degrees in Chemical Engineering, but students from other departments can also do their experimental work in the Center. In these cases, there is joint direction by professors from the department and the Center.

The Japanese approach was cited as an example of how to organize a coordinated approach to technological innovation. When MITI decreed that EP was important, Mitsubishi and Hitachi joined forces to develop a program. Hitachi alone has eight engineers devoted to EP.

The importance of a ground-based program was emphasized, with low gravity playing only a part. The need to critically assess the space experiments is also recognized, in order to ensure that expensive undertakings are geared to testing a useful hypothesis.

2.3.3 Center for Low-Gravity Fluid Mechanics and Transport Phenomena University of Colorado, Boulder, COL

The Center for Low Gravity Fluid Mechanics and Transport Phenomena (CLgFT) is part of the program of the University of Colorado to meet the challenge of the President who has proclaimed that "The University of Colorado will achieve national pre-eminence as a leading university in space education and research". The Center was formally established in September 1986, and acts as a Coordinator for faculty and students from discipline departments who wish (or can be persuaded) to pursue their own research interests using low gravity as one laboratory. It is only one of many University of Colorado initiatives and programs in science, technology, education and law, all related to low gravity.

It appears that the initial interest in low gravity was stimulated by the availability of NASA funds. This has developed into a program to introduce recent graduates, and where possible established investigators, into the possibilities of the low gravity environment. At first, the established faculty were skeptical, but after three seminar series presented by the Center, enthusiasm appears to have developed. This seminar program started in 1986 and is open to faculty, students and industry. The aim is to promote experimentation in low gravity through the careful selection and evaluation of projects.

Industry participation in the seminars has been largely Western US, particularly local. There has been no industry funding to date. The Center has an "affiliate" program, with no fee or other financial commitment required. Affiliates are expected to provide information such as technical reports to the Center, and in return receive information of a similar nature from the Center. They can also participate in the outreach program.

Funding for the Center comes from NASA and the University of Colorado. The former is providing \$750K and the latter \$400K for the initial period September 1, 1986 to February 29, 1988.

The program of the CLgFT has three major components

- Research
- Education
- Outreach

In the research field, the Center has initiated 5 projects involving 7 staff members. All projects are in the very early stages of development. The Low-Gravity Science Seminar Series represents an important educational activity of the Center. This series, begun when the Center was formed, will have included 24 lectures by the end of the spring 1987 semester. The goals of the outreach program include the development of cooperative research and education programs with industry, government and university groups.

The experimental program and the outreach program together have attracted 19 investigators, generally from the discipline departments. There is some expectation that a tenure-stream position for the program may be obtained for the Center in the near future. The main thrust at the moment seems to be on education - seminars and courses on subjects of potential interest in microgravity research. This has brought some new graduates into the program, and has stimulated a few undergraduates to produce papers on planning experiments in low gravity.

There is some criticism of the US microgravity research program, and it is compared rather unfavorably with the careful planning that takes place in, for instance, the German program. There is a perception that this situation could be rectified if all Centers of Excellence were to be managed by JPL, who perform research themselves and have a good reputation, as opposed to the present arrangement whereby the management resides in NASA Headquarters where there are no practicing scientists.

A further perception is held that coordination between the various offices in NASA that support microgravity research could be improved. Better focus and leadership would result. NASA is viewed as purely responsive, but it is acknowledged that NASA funding, which was easy to start with, was a key factor in drawing investigators into the microgravity program. The funds have been more difficult to obtain in recent times.

There is a strong advocacy for careful experimental planning. It is held that the 3M experiments lasting 7 days might have been carried out in one hour, thus freeing up valuable shuttle time. There is also the story (repeated in another center) of an electrophoresis experiment that employed a vapour lamp as a source of illumination. When turned on in low gravity, the convection currents were absent, resulting in an intensity that masked the effect to be recorded - before the lamp burned out! There is a suspicion that other experiments may have suffered from similar, but not so drastic, miscalculations.

There is also a perception that the materials processing community is not well organized, in contrast to the life science community who have a returnable capsule ready for an Ariane launch. This will be a short duration flight, potentially of interest to materials processing, and apparently not known within the latter community. The space science community are seen as particularly active and well organized in Washington.

CLgFt was started as a result of a UP. It appears that there is a lot of competition between Centers, rather than cooperation, and it is felt there is a danger that in the long run this will harm the program as a whole and good centers may lose out along with the bad.

The policy regarding affiliates is that they

- will be kept informed of seminars, papers etc.
- will provide the CLgFT with information
- will exchange publications without requests
- have a standing invitation to collaborate
- submit a letter of agreement to participate, with the name of a contact
- join on a no exchange of funds basis

3.0 CONCLUSIONS AND RECOMMENDATIONS

The purpose of this assignment was to seek answers to some specific questions regarding NASA CCDS and Centers of Excellence, and also to reach some judgement on the results achieved, both actual and in relation to expectations.

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 center is required to have a Board of Directors, the exact shape of which is left to the discretion of the center. 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 center 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 center by responding to a solicitation. At least one submitted an unsolicited proposal that was accepted.

2. Every center 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, center projects have an industrial PI participating. One center 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 center 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. Of the centers visited, only one seems to be in trouble with the sponsor. The reasons are not obvious. There has been reasonable productivity, but difficulty in retaining industrial affiliates. The staff has dwindled, so productivity will surely follow.

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.

The process of developing commercial interest in using microgravity has been, and still is, difficult. There are few if any immediate applications that can yield short-term returns, and therefore industrial interest only arises if a particular company has a research program of its own in a subject area where gravitational effects play a role, and there is benefit from acquiring a better understanding of the part played by these effects. Furthermore, in almost all cases, the industrial contribution is modest, a few tens of thousands of dollars annually cash, or services/personnel/equipment provided in-kind. One exception is the growth of protein crystals, where industry has provided materials that are valued at about $1M. The US experience suggests that the Canadian program should concentrate on acquiring results that will be generic in nature, rather than focussing solely on projects that appear to serve only proprietary interests. This leads to

Recommendation 1. **The Canadian program to support commercialization of space should concentrate mainly on the development of a non-proprietary data base in subject areas of interest.**

Most of the Centers are located in the university environment, and are based on particular expertise entrenched over a period of time. One exception is a non-profit organization, which sub-contracts a portion of its program to universities, thus introducing an additional level of management into parts of the program. There does not appear to be significant differences in the approach taken by the CCDS or Centers of Excellence in respect of quality. Both attempt to attract industrial affiliates, and both have programs that are terrestrially based with projects that will use the microgravity environment.

Recommendation 2. **If Canadian centers are established, they should be located at universities with established departments where the investigators are willing to perform experiments in low gravity, involve industrial participation, with the requirement that affiliate companies undertake a formal commitment to support the work of the center.**

There is a difference in the requirements regarding industrial affiliates. CCDS affiliates must be American owned and American controlled. There is no such restriction on affiliates of the Centers of Excellence. This causes some problems, partly because many PI's operating within CCDS are also supported from Code E, but more importantly, at least one American company has been taken over by European interests and therefore has had to withdraw from participation. Others who would like to join have been barred. The intent is to keep technology within the US, but the effect will probably be to drive technology development to ESA, to the detriment of development and application in the US. The differing requirements by different groups within NASA reflects a dichotomy in the organization's approach to its mandate and the US policy requirements. Code I has grave concerns regarding the Code E approach as it relates to US technological sovereignty.

Recommendation 3. **Given that the focus at centers will be on acquisition of generic data, there should be no restriction on ownership or control of participating companies.**

In total, relatively few experiments have taken place in low gravity as a direct result of the formation of both types of centers. This is not surprising since both programs are new - about two years old.

The NASA approach has not met with universal approval by the Centers, not surprisingly. There is one view that NASA should be more selective and in fact should have a strong hand in defining programs. This view is coupled with an opinion that this cannot be done from Washington (no experts) and must be run from one of the NASA laboratories with a proven track record, JPL for instance.

Another opinion expressed is that NASA never wanted to establish Centers of Excellence - it was forced on them by a determined Congress. NASA has then failed to focus the Centers by allowing more than one center to develop when there should have been one coordinated approach by several centers.

Recommendation 4. Canada should be selective in establishing centers for the commercial development of space, and should concentrate on those subject areas that coincide with Canadian industrial strength.

On a more positive note, in at least two cases, NASA support has led to significant results, although as is usual with basic research, in unexpected areas.

Whatever the actual merits of the NASA approach, it has been developed to meet the agency objectives to support research on the one hand, and the national interest to see the results of research find their way into the marketplace on the other. Money has been used as an incentive, and at least in the early days has been easier to obtain from that source than from others such as NSF or NIH. There are signs that as PI's are drawn in and become competent in microgravity work, funding from NASA will become more competitive.

The program is still expanding, with more CCDS to be established over the next few years. The subject areas for funding have been specified by NASA in the solicitation for proposals, and eventually all areas will be supported. At present there is some overlap between centers, but that will not be continued with new centers.

With regard to commercial potential, there is virtually a consensus that commercial returns are a long way in the future and that factories in space are figments of imaginations. In fact, there is a very real concern that commercial aspects have been oversold, and that before long there will be a political backlash. On the other hand, there is universal enthusiasm and belief that investigation in microgravity will yield results that will benefit terrestrial processes. One concern expressed is that once the shuttle commences flying again, there will be a further explosive push to develop commercial applications, and the base to even enrich the current activities will not be present.

Some points regarding funding are worth noting. CCDS receive on average about $750 annually from Code I, and CE in the same general range from Code E. Matching funds, usually from the university or state, can bring the total to over $1M annually, which leads to about $200K for each project. BY the time overheads are stripped and salaries paid there is not a lot left for supplies, equipment, travel (of which there seems to be a lot, much at NASA's beckoning) etc. And none of these funds is required for purchase of flight facilities or for use of NASA laboratory facilities such as drop tubes. Unless Canadian investigators can join with US counterparts, Canadian projects requiring the use of these facilities will have to pay the user charges, which will add considerably to costs.

Amongst the US centers visited, there is universal support for the concept of joint projects with Canadian PI's, and in fact several cooperative arrangements are already in place. Because of the Code I restrictions, these take place with US PI's who are supported by Code E, but also affiliate with the Code I centers. While there may be some reluctance to submerge Canadian R & D in a US program, cooperative projects are attractive because of the opportunity to move up on the learning curve, and also for the not inconsiderable financial benefits of free access to low gravity. While this approach will have to be pursued with care, there are significant opportunities, particularly for training young scientists.

Recommendation 5. **Future symposia, workshops or similar gatherings should have guest speakers from US centers who would describe their operations in the context of Canadian participation.**

Recommendation 6. **Consideration should be given to establishing a program to support Canadian doctorate and post-doctorate studies at appropriate US centers.**

Given the US experience, the long-term nature of space commercialization, and the not inconsiderable costs involved in space R & D, the establishment of centers in Canada should be approached with care, and the way in which other countries are dealing with the situation should be determined and assessed.

Recommendation 7. **The experience of European countries, Japan, and other countries pursuing commercial development of space should be determined and assessed before a decision on the establishment of centers in Canada is taken.**

APPENDIX A

Interview List

1.	Mr. Ike Gillam	Office of Commercial Programs NASA Headquarters 600 Independence Ave. Washington, D. C. 20546S (202) 453-1123
2.	Dr. Paul Todd	Bioprocessing Research Center University City Science Center 3624 Market Street Philadelphia, PA 19104 (215) 387-2255
3.	Mr. Tom Glasgow, Manager	Microgravity Materials Science Laboratory Lewis Research Center 21000 Brookpark Rd. Code 5180 Rm 103 Cleveland, OH 44135 (216) 433-5013
4.	Dr. Jean N. Koster (Assoc. Director)	Center for Low-Gravity Fluid Mechanics and Transport Phenomena University of Colorado at Boulder Engineering Center, ECOT 5-7 Campus Box 432 Boulder, COL 80309-0432 (303) 492-6945
5.	Dr. Milan Bier	Center for Separation Science Building 20. Room 157 University of Arizona Tucson, AR 85721 (602) 621-4952
6.	Dr. Charles Bugg	Center for Macromolecular Crystallization University of Alabama 1918 University Blvd. Birmingham, AL 35294 (205) 934-5329
7.	Dr. Charles Lundquist	Consortium for Materials Development in Space Research Institute Building University of Alabama Huntsville, AL 35899 (205) 895-6100

8. Dr. R. A. Overfelt (Assistant Professor)
   Center for Space Processing of Engineering Materials
   Olin Hall
   Vanderbilt University
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9. Dr. Alan J. Markworth (Assoc. Manager)
   Battelle Center for Commercial Development of Space
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   (614) 424-6376

APPENDIX B

Reference Literature

Reference Literature

1. Microgravity Science and Applications Bibliography (1986 Revision), NASA Technical Memorandum 98608, January 1987

2. Research Opportunities in MIcrogravity Science and Applications During Shuttle Hiatus, Bruce N. Rosenthal and Thomas K, Glasgow, Lewis Research Center, Cleveland, Ohio, Richard E. Black, George C. Marshall Space Flight Center, Marshall Space Flight Center, Alabama, Daniel D. Elleman, Jet Propulsion Laboratory, Pasadena, California, 32nd International SAMPE Symposium and Exhibition, Anaheim, California, April 6-9, 1987

3. Semi-Annual Progress Report, Center for Low-Gravity \fluid Mechanics and Transport Phenomena, College of Engineering and Applied Science, University of Colorado, Boulder, September 1, 1986 - February 28, 1987

4. Annual Report, Technical Section, Consortium for Materials Development in Space, The University of Alabama in Huntsville, Huntsville, Alabama 35899, Sept. 15, 1985 - Sept. 14, 1986

5. Annual Report, Center for the Space Processing of Engineering Materials, Vanderbilt University, Nashville, TN

6. Annual Report, The Advanced Materials Center for the Commercial Development of Space, Battelle, Columbus Division, 505 King Avenue, Columbus, Ohio 43201-2693, October 1, 1985 - September 30, 1986

7. Technical Programs of the Bioprocessing and Pharmaceutical Research Center, University City Science Center, Philadelphia, PA 19104