BOEING

Volume 7-2
Final Report

7

Data Book
D180-27477-7

Space Station Needs, Attributes, and Architectural Options Study

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Battelle
Life Systems, Inc.
HAMILTON STANDARD Division of UNITED TECHNOLOGIES
RCA
ENVIRONMENTAL RESEARCH INSTITUTE OF MICHIGAN
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Microgravity Research Associates, Inc.
NBS
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Space Station
Needs, Attributes and Architectural Options Study

Contract NASW-3680

D180-27477-7

Final Report

Volume 7 - 2

Data Book

Commercial Missions

April 21, 1983

for

National Aeronautics and Space Administration

Headquarters

Washington, D. C.

Approved by Gordon Woodcock
Gordon Woodcock,
Study Manager

Boeing Aerospace Company

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BOEING

FOREWORD

The Space Station Needs, Attributes and Architectural Options Study (Contract NASW-3680) was initiated in August of 1982 and completed in April of 1983. This was one of eight parallel studies conducted by aerospace contractors for NASA Headquarters. The Contracting Officer's Representative and Study Technical Manager was Brian Pritchard. The Boeing study manager was Gordon R. Woodcock.

The study was conducted by Boeing Aerospace Company and its team of subcontractors:

Arthur D. Little, Inc. (ADL)	Materials Processing in Space
Battelle Columbus Laboratories	Materials Processing in Space
ECON, Inc.	Pricing Policies and Economic Benefits
Environmental Research Institute of Michigan (ERIM)	Earth Observation Missions
Hamilton Standard	Environmental Control and Life Support Equipment
Intermetrics, Inc.	Software
Life Systems, Inc. (LSI)	Environmental Control and Life Support Equipment
Microgravity Research Associates (MRA)	Materials Processing in Space
National Behavioral Systems (NBS)	Crew Accommodations and Architectural Influences
RCA Astro-Electronics	Communications Spacecraft
Science Applications, Inc. (SAI)	Space Science

This document is one of seven final report documents:

D180-27477-1	Volume 1, Executive Summary
D180-27477-2	Volume 2, Mission Analysis
D180-27477-3	Volume 3, Requirements
D180-27477-4	Volume 4, Architectural Options, Subsystems, Technology, and Programmatics
D180-27477-5-1	Volume 5-1, National Defense Missions and Space Station Architectural Options Final Report (SECRET)
D180-27477-5-2	Volume 5-2, National Defense Missions and Space Station Architectural Options, Final Briefing (SECRET)
D180-27477-6	Volume 6, Final Briefing

D180-27477-7-1	Volume 7-1, Science and Applications Missions Data Book
D180-27477-7-2	Volume 7-2, Commerical Missions Data Book
D180-27477-7-3	Volume 7-3, Technology Demonstration Missions Data Book
D180-27477-7-4	Volume 7-4, Architectural Options, Technology, and Programmatics Data Book
D180-27477-7-5	Volume 7-5, Mission Analysis Data Book

Note: The volume 7 data books will be distributed to a limited number of requestors.

The study task descriptions and a final report typical cross reference guide are found in Appendix 1.

The Boeing and subcontractor team member are listed in Appendix 2.

Acronyms and abbreviations are listed in Appendix 3.

VOLUME 7-2
DATA BOOK

Commercial Missions

TABLE OF CONTENTS

7.2.1 Subcontract Study Results

7.2.1.1 Space Production of Semiconductor Crystals (Microgravity Research Associates, Inc.)

SPACE PRODUCTION
of
SEMICONDUCTOR CRYSTALS

A STUDY PRODUCED
for
BOEING AEROSPACE COMPANY

by
MICROGRAVITY RESEARCH ASSOCIATES, INC.
P.O. BOX 12426
HUNTSVILLE, AL 35802

in
Response to
PURCHASE CONTRACT CC0111

TABLE OF CONTENTS

TABLE OF CONTENTS - Continued

LIST OF CHARTS

INTRODUCTION

This report responds to the Statement of Work delineated under the Purchase Contract. It addresses 1) support requirements for producing electronic crystals in space to meet market requirements, 2) orbital operations issues 3) comparative evaluation of systems, and 4) resupply considerations.

No industrial or trade secrets are included in this report.

In order to determine support requirements it was first necessary to examine market needs for space-produced semiconductor crystal materials and project market requirements through the year 2000. It was also necessary to estimate expected costs of space production as these costs will largely determine the price at which the materials can be sold and thus the magnitude of the market.

These projections are included in the report.

Part I MARKET PROJECTIONS

1. Overview

This section reports the results of studies to evaluate the market requirements for space-produced electronic materials through the year 2000. These studies took the form of:

Literature search
Evaluation of developments and trends
Comparisons with other developing technologies
Seeking out expert opinion from within industry, universities and government
Commissioning special studies from highly qualified sources
Reviewing commercially available market projections.

Attention has been given to developments and trends within evolving electronic and electro-optical technologies and to areas of application which promise to drive market demand for improved materials. Particular attention has been directed to gallium arsenide (GaAs) integrated circuit (IC) technology which has recently emerged from the laboratory into applications involving a wide variety of electronic equipments. Other materials have also been investigated where enhancement from space-production can be expected to stimulate new market demands.

Projections of world-wide market requirements for GaAs ICs have been made through the year 2000. Similar projections have been made for space-produced GaAs and other semiconductor crystals.

As a general statement, it can be said with confidence that beyond the Si single crystal applications there are numerous areas of applications where high quality space-produced compound semiconductor single crystals can support and enhance emerging electronic, electro-optical, energy conversion, and perhaps other, technologies and can be expected to open new opportunities beyond present technology.

2. The Incentive for Space Processing of Electronic Materials

As the broad base of technology expands, it generates increasing complexities and places ever-increasing demands upon supporting systems. This, in turn, places increasing demands upon the materials which support the systems.

In electronics, solid state technology based upon the semi-conductor characteristics of silicon has supported rapid technological advances over the past several decades. In the decades ahead, the requirement to support increased levels of complexity and to advance into new dimensions of speed and performance, including handling higher frequency ranges, will necessitate quantum advances in materials performance. Although silicon based technology will continue to advance, these advances will have their limits and new material technologies will be required. The most promising of these appears, at present, to be gallium arsenide based technology. This is because of inherent advantages of this material in such areas as high speed capability, low power requirements and low heat generation, high temperature tolerance, radiation resistance, ability to process very high frequencies and light emitting capability. These characteristics make GaAs a very attractive material for a broad range of applications.

Processing difficulties in growing high quality GaAs crystals on earth, due in large part to the effects of gravity during the crystal growing process, have been a limiting factor in the development and acceptance of GaAs based technology.

There is promise that significantly enhanced GaAs crystals can be grown in space where the adverse effects of gravity are essentially eliminated. Encouragement in this direction is found in the success of previous experiments in growing crystals in space and in more recent process studies and evaluations in electronic materials laboratories, particularily at MIT. Near perfect space-produced materials will provide enhanced electrical characteristics and greater device reliability vs earth produced materials of lesser perfection.

3. Major Market Segments

The electronic materials market can be broken down into several general categories. Applications and developments have been analyzed in each of the following:

a. Business
b. Communications
c. Consumer
d. Electronic Data Processing (EDP)
e. Government/Military
f. Industrial/Instrumentation

The market projections of this report represent a summation of the projections of world-wide requirements in each of these categories.

4. Status and Direction of Gallium Arsenide Development

GaAs has been studied as a promising electronic material for many years. Discrete GaAs transistors have been on the market for several years. Within the last few years the interest and development effort put into GaAs technology has expanded rapidly, encouraged largely by improvements in crystal growing techniques which have made more useful qualities and quantities of GaAs material available to laboratories and to industry. There are at present at least fifteen suppliers of GaAs material and numerous U.S. companies have active programs underway for pursuing GaAs technology. The technology is rapidly advancing both in complexity and in the diversification of product applications. This was particularly evident a the Fourth Annual Gallium Arsenide Symposium held in New Orleans on November 9-11, 1982 and attended by 372 people from around the world and where 48 papers were read, a number, for the first time, addressing production related topics.

5. Applications and Development Trends

Encouraged by the availability of better GaAs material from improved crystal growing techniques and better equipment, and supported in large degree by government/military initiatives and funding, industry is moving quickly ahead in the pursuit of GaAs technology from the discrete transistor to components and circuits of increasing complexity, including both analog and digital ICs. This effort is encouraged by the recognition of increasing numbers of market applications. A review of company and government programs involving GaAs reveals that serious efforts are underway to develop GaAs technology in support of:

a) Government/Military
   - Space based radar
   - Wideband electronic warfare
   - Command and control communications
   - Weapons target acquisition, guidance and control
   - Secure communications systems
   - Military satellite communications
   - Expendable jammers
   - Expendable decoys
   - Phased array radar
   - Missile seekers
   - Wide band early warning
   - Antijam data links

b) Electronic data processing
   - Faster, more powerful computers

c) Communications
   - Satellites
   - Fiber optics
   - Secure communications

d) Business
   - Systems and equipment for "office of the future"

e) Consumer
   - Home information systems

GaAs chips developed or under development include A/D and D/A converters, gate arrays, multipliers, high speed memory, digital logic, variable alternators, front end filter correlators, programmable filters, phase shifters, tunable sources, receiver front ends, power amplifiers, charged couple devices and phased array transmit/receive modules.

6. Quantitative Market Forescasts for Gallium Arsenide ICs

In consideration of the early stage of development of GaAs technology, and allowing for equipment development cycle times, it is projected that equipment using GaAs ICs will not see volume production until 1985. Projections for emerging technologies and the growth of GaAs markets are given by general category of application as follows:

a) Government/Military

This segment is expected to consitute the largest element of the market for GaAs devices throughout the present decade. Military weapons systems applications and government/military communcations and high speed signal and data processing requirements will be primary drivers of the market. GaAs Technology will be found of increasing importance to the advancement of sophisticated systems requiring small size, fast speeds, high frequency response, communications security, low power consumption and radiation hardness.

This market segment is expected to grow to a total market volume of about $108 million world-wide by 1985, $779 million by 1990, $4.05 billion by 1995 and $16.5 billion by the year 2000.

b) Electronic Data Processing (EDP)

This market segment will be accellerated by a keen international competition in advanced high performance main-frame computers based on GaAs technology. These developments will begin to significantly impact the GaAs IC market in the last half of the present decade growing to a total sales volume in the order of $13 million by 1985 and $394 million by 1990. Throughout the decade of the 1990s, developments in high-speed RAM, gate arrays and custom ICs will expand this market segment to reach a volume of about $6.28 billion world wide by 1995 and $56.5 billion by the year 2000.

c) Communications

Building upon the broad GaAs technology base funded by governments, this market segment is expected to see meaningful emergence and rapid growth during the second half of the present decade. Applications will include microwave communications, pay TV, CATV, digital microwave radio (DMR) and a number of other lower volume uses. Fiber optics communications and direct satellite-to-home communications will grow into major market drivers in this segment.

Communications applications are expected to consume some $21 million of GaAs devices by 1985, $526 million by 1990, $4.64 billion by 1995 and $12.4 billion by the year 2000.

d) Business

Business equipment applications utilizing GaAs ICs will begin emerging in the mid 1980s, including fiber optic transmitter and receiver functions for the Office-of-the-Future. Voice recognition, coming on late in the decade, will require large numbers of GaAs ICs. European and Japanese systems will represent a significant portion of the business market requiring GaAs ICs. This market segment is expected to grow to about $11 million by 1985, $342 million by 1990, $3.86 billion by 1995 and $26.9 billion by the year 2000.

e) Consumer

Satellite-to-home applications, emerging in Europe and Japan in the mid 1980s will be a major market driver in the consumer segment of the GaAs market. World wide volume of GaAs based TV receivers operating in the 12 GHz range is expected to reach about 10 million by 1985.

This total consumer market segment for GaAs ICs world wide will grow to about 12 million by 1985, $411 million by 1990, $4.13 billion by 1995 and $15.2 billion by the year 2000.

f) Instrumentation/Industrial
GaAs ICs in microwave devices for this market segment will find early growth beginning in the mid 1980s and will experience steady growth thereafter. Also, the use of GaAs ICs in test equipment will represent a considerable and growing market through the year 2000. New generations of IC testers will include GaAs ICs in functions such as comparator amplifiers, A to D converters and line drivers. Also GaAs ICs will find applications in high frequency oscillators and logic analysers. The total world wide market for this segment will reach $19 million by 1985, $565 million by 1990, $4.37 billion by 1995 and $10.3 billion by the year 2000.

These world wide GaAs market projections are summarized on Chart 1.

7. <u>Quantitative Market Projections for Space-Produced Gallium Arsenide</u>

Case 1. Orbiter Only

Significant quantities of GaAs materials from space production will not begin to appear until the last two years of the present decade. By that period GaAs based devices will have emerged for numerous applications. Some of these, especially in the government/military segment and in advanced main frame computers, will demand the best available material for optimum performance and reliability. It is expected that these market demands will absorb all of the very high quality GaAs materials coming from Orbiter production, and that the ability of the Orbiter to support quantity production will be the limiting market factor. Quantities available from this source are expected to reach about 44Kg per year by 1990 and, lacking a space station, will expand at a compound average growth rate of 15% per year through 1995 and 6% thereafter. These

Market Projection for GaAs

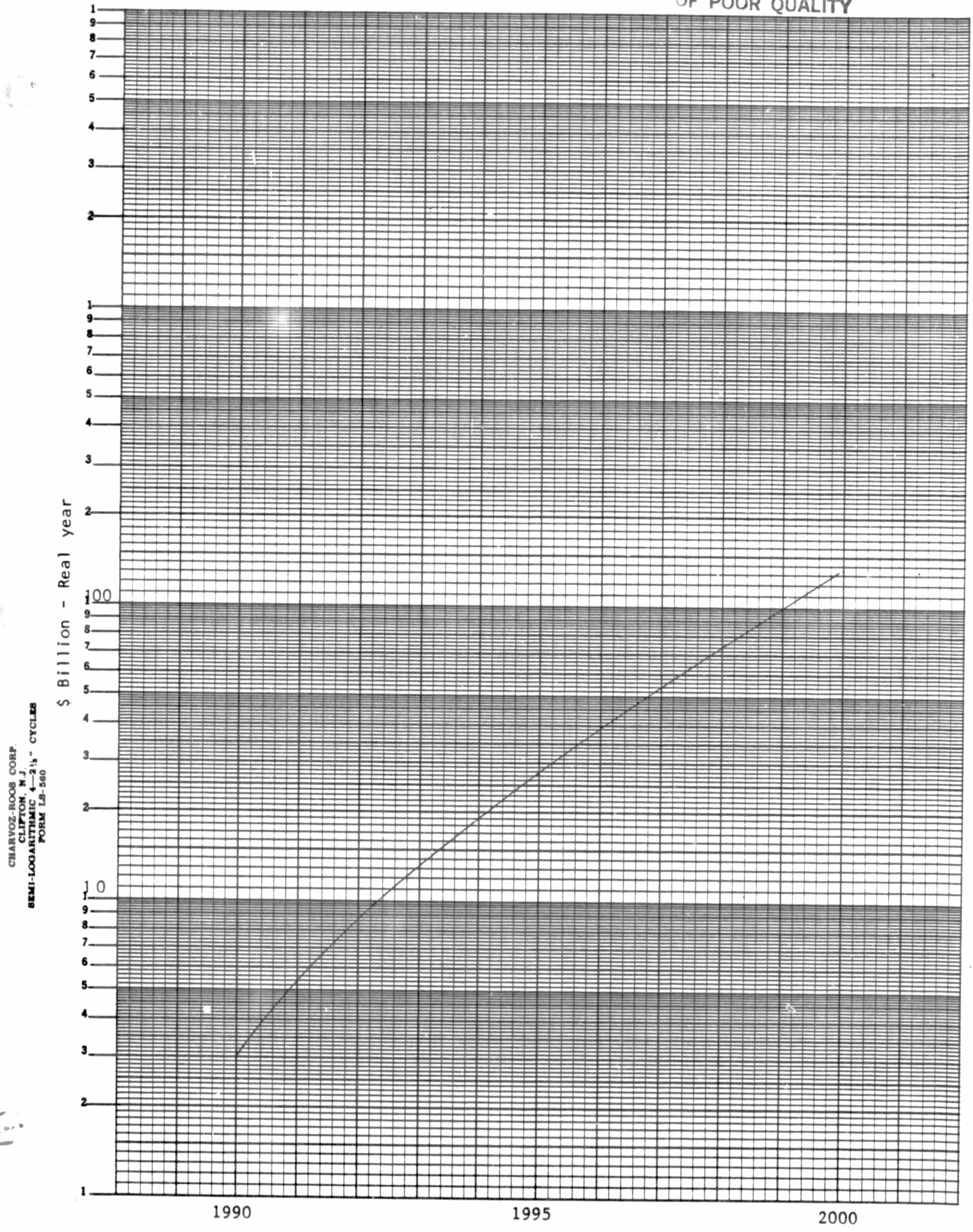

Chart 1

projections are shown on Chart 2.

Case 2. Orbiter and Space Station/Free Flyers

The availability of a Space Station, with some form of attached or free-flying production facilities, with adequate and reasonably priced energy from solar arrays, will support the production in space of much greater quantities of materials than from on-board Orbiter production alone. In this case, it is important to investigate both the market demand and the capability to expand production in space. Either of these factors might prove to be the limiting factor to the amount of space production to be expected through the decade of the 1990s.

In this regard, early market forecasts provide a needed early planning input with respect to accommodation requirements forseen for Space Station design. Also, the economies of electronic materials production aboard the Space Station will impact on product price and thus on market demand.

Initial studies of cost saving factors related to production with 1) free flyer only and 2) Space Station,vs. production on the Orbiter,indicate that the availability of a free flyer will reduce GaAs space production costs by at least a factor of three,and availability of a Space Station by a factor of six. These cost reductions are in consideration of weight and space savings on Orbiter flights stemming from the fact that, once production facilities are in place on the Space Station, needs for Orbiter transportation will decline essentially to the delivery of raw materials to the Space Station and the return of finished product, and possibly waste materials, to earth. Also, production costs will be reduced due to economies arising from the extended times available for the crystal growth process on the Space Station vs. the Orbiter and by more favorable electrical power availability.

In large part, the savings from free flyer and/or Space Station production can reflect in reduction of market price of the material. This will

SPACE PRODUCTION OF GaAs - ORBITER ONLY

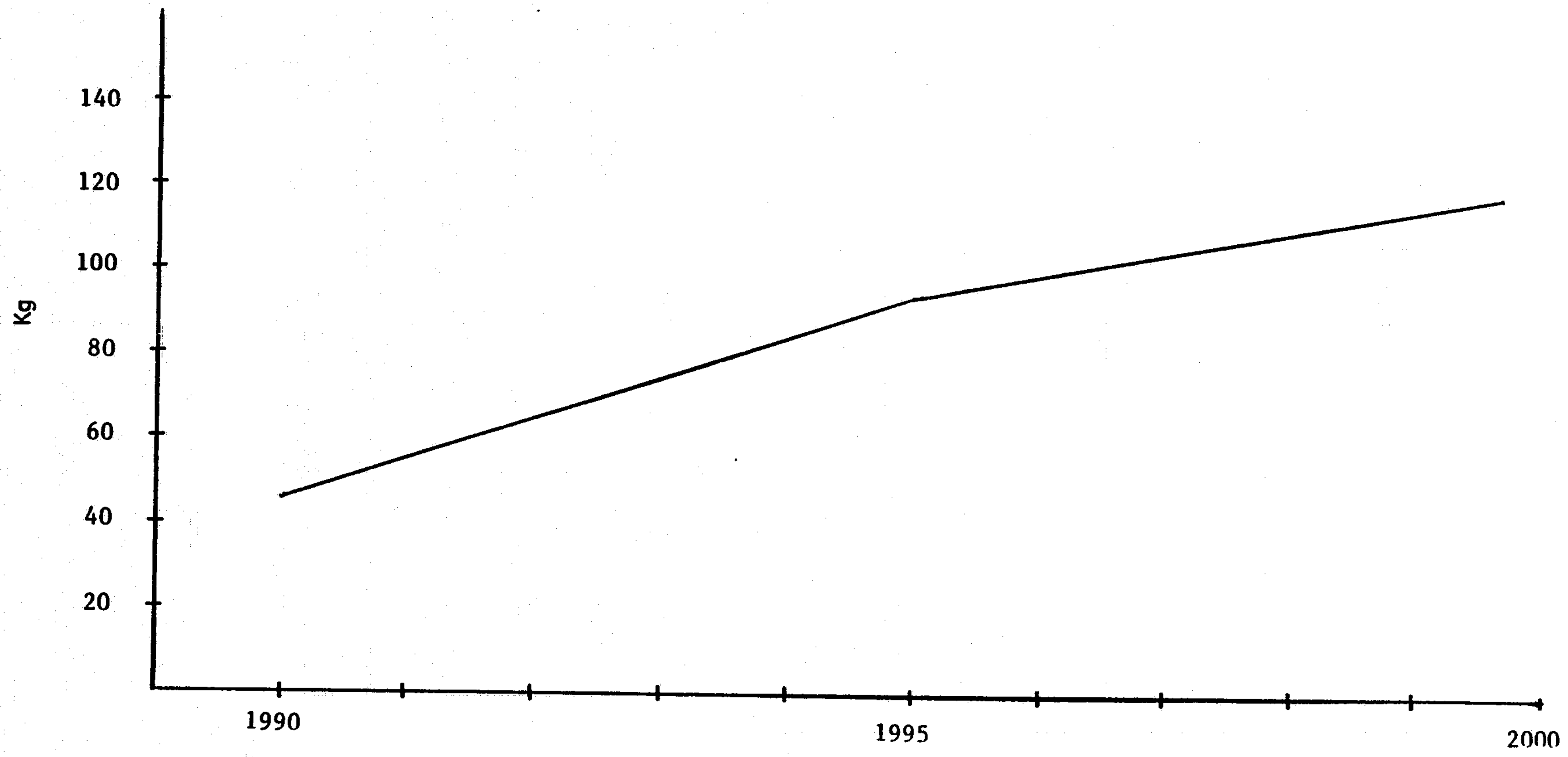

Chart 2

encourage the use of space-produced GaAs in a broader range of applications, increasing overall market demand.

Basing price projections on the expectation of Orbiter-only operations through 1990, Orbiter plus free flyer by 1991 and Orbiter plus Space Station by 1992, the projected market price of space produced GaAs is as shown in Chart 3. These price projections support the following market demands.

a) Government/Military
It is expected that applications for space-produced GaAs in this market segment will rapidly expand through-out the 1990s driven by needs to exploit the full potential of this enhanced-quality material. The market demand for space-produced GaAs will reach $116.8 million in this segment by 1990, $405.0 million by 1995 and $1,650 million by the year 2000.

b) Electronic Data Processing - Faster Computers. Spurred by international competition and increasing demands for higher speeds and greater performance, especially in large main-frame computers, it is forecast that market demands in this segment for space-produced GaAs will reach $11.8 million by 1990, $125.6 million by 1995 and $1,130 million by the year 2000.

c) Communications
The quality of earth-produced GaAs is expected to support most applications in this market segment throughout most of the decade of the 1990s. By 1990, spurred by requirements for very high performance and reliability in support of satellite and fiber optics communications, spaced-produced material is forecast for market demands of $5.3 million in 1990, $46.4 million by 1995 and $124 million by the year 2000.

d) Business
Voice recognition, emerging toward the end of the 1980s, will

MARKET PRICE PROJECTIONS

Space Produced GaAs

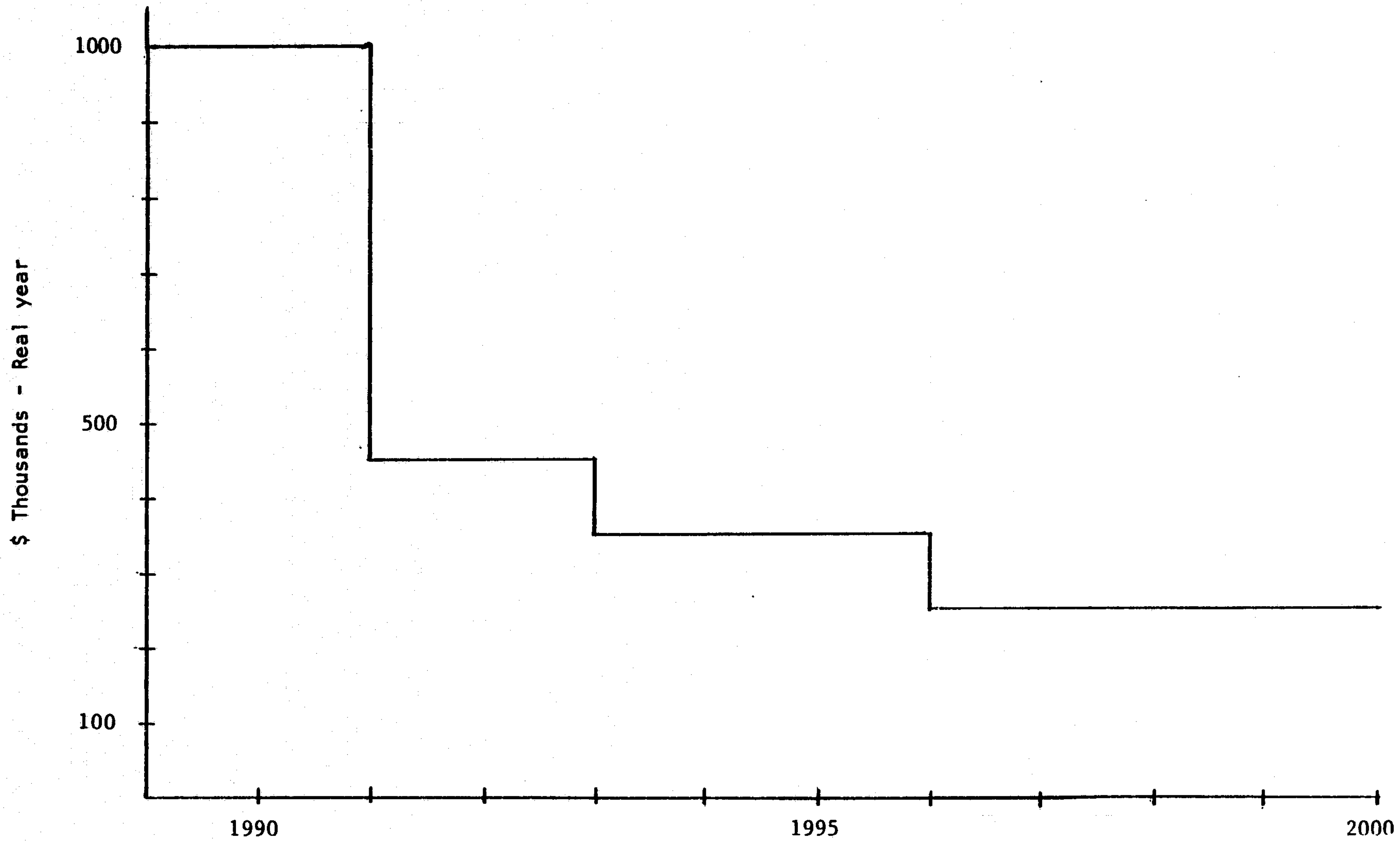

Chart 3

prove to be an application requiring significant quantities of high quality, high performance spaced-produced GaAs. With this as the primary market driver, it is forecast that the market demand for spaced-produced GaAs in this segment will reach $34.2 million by 1990, $38.6 million by 1995 and $134.5 million by the year 2000.

e) Consumer

Most applications in this market segment will probably be satisfied by available, less costly earth-produced GaAs material. Significant applications requiring space-produced GaAs have not been identified.

f) Instrumentation/Industrial

Most applications in this market segment will be satisfied by lower-cost earth-produced GaAs material. The total world-wide market for space produced GaAs for this segment will be $1.7 million by 1990, $8.7 million by 1995 and $20.6 million by the year 2000.

These market projections for space-produced GaAs have been summarized and are shown on Chart 4 in terms of kilograms per year of finished crystal ingot ready to be cut into wafers.

8. Electronic Materials other than GaAs

Market demands will emerge for space-produced electronic materials in addition to GaAs. For example, mercury cadmium telluride and indium phosphide are widely recognized candidates. While no other materials have yet been identified with the broad range of market applications and potential bulk requirements of GaAs, emerging demands for urgent specific requirements, such as detectors effective in particular frequency ranges, will lead to space-production of a growing number of crystal materials. It is expected that these other materials, in total, will represent no more than one or two percent of total of space crystal production by 1992. However, increasing market demand is forecast to raise this percentage to 10% of total of space produced electronic

Market Projections for S P GaAs (Kg)

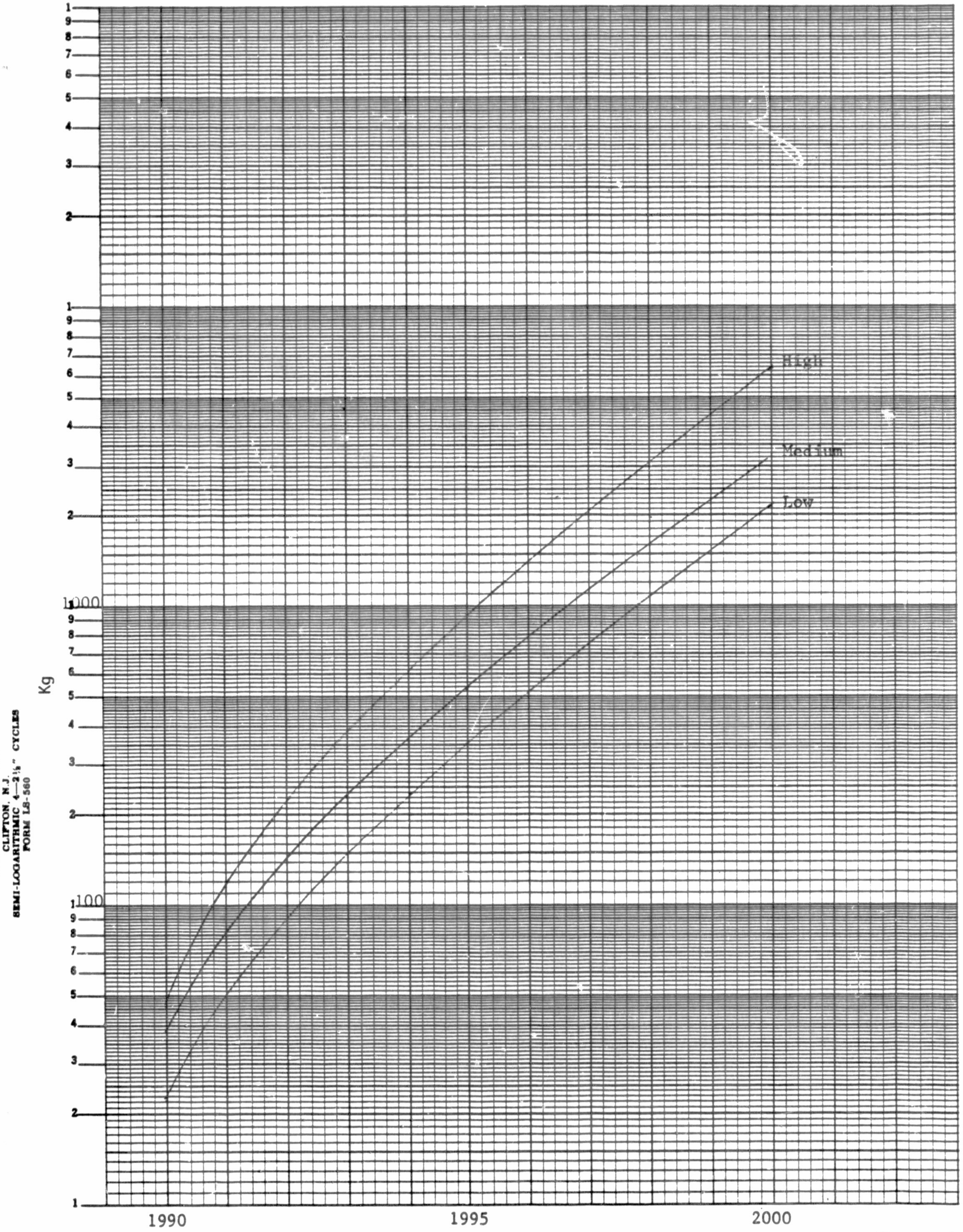

Chart 4

materials by 1995 and to 35% by the year 2000.

These projections are shown on Chart 5 (finished ingot). Combined requirements for space-produced GaAs and other crystals are shown on Chart 6 (Bulk).

9. Rationale for Market Projections

It should be recognized that projections of world wide market demand for space-produced electronic materials are based on a number of assumptions and related forecasts. A great deal of elasticity exists in the assumptions and methods of calculation. Reductions in material cost will increase potential market demand accordingly. On the other hand, substantial improvements in earth processing technologies or the emergence of alternate material combinations might soften demands for space-produced materials.

For these reasons, projections have been made and reflected on Chart 5 which present a conservative low market demand together with a more optimistic high market demand, as well as a medium level projection based upon assumptions and calculations which appear to represent best present judgements.

Requirements for flight accommodations as shown in Part II of this report are based upon the higher market demand figures since these are well within the realm of possibility and, in the time frame considered, could easily become the more realistic portrayal of actual requirements for space station accommodations.

Although accomplishments in technology with semiconductor single crystals over the past several decades have been remarkable, fundamental research in bulk crystal growth has not kept pace with advances in solid state science. An urgent need is evolving for crystal growth with optimum perfection.

Crystal growth with optimum perfection is extremely complex and solutions to the problems encountered are made most difficult by the forces of

Market Projections for III-V Crystals
Other than GaAs

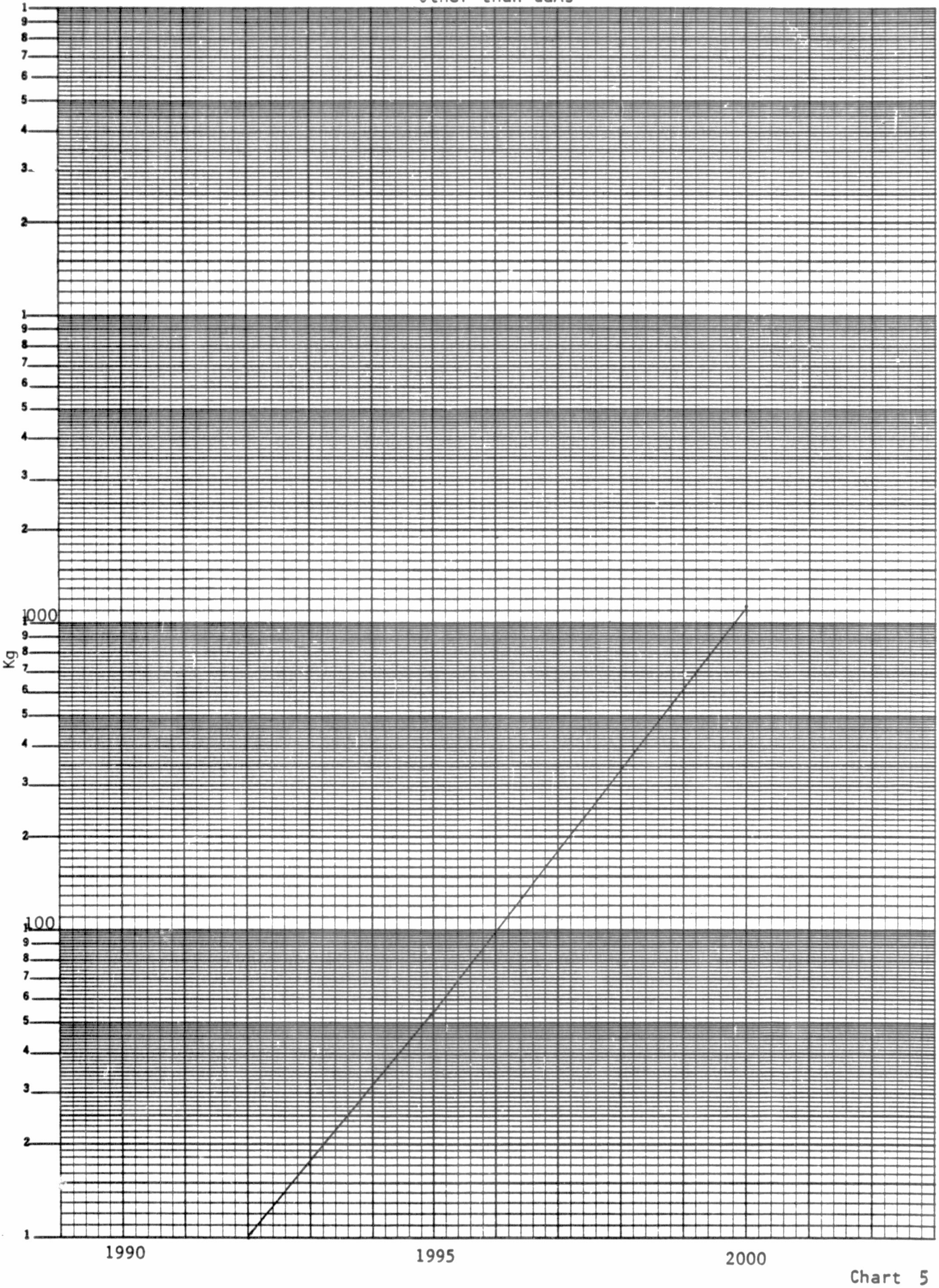

Chart 5

Total Space Production Requirements
For Semiconductor Crystals (Bulk)

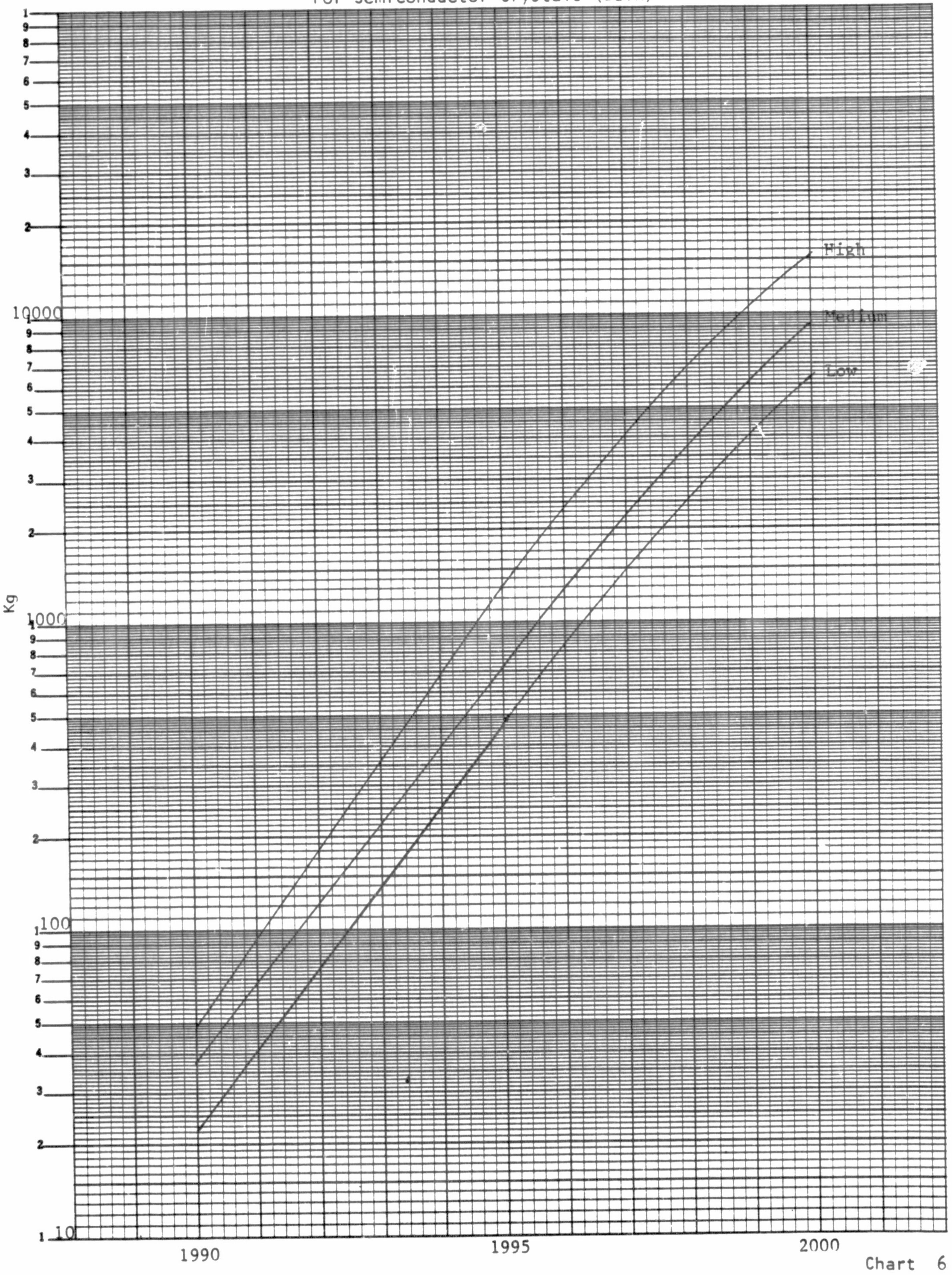

Chart 6

gravity always present with earth production. The microgravity conditions of space can accelerate immensely the solution of the semiconductor single crystal problems.

Some authorities eminently qualified to evaluate and project electronic materials developments are saying that, if one considers the applications possibilities of near perfect GaAs ICs from space production (as in areas suggested in this report) and considers an extrapolation to other alloy III-V material combinations,together with advanced circuit concepts, the possibility for improved performance and new devise-circuit interaction scenarios becomes virtually endless. In these directions we can look beyond the VHSIC era.

The opportunity to produce bulk quantities of much improved semiconductor crystals in space as made possible by the Orbiter, and the opportunity to achieve reasonable production costs as made possible by the availability of a Space Station, promises to open a major door for advances in the direction forseen by these highly qualified authorities. There seems little question that the space-produced materials will find a ready and growing market, and it is not beyond the realm of possibility that the market demand will be even greater than we can now foresee.

Part II SUPPORT REQUIREMENTS

1. Projected Profile of Flights for GaAs Production, 1990-2000

a. Introduction

In the period for the years 1990 to 2000 commercial quantities of crystals will be grown in three flight modes: 1) Orbiter only; 2) Orbiter-serviced free-flying platforms; 3) Orbiter-serviced Space Station. The flight mode selected will be determined by availability of the flight modes, the need as indicated by projected market demands, the ability of each mode to meet the support requirements, and the economies of the different modes. Typical flight modes are:

1990	Orbiter sorties, or Orbiter-serviced free-flying platforms
1991	Orbiter-serviced free-flying platforms
1992-1993	Space Station with attached dedicated modules
1994-2000	Space Station with attached dedicated modules and Space Station-serviced free-flying platforms

This profile of missions envisions that Orbiter sorties will be used until the free-flying platforms become available. The Orbiter-serviced free-flying platforms mode will be used until the Space Station is available. Detailed analyses must be done later to determine if the Space Station alone, Space Station with attached dedicated module, or Space Station-serviced free flyer platforms will be used.

The growth requirements by year to meet the projected market demand is shown in Table 1, along with the diameter of the crystal to be grown. This assumes a factor of 1.25 over the requirements shown on Chart 5 to allow for ingot trim and wastage.

TABLE 1

Year	Diameter (inches)	Mass (Kg) Low	Medium	High
1990	2	28	49	58
1991	2	58	85	115

1992	2	99	146	213
1993	2	181	250	438
1994	3	306	431	713
1995	3	500	646	1194
1996	3	785	1031	1988
1997	5	1156	1600	3125
1998	5	1688	2250	4500
1999	5	2194	3120	5938
2000	5	2700	3979	7975

b. Orbiter Sortie Flights, 1990

Flights using the Orbiter sortie mode for growing commercial quantities will begin in late 1988. Each flight should have the capability of growing a minimum of 12 kg of crystal. A typical sequence will be for the growth cells to be loaded with the crystal seeds and source materials in a laboratory, integrated into the furnaces, and the furnaces loaded with the growth cells delivered for integration with the carrier assembly. The carrier assembly will be similar to the MEA currently envisioned by NASA, and will have the systems necessary to support the growth furnaces, with the exception of the power conversion equipment. For purposes of computing up and down mass, the supporting equipment has been included on the assumption that the user will pay the transportation cost even if the equipment is provided by someone else.

The crystals grown will be 5.08 cm (2 inches) in diameter and 1 cm long. The seed crystal will be the same diameter and 1mm, or less, in length.

A typical furnace will weigh about 500 kg and will support the growth of 20 kg of crystals. Each furnace will accommodate up to 200 growth cells. The exact number for each flight will most likely be determined by the power and energy available.

Assumptions

1) Flights will be on missions that deliver primary payloads, with 6 days remaining available for crystal growth.

2) Power and energy is available to support growth of 12 kg of crystals on each mission.

3) Grown crystals are 2-inches diameter

4) Furnace capable of growing 20 kg will be used.

5) Furnace to crystal mass ratio 25/1.

Growth requirements - up to 68 kg

Number of Flights - 6

Mass, up and down

Furnace	500 kg (includes crystal material)
Structure	500 kg
Support Equip.	300 kg
Total	1300 kg

Electrical Power - 12 kw

Structure Support - Bridge type similar to MEA

Data/Communications - Data requirements include on-orbit accelerations, temperature, current voltage, discrete events, and other normal housekeeping data to permit limited on-board and post-flight assessment. The exact number of measurements and sampling frequency is to be determined with system design, however housekeeping data normally required for post-flight assessment should suffice. The flight crew will require access to limited parameters, however real-time access on the ground is not anticipated.

Thermal/Environmental Control - Thermal control will be required for the heat losses in the electronic equipment and the power conversion equipment. The power conversion equipment will be the primary source amounting to about 35% of the applied power. The MEA type carrier should have an active cooling system to support this requirement. An objective of the design of the furnace will be to design the thermal system such that the power input for crystal growth can sustain the operating temperature, and the heat losses are manageable without active cooling.

Flight Crew - The flight crew will be required to turn the furnaces on and provide some monitoring of certain parameters to assure no anomalies have occurred.

Crew Safety - Since the payload will be carried in the payload bay of the Orbiter there should not be any unusual safety concerns.

c. Orbiter Serviced Free-Flying Platforms, 1991

Since the Orbiter is power and energy limited, the free-flying platforms will be utilized as soon as they are available. The ground procedure will be the same. The power and energy from the platform should not be limiting, therefore a larger number of furnaces can be flown at once. It is anticipated that a minimum of 20 kg will be grown in each furnace, with the number of furnaces per mission and the number of missions determined by the annual market needs.

The loaded furnaces will be transported to the platform with the Orbiter and with a robotics device, or EVA, transferred to the platform, checked out, and activated. The system will be automatic from there through the growth period. After growth is complete the furnaces will be removed and returned to earth for removal of the grown crystals, refurbishment, and reloading for the next flight.

In order to meet the market demands multiple furnaces will have to be used in the platform. If adquate power is available to run the furnaces simultaneously the mission can be accomplished in one week. In this mode the Orbiter would load the furnaces in the platform at the beginning of the mission and then proceed with other mission activities. After the growth period of about a week the Orbiter would rendezvous with the platform, retrieve the furnaces, and return.

If the power on the platform is limited such that only one furnace can operate at a timethe mode will be such that the furnaces are delivered to the platform on one flight and returned on another. If power on the platform is not limiting either mode may be selected depending on flight opportunities and the economies offered. For the convenience of this study, it is assumed that power on the platform is unlimited and the furnace will be delivered and retrieved on the same mission.

Growth requirement - up to 115 kg

Number of flights - 2

Flight configurations:

Flight 1 and 2

Three furnaces

Grow 60 kg crystals

Mass, up and down

Furnaces	1500 kg
Structure	500 kg
Support Equipment	600 kg
Total	2600 kg

Electrical Power - 20 kw/furnace, 60 kw total if operated simultaneously.

Structure Support - Bridge type similar to MEA

Requirements Common to both Flights

Data/Communications - Data requirements include on orbit accelerations, temperature, current voltage, discrete events, and other normal housekeeping data to permit limited on-board and post-flight assessment. The exact number of measurements and sampling frequency is to be determined with system design, however housekeeping data normally required for post-flight assessment should suffice. The flight crew will require access to limited parameters, however real-time access on the ground is not anticipated.

Thermal/Environmental Control - Thermal control will be required for the heat losses in the electronic equipment and the power conversion equipment. The power conversion equipment will be the primary source amounting to about 35% of the applied power. The MEA type carrier should have an active cooling system to support this requirement. An objective of the design of the furnace will be to design the thermal system such that the power input for crystal growth can sustain the operating temperature, and the heat losses are manageable without active cooling.

Flight Crew - The flight crew will be required to transfer the furnaces to the free-flying platform and activate them. After the activation is accomplished the process will be automatic, however it is anticipated that some parameters will be displayed to the crew on the Orbiter to alert them to anomalies that are compatible with corrective action. At the end of the growth period, at the end of the Orbiter mission, the crew will be required to transfer the furnaces from the platform to the Orbiter payload bay for return to earth.

Crew Safety - Crew safety concerns will be those associated with EVA and cargo transfer processes. There should be no unusual safety hazards since the payload is self-contained and operates automatically after activation.

d. Space Station

It is expected that the Space Station will be available for commercial use beginning in 1992. In the Space Station mode the furnaces will be transported initially to the station, or built in as a part of the generic configuration. For the purpose of this study it is assumed that the furnace is user provided. The growth cells will be loaded with the seed crystal and source material in a ground based laboratory and transported to the Space Station by the Orbiter. After the growth period, the growth cells with the completed crystals will be removed from the furnaces and returned to earth for processing. The Space Station will serve as a supply depot where cartridges will be delivered to support growth over a period of up to three months. At the end of the period a new supply of cartridges will be flown up and the cartridges with the grown crystals will be flown down.

Whether the production growth will occur in the Space Station, or in an attached dedicated module, or in a free-flying platform, will depend on the ability of the Space Station to satisfy all the requirements, scheduled utilization of the Space Station laboratories, and the availability of dedicated attached modules and free-flying platforms. Currently there is some uncertainty whether the Space Station can meet the low acceleration requirements, and the quantity of power available.

In the attached dedicated module mode, and in the Space Station-serviced free-flying mode, the furnaces must be loaded in the space station and then transferred to the module or platform. Loading the furnaces with the large number of growth cells outside the Space Station is considered impractical.

In this study it is assumed that the crystal growth will occur either in an attached module, or in a free-flying platform. Also, it is assumed that routine Orbiter flights to the Space Station will occur every 90 days. More frequent flights can be available on demand but at a premium cost.

Year 1992

The Space Station is available for commercial use with attached modules that can be dedicated to users for discrete periods of time, or time shared. At least 20 kw of power is available to the user. Three furnaces are available from the previous flights, each with a capability of growing 20 kg of 2 inch diameter crystals.

Growth requirements - up to 213 kg
Crystal diameter - 2 inches
Growth period - 6 days
Two mission - 100 kg each

Mission One

Take up two furnaces and cartridges with material to grow 100 kg of crystals. Only one furnace will be used, with the other designated as a spare.

One furnace will be used to grow 20 kg of crystals per week for five weeks. The cartridges with the grown crystals will be returned on the first return opportunity, or held in the Space Station for return when supplies for the next growth cycle are carried up.

Mass up

Cartridges	1000 kg
Structure	500 kg
Support equipment	450 kg
Total	1950 kg

Electrical Power = 20 kw

Mission Two

On this mission cartridges with crystaline material to grow 100 kg of crystals will be carried up. On the return of that same Orbiter the cartridges with the crystals grown in mission one will be returned. As in mission one, a single furnace will be used to grow 20 kg per week for five weeks, a total growth of 100 kg.

Mass up and down - 1000 kg of cartridges
Electrical Power - 20 kw

Year 1993

Production will continue with the growth of 2 inch diameter crsytals. In addition, with the third flight, preparations will be made to start production of 3-inch diameter crystals during the first flight of 1994.

Growth requirements - up to 438 kg
Crystal diameter - 2 inches
Groth period - 6 days
Three missions - 146 kg each, 438 kg total

Mission One

At the beginning of the mission take up cartridges loaded to support growth of 146 kg of crystals. Return the cartridges with the 100 kg of 2 inch crystals from the last growth cycle.

Mass up	
Cartridges	1460 kg
Mass down	
Cartridges (2")	1000 kg
Electrical Power	20 kw

Mission Two

On this mission 2 inch crystals will continue to be grown at 20 kg per week for a total of 146 kg. The crystals grown during the previous mission will be returned.

Mass up	
Cartridges	1460 kg
Mass down	
Cartridges	1460 kg
Electrical Power	20 kw

Mission Three

This mission will be the same as mission two except that a furnace for growing 3 inch diameter crystals will be taken up and a prototype run of one week duration will be made. A power conversion unit will also be taken up.

Mass up	
Cartridges	1460 kg
Furnace	500 kg
Power conversion	150 kg
Total	2110 kg
Mass down	
Cartridges (2")	1460 kg
Electrical Power	20 kw

Year 1994

This year will see the growth of 3-inch crystals at 20 kg per week. At this time a second furnace will be required to meet the growth demands.

Growth requirements - up to 713 kg

Crystal diameter - 3 inches

Growth period - 6 days

Three missions - 3 at 238 kg each

Mission One

Take up one furnace to be used as a spare, and enough cartridges loaded with crystals to grow 238 kg of crystals. Take down the crystals grown during the previous growth cycle. Also take down the two furnaces for growing 2 inch diameter crystals.

Mass up	
Furnaces	500 kg
Cartridges	2380 kg
Total	2880 kg
Mass down	
Cartridges	1460 kg
Furnaces	1000 kg
Total	2460 kg
Electrical Power	20 kw

Missions Two and Three

On these missions 20 kg per week will be grown for a total of 238 kg per mission.

Mass up per mission	
Cartridges	2380 kg
Mass down	
Cartridges	2380 kg
Electrical Power	20 kw

Year 1995

Production will continue for 3-inch diameter crystals.

Growth requirement - up to 1194 kg

Crystal Diameter - 3 inches

Growth period - 6 days

Three missions - 400 kg each, 1200 kg total

Mission One

Take up a third 3-inch furnace and cartridges to grow 400 kg. The cartridges with crystal grown in the last flight of 1994 will be returned. Two furnaces will operate to grow 40 kg. per week.

Mass up		
	Furnace	500 kg
	Cartridges	4000 kg
	Total	4500 kg
Mass down		
	Cartridges	2400 kg
Electrical Power		40 kw

Mission Two and Three

Mass up		
	Cartridges	4000 kg
Mass down		
	Cartridges	4000 kg
Electrical Power		40 kw

Year 1996

During this year three furnaces will be operating at 60 kg per week to continue to grow crystals at 3-inches in diameter. Since it is anticipated that by 1997, next year, the industry will be using GaAs crystals at 5-inches in diameter the furnace added in the third flight will be designed to grow 5-inch crystals. Crystals at 5-inch diameter and a current-density of 10 amps per cm2 require a constant current of 1267 amps. Each 5-inch furnace carried up will also have with it a power conversion unit.

Growth requirements - up to 1988 kg

Crystal diameter - 3 inch

Growth period - 6 days

Three missions - at 660 kg each

Mission One

Mass up	
Cartridges	4000 kg
Electrical Power	60 kw

Mission Two

Mass up	
Cartridges	6600 kg
Mass down	
Cartridges	6600 kg
Electrical Power	60 kw

Mission Three

A 5" crystal growth furnace will be taken up and tested, along with a power conversion unit.

Mass up	
Furnace (5")	750 kg
Cartridges	6600 kg
Power conversion	150 kg
Total	7500 kg
Mass down	6600 kg
Electrical Power	60 kw

Year 1997

This year production will convert to 5-inch crystals. To grow crystals at this diameter will require a power conversion unit capable of providing 1267 amps constant current. Three 5-inch furnaces will be producing at 20 kg each per week on the first flight and four 5-inch furnaces will be producing at this amount on the second and third flights. Two additional 5" furnaces will be taken up on the first flight and two (one as a spare) will be taken up on the second flight.

Growth requirements - up to 3125 kg
Crystal diameter - 5-inch
Growth period - 6 days

One mission - at 725 kg
Two missions - at 1200 kg

Mission One

The second and third 5-inch furnaces and supporting power conversion units will be carried up. For the crystal growth three 5-inch furnaces at 20 kg each per week will be employed.

Mass up	
Furnaces	1500 kg
Power conversion	300 kg
Cartridges (5'')	7250 kg
Total	9050 kg
Mass down	
Cartridges	6600 kg
Furnaces (3'')	1000 kg
Electrical Power	60 kw

Mission Two

The fourth and fifth 5-inch furnaces and supporting power conversion units will be carried up. One of the furnaces will serve as a spare.

Mass up	
Furnaces	1500 kg
Power conversion	300 kg
Cartridges	12000 kg
Total	13500 kg
Mass down	
Cartridges	7250 kg
Electrical Power	80 kw

Mission Three

Mass up	
Cartridges	12000 kg
Mass down	
Cartridges	12000 kg
Electrical Power	80 kw

Year 1998

In this year there will be growth capability of 100 kg per week provided by five furnaces. All diameters will be 5-inches.

Growth requirement - up to 4500 kg

Crystal diameter - 5 inches

Growth period - 6 days

Four missions - 1125 kg each, total of 4500 kg

Mission One

Mass up	
Furnace	500 kg
Power conversion	150 kg
Cartridges	11250 kg
Total	11900 kg
Mass down	
Cartridges	12000 kg
Electrical Power	120 kw

Mission Two

Mass up	
Cartridges	11250 kg
Mass down	
Cartridges	11250 kg
Electrical Power	100 kw

Mission Four same as Three but take up one furnace, mass 500 kg.

Year 1999

This year will have six furnaces capable of growing 120 kg of 5-inch crystals per week. The six furnaces are on board. Another furnace will be carried up during the first mission as a spare.

Growth requirement - up to 5938 kg
Crystal diameter - 5 inches
Five missions - 1200 kg per mission, total 6000 kg

Mission One

On the first flight of this mission take up a sixth 5" furnace, with power conversion unit, as a spare.

Mass up

Furnace	500 kg
Power conversion	150 kg
Cartridges	12000 kg
Total	12650 kg

Mass down

Cartridges	11250 kg
Electrical Power	120 kw

Mission Two, Three, Four and Five

Mass up

Cartridges	12000 kg

Mass down

Cartridges	12000 kg
Electrical Power	120 kw

Year 2000

During this year eight furnaces will be growing crystals with a capability of 160 kg per week.

Growth requirement - up to 7975 kg
Crystal diameter - 5 inches
Growth period - 6 days
Five missions - 1600 kg each, total of 8000 kg

Mission One

On this mission take up three additional furnaces and power conversion units to meet the requirement for eight for the growth process plus one as a spare.

Mass up	
Furnace	1500 kg
Power conversion	450 kg
Cartridges	16000 kg
Mass down	
Cartridges	12000 kg
Electrical Power	160 kw

Mission Two, Three, Four, Five, Six.

Mass up	
Cartridges	16000 kg
Mass down	
Cartridges	16000 kg
Electrical Power	160 kw

At the end of mission six there will be 1,330 kg of crystals to return for marketing. Also, there will be in orbit seven furnace systems.

2. Crystal Growth Research and Development on a Space Station

a. Scope

There are two types of activities that require the identification of support requirements. First, it is anticipated that there will be a continuing need for flights for the purpose of conducting crystal growth process experimentation and development. These flights will be required for process improvements and for experimental and developmental work on crystals not yet in the production phase. Second, there are requirements to support the production runs of the crystal growth process to meet the projected market demands. The production runs are discussed elsewhere in the report.

b. Experimental Research and Development

There should be a continuing need for support to experimental work in orbit, especially after the Space Station is available and a professional researcher can perform the work in a laboratory in the station. The laboratory must have standard research equipment for the process development, and for the characterization of the crystals. The equipment required for the laboratory is listed in item 2 under requirements.

It is expected that most of the experimental work will be done on crystals at production diameters, however the growth thickness can be considerably less. For this reason furnaces for the experimental work should be designed for laboratory use.

c. Requirements

1) Crew Skill

The experimental work on board will require the same skills as that required for ground based crystal growth experimental work. A trained materials scientist with a terminal degree and the equivalent of several years of experience is the minimum requirement. Because of the limited communication opportunities for collaboration with associates the researcher should have demonstrated efficiency in all phases of the crystal growth process development and characterization.

2) Laboratory Equipment

The laboratory should include the following equipment or capability:

-Raw material storage
-Raw material handling equipment
-Raw material weighing equipment
-Furnace(s)
-Cutting machine
-Polishing and etching equipment
-Microscope

- Hall effect measurement equipment
- Spreading resistance measurement equipment

The above is considered the minimum capability. A more elaborate laboratory could include a Scanning Electron Microscope and an X-Ray Defraction Machine.

3) Utility Services

Electrical power requirements are in two categories. The basic laboratory equipment will require 60 hertz a-c power unless it is redesigned to be compatible with "normal" spacecraft power. It is anticipated that there will be numerous needs to use equipment usually found in research laboratories on board the space station, therefore it is recommended that consideration be given to providing 60 hertz power on board.

The crystal growth process requires d-c power at low voltage and high currents. This requirement is caused by the need for current densities up to 50 amps per cm squared. In the latter part of the 1990's there will be a requirement for crystals up to six inches in diameter. The initial work will be done at two inches in diameter. This identifies a need for d-c power at five volts or less with current adjustable from 200 amps to 9000 amps.

A supply of inert gas, such as nitrogen, argon or helium, is required at every low operating pressure, about one atmosphere.

4) Structure/Physical Accommodations

The laboratory must be large enough to accommodate the equipment listed, be environmental controlled, and have space for two researchers.

5) Duration of Process Runs

It is anticipated that there will be a demand for use of the space station crystal growth laboratory for all of the different methods of crystal growth. The various methods require different amounts of time varying from days to weeks. The experimental work will be done on crystals ranging from very small samples to production sizes which will also cause the growth periods to vary. The duration of a particular run can vary then from one day to perhaps as much as months.

6) Number and Frequency of Experiments

It is anticipated that a research team will visit the space station for periods of from three to six months to conduct a set of experiments. A team, perhaps of two, working end to end shifts, will allow the laboratory to be used on a near full time basis, providing for a more efficient use of the facility and a greater return on the investment. While there they will be growing experimental crystals, performing characterization studies, and other analyses on a continuing basis. Because of the expected demand for use of the laboratory the research team for a particular mission period will perform work for a number of organizations on a cooperative basis.

Considering the large number of organizations performing ground based research in crystal growth, and the expanding interest in growth in space, it is expected that a well equipped laboratory will be in use full time, probably with the demand exceeding the capability. The potential test candidates are almost endless.

Space laboratory work will be complementary to that done in the ground based laboratories, with some work done concurrently with communication between the two laboratories. Since the space laboratory will have the capability of doing only a fraction of the work being performed in the ground laboratories it will be necessary to limit the space work to those experiments that require the space environment.

7) Data Acquisition and Recording

The laboratory must have the capability to acquire, record and display data from the experimental processes. This will include access to an on board computer. There will be a need for transmitting selected data to the ground, and voice and video communications to permit collaboration with associates in ground based laboratories.

8) Thermal/Environmental Control

The laboratory must be environmental controlled comparable to that normally experienced in ground based laboratories. Temperature should be 70-72 degrees F., with humidity not more than 60%. A standard clean laboratory should be adequate.

9) Crew Safety Provisions

Safety hazards can be categorized as those found in the ground based laboratories conducting crystal growth process development. These are working with electrical power, handling materials at high temperatures, and the potential of escaping toxic products. Standard safety procedures, and the professional experience of the researcher should be adequate to make these potential hazards acceptable. The potential of escaping toxic gases, such as arsenic from GaAs, will require special attention.

Flight satefy has been and continues to be a major concern of NASA. This is brought about, and rightly so, by the Apollo spacecraft fire on the pad at KSC, the failure on Apollo 13, and other events. The approach is to take safety precautions to assure that there is not loss of life of a crewman, or a loss of the mission. Some of the raw material used in crystal growth are toxic, and if flown today on the Orbiter would require containment that is two failure tolerant and still safe. Because of these valid concerns, and because it is anticipated that these raw materials will need to be handled in the Space Station laboratory, it is recommended that the design of the laboratory include a capability to cope with these potential safety hazards.

Part III ORBITAL OPERATIONS ISSUES

1. Feasibility of Loading, Off-loading and Reloading Furnaces

Loading, off-loading and reloading of furnaces fall into three categories, 1) the handling of the furnace as a unit, i.e. installing the furnace on the spacecraft before flight and its removal afterwards, 2) loading of cartridges into the furnace and their removal, 3) loading of the seed crystal and the raw material into the cartridges.

a. Orbiter Sortie Flights

For the Orbiter sortie flights the cartridges will be loaded with the seed crystal and the raw material in a laboratory provided for this purpose. The laboratory will have a controlled environment to protect the seed and material from contamination. Quality control will be exercised during and at the end of the process to assure that flight standards are met. The quality inspection will include specified tests, for example a test to assure that proper electrical contact has been made in the cartridge.

The furnace can be loaded with the cartridges at either the laboratory where the cartridges are loaded, at the furnace or integrating contractor facility, or at the launch site. Without benefit of a detailed analysis it appears that the furnace should be loaded at the laboratory where the cartridges are loaded. The advantages include 1) a controlled environment exists, 2) skilled personnel are available, 3) skilled personnel do not have to disperse to multi-sites, 4) the handling and shipment of the cartridges as individual units is minimized. After the furnace is loaded with the cartridges a test will be performed to assure that the loaded furnace is functioning properly. After the furnace is tested it is shipped for integration with the support structure.

The next level of integration is the installation of the furnace on the support structure. This can be done at the launch site or at a remote integration site. Since the flight, and most likely the support structure, will be shared with another payload NASA will designate the site for this integration. Beyond this point the furnace will not be handled as a unit, rather it will treated as a part of an integrated payload.

After the flight the furnace will be removed from the support structure and returned to the laboratory for removal of the cartridges, and for removal of the grown crystals from the cartridges. The cartridges and the furnace will be cleaned, as required, and prepared for the next flight.

All of the above loading and off-loading procedures should be straightforward, therefore do not present any identifiable significant issues.

b. Orbiter-Serviced Free Flying Platforms

The handling of the cartridges and furnaces for the Orbiter part of these flights should be identical to that for Orbiter sorties. The interface between the Orbiter and the free-flyer presents a number of issues that must be addressed.

The first issued is how much of the support services will be provided by the free-flyers and how much must be provided as a part of the crystal growth system. One must assume that the crystal growth system will include the furnace, and the power conditioning and conversion equipment. The thermal/environmental control, and data and communications possibly will be provided by the free-flyer. In any case the task of transferring the crystal growth system to the free flyer may require that the system as an integrated package be moved rather that individual components. This approach would require the support structure, with the growth system integrated, be transferred.

The mechanism for the transfer must be decided and will most certainly be influenced by the dexterity and capability of the systems available. Currently, the systems available are the Remote Manupilator System (RMS) and by EVA. A number of flights planned by NASA with the

Orbiter should provide information on the capability of the two approaches.

Return of the system from the free flyer to the Orbiter should be as simple as reversing the procedure for transfer over.

2. Refurbishing Furnaces and Equipment

Indications are that the furnaces, operating at the temperatures planned, with a good design, proper selection of materials and protection against oxidation, should last from five to ten years. It will be noted from the projected flights profile that the crystal diameter increases such that a single diameter lasts for two to four years. In order to accommodate the increase in diameter it is anticipated that the furnaces will have to be modified, or replaced. Therefore, it is not anticipated that there will be much need for refurbishing or repair of the furnaces due to failure. It should be noted that the flight profile makes provisions for spare furnaces at discrete times. This is to protect the production process against the consequences of a furnace failure, irrespective of the projected lifetime.

As the crystal diameter increases, so does the current used in the growth process. This will require that the power conversion equipment be procured initially with a range of current outputs, or be modified or replaced as the diameter is increased. Because of the low efficiency of the power conversion equipment, and the desire to keep it as high as possible, it is anticipated that the equipment will be replaced as the crystal diameter increases. This replacement should be within the expected lifetime of the equipment.

The rest of the equipment should be standard space flight hardware with the expected life normally associated with it. After each flight, all the equipment will be inspected and tested to confirm that it is still of flight quality. A spares program will need to be implemented to insure against loss of production time due to failure. During the Space Station era, some of the spares will be kept on board the station.

3. Modifying Experiments or Processes

As noted in Part II there are two kinds of crystal growth, that for production and that for research and development. During the production of a particular crystal, like GaAs, it is anticipated there will be activity directed toward process improvements. These improvements will be developed in complementary ground and flight activities, and will be incorporated into the production process at the appropiate time.

The flight profile in Part II forecasts that even during the Space Station era the cartridges will be loaded on the ground, carried to the station and returned to the ground for unloading. An issue is whether it is more economical to leave the cartridges on the Space Station and use the Orbiter to transport the growth material and the grown crystal. There is no apparent reason that the cartridges cannot be loaded on orbit with a properly equipped laboratory and crew skills.

Also, it is anticipated that there will be a continuing ground and flight activity in the development of growth processes for new crystals. After the Space Station is available, the flight development work will be done in the Space Station laboratory. It is projected that the R&D work will grow such that the Space Station laboratory will be in full time use in the latter part of the 1990's.

4. Evaluating Results

The Space Station laboratory should be equipped to provide some on board evaluation of the R&D work done there. This will permit real time assessment, adjustments in the experiment or process, another run and evaluation. There are very obvious savings in time by having this evaluation capability on board.

Although there will be an evaluation capability on board the Space Station, it is not anticipated that, due to practical limits, it will replace the need for evaluation of crystals in a ground based laboratory. In ground based evaluation there are opportunities to bring in the judgement of many experts, and to have the evaluation done in multiple facilities if desired. There will probable not be more than two crystal experts on board the station at any one time.

It is expected that all production run evaluation will be done in ground based laboratories. This will be a part of the post flight quality control process to determine the quality of the crystals before they are marketed.

5. Crew Skills to Support Operations

For all of the Orbiter sortie flights, Orbiter-serviced free flyer flights, and the production runs in or supported by the Space Station, the crew skills should be compatible with that normally associated with the NASA astronaut corps.

The R&D work to be done in the Space Station laboratory must be performed by someone especially skilled in crystal growth. He should have a number of years experience in a laboratory with crystal growth research and development, including crystal characterization, and probably will have an advanced degree in the field, most likely a terminal degree. Some of the work can be assisted by an astronaut-scientist. The degree of assistance will depend on the skills and training of the individual.

Part IV COMPARATIVE EVALUATION OF SYSTEMS

1. Orbiter Sorties Flights

a. Production Limitations

The quantity of crystals that can be grown on the Orbiter in a sortie mode is limited by the electrical power available. The Orbiter electrical power is limited to a maximum output of 12 kw, and it still has to be confirmed that 12 kw is available on a continuous basis. In addition, for a typical mission the Orbiter has 50 kwh electrical energy available for use by the payload. Additional energy is available by using extra cryo tank sets (energy kits) to supply reactants to the fuel cells. Each additional energy kit is advertised to provide 850 kwh of energy, however experience to date has shown that up to 1100 kwh, or more can be provided. Analysis indicates that two extra energy kits are required for a mission of seven days. Even with the two extra energy kits about 12 kg is all that can be grown on a single mission.

There are no production limitations from a mass and volume standpoint. On the contrary, the Orbiter has much more capacity in that respect than is needed, making crystal growth as an ideal payload for sharing a mission with a payload that is delivered on initial arrival in orbit.

b. Schedule Uncertainties

Because of the cost of a dedicated mission in the late 1980's and early 1990's it is almost mandatory that crystals be grown on a flight that can be shared, especially one that has its mission performed immediately after arrival on orbit leaving the rest of the mission, with all available electrical power and energy, for crystal growth. The flight constraints will place considerable uncertainties on the flight schedule, and will require long lead-time commitments, with little or no opportunities for schedule delays.

c. Cost Considerations

A cost analysis is provided elsewhere in the report. A review of that analysis shows that growing crystals by the Orbiter sortie mode costs much more per kg of crystal grown than any other mode. The major cost factors are the cost per mass of payload, the cost per day for extra stay time on orbit, and the cost for transporting the cryo reactants for the two extra energy kits that are chargeable to the payload. The cost for extra time on orbit is the dominant factor.

d. Market Considerations

The cost of space production will be the predominant determinant in market demand for space-produced semiconductor crystals. As the cost can be brought down, additional applications for the materials can be considered and market demand will grow. Chart 7 reflects the dramatic reductions in space production costs expected from the availability of free flyers and the Space Station. The market projections shown in this report reflect the anticipated availability of these systems.

2. Orbiter-serviced Free Flyer

a. Production Capability

The production capability using a free flyer such as the Leasecraft is limited only by the electrical power available. The basic configuration is discussed as having 6 kw of power, with 5 kw available to the payload. The electrical power is from a set of solar panels on the spacecraft. For the purposes of this report it is assumed that the solar panels will be expanded to provide 20 kw to the payload. Costs have been included in the cost analysis to compensate for this addition.

PRODUCTION COST COMPARISON

Per Kg

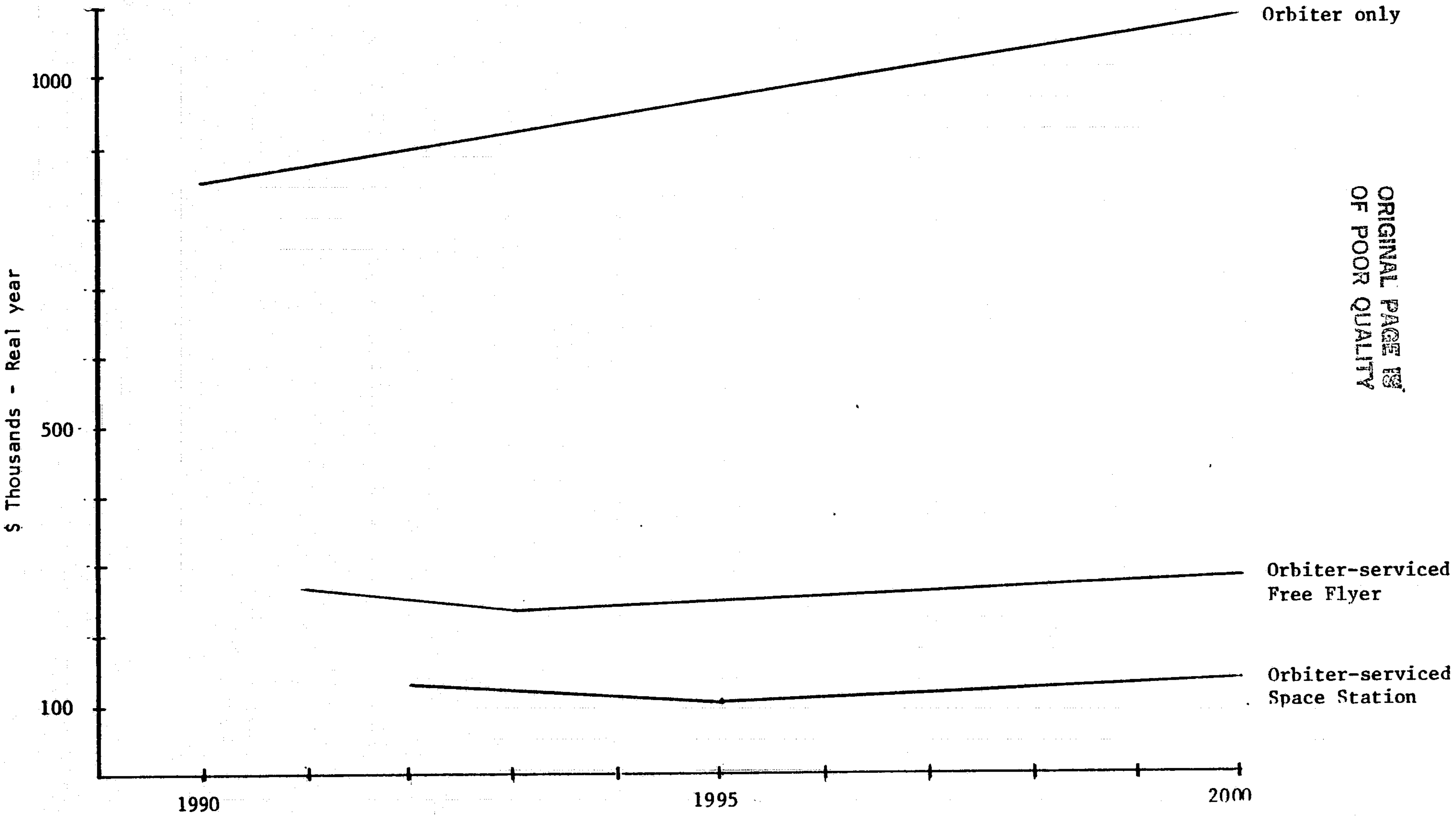

Chart 7

Since a typical growth period will be one week with about 20 kg output, and since most missions will need to grow for a number of weeks, a furnace loaded with raw material will be placed on the free flyer for each 20 kg of crystal to be grown. Provisions must be made for switching from one furnace to another as one growth period ends and another begins.

b. Frequency of Service Visits

The total growth period will be limited to the number of furnaces available for use and the space available on the spacecraft. For example,to grow 100 kg on a single mission five furnaces are required operating in sequence one week at a time. A flight is required by the Orbiter to place the furnaces on the spacecraft, and another to retrieve them. The retrieval time can be anytime after the growth cycle is completed and can be compatible with another visit needed by another payload on the spacecraft, or it can coincide with another flight of the Orbiter for other purposes. The Leasecraft sponsors discuss visits to the spacecraft every three to six months.

c. Automation Requirements

From a practical standpoint the electrical power available to the payload will probably be limited to about 20 kw. A single furnace growing 20 kg of crystals takes one week. For larger quantities,multiple furnaces at 20 kg capacity must be operated in series. Another possibility is to have a single furnace with the furnace loaded and unloaded after each growth period. In either case,the operation must be automated to preclude weekly visits of the Orbiter. If multiple furnaces are used,an automatic method of switching from one furnace to the other at the end of each growth period is required. If a single furnace is used,then an automatic method must be provided for moving the raw material into the furnace and removing the grown crystal. At the end of the mission the furnace(s) with (or and) the grown crystal will be removed and returned to earth.

d. Reliability Considerations

Operating in the free flyer mode requires a degree of demonstrated reliability above that for missions where the crew has direct access to the system. This is brought about by the fact that the free flyer will be loaded with the growth system at the beginning of a mission and removed at the end of the mission. Crew participation is limited to the initial activation after the installation of the system with parameters monitered in the Orbiter or on the ground, or both. After initial activation, monitoring of the system will be by looking at a limited number of parameters on the ground. Corrective action should a failure occur will be extremely limited, probably to the extent of turning the system off to avoid damage. Should such an event occur early in a mission the entire mission could be a failure.

e. Cost Considerations

A cost analysis for this flight is provided elsewhere in the report. Assuming the basis for the cost analysis is reasonably accurate the Orbiter-serviced free flyer mode offers considerable cost advantage over the Orbiter sortie mode, by a factor of more than three to one. There is some uncertainty in the free flyer cost numbers pending obtaining better information from Leasecraft, however the overall cost advantage should not change.

3. Space Station

There are three modes identified for use of the Space Station. First, there is a mode where the crystals are grown in a laboratory in the basic Space Station. Second, there is an attached dedicated module where materials processing activities requiring very low acceleration rates are performed. The attached module is physically a part of the Space Station with the provision for protection from acceleration forces generated in the station. From an operational standpoint there are essentially no differences in these two modes.

The third mode is Space Station-serviced free flyer which is discussed in paragraph 4 below.

a. Production Capability

Within the market projections the only production limitation in this mode should be in the electrical power available. Taking into consideration equipment efficiencies, losses, etc. the crystal growth system requires about 1kw of power for 1kg of grown crystal at a current density of 10 amps per square centimeter. It should be noted that the power demand increases with the growth. With 40kw of power available a system running full time could produce 2000 kg of crystal in a year. If the high market projection of over 6,200kg per year materializes, then 180 to 240 of power will be required.

b. Advantages of Free and Ready Access

An obvious advantage of having the crystals grown in the Space Station is the ready access to the system by the crew. The crew can load and unload the furnaces at the beginning and end of the growth period, and can monitor the growth process for anomalies and take corrective action. The monitoring should not be time consuming and should be limited to periodic check of parameter displays for out of tolerance condition. The parameters could be connected to an audible alert system so that the periodic monitoring can be avoided.

c. Cost Comparison

A cost analysis of typical missions is shown elsewhere in the report. It shows a considerable advantage over the Orbiter sortie mode and the Orbiter-serviced free flyer mode.

4. Space Station-serviced Free Flyer

a. Production Capability

The comments for Orbiter-serviced free flyer are applicable here.

In addition it should be noted that there probable will be a practical limit to the quantity of crystal that can be grown on a single free flyer. To accommodate the high market projection for the late 1990's multiple free flyers probably would be required.

b. Frequency of Service Visits

The comments for Orbiter-serviced free flyers are applicable. For this mode the opportunities for service visits will be limited by the orbital parameters of the space station and the free flyer. It is anticipated that neither the Space Station nor the free flyer will have large propulsion systems for orbit adjustments for rendevous, nor would it be economical.

It should be noted here that there does not appear to be any advantage to using a Space Station-serviced free flyer mode, while there seem to be a number of disadvantages. Some of these disadvantages might disappear, or be minimized, if the free flyer can fly continuously in a convoy mode with the Space Station such that it is accessible by the crew using a mobile maneuvering unit.

c. Automation Requirements

See comments under Orbiter-serviced free flyer.

d. Reliability Considerations

See comments under Orbiter-serviced free flyer.

e. A cost analysis is shown in Part 5 of this report. For the cost analysis, a mission was costed using the Space Station only and the same mission in the Space Station-serviced free flyer mode. An increase of about 28% is shown when the free flyer is added.

Part V COST ESTIMATION AND COMPARISON

1. <u>Orbiter Sortie Mission</u>
    a. Typical Flight (1990)
        1) Assumptions
            a) Mission is shared such that a payload is delivered at the beginning of a 7-day mission with 6 days for crystal growth. Furnace warmup will begin on the first day.
            b) The fourth and fifth energy kits are available to provide electrical power to the payload to a peak of 12 kw at the end of the growth period.
            c) Payload mass is 1300 kg.
            d) Crystal grown - 12 kg
            e) Payload must pay for transportation of the fuel cell reactants for the two extra energy kits, 382 kg per kit.
            f) STS charges, real year dollars:
                - $2652/kg mass
                - $825,00/extra day on orbit

        2) Cost calculation

1300kg x $2652 = $3,447,600
764kg x $2652 = $2,026,128
6 days x $825,00 = $4,950,000
Total Cost $10,423,728

Cost per kg $ 868,644

2. <u>Free Flyer-serviced by Orbiter</u>
    a. Flight 1 (1991)
        1) Assumptions
            a) Orbiter flight is shared such that the crystal growth payload is delivered to the free flyer.
            b) The free flyer is shared with another payload.
            c) Crystals in 20 kg lots will be grown over a six day period.

d) Electrical power up to 20 kw is available for crystal growth.

e) Crystal grown - 60 kg.

f) Crystal growth payload mass delivered to and retrieved from the free flyer is 2600 kg.

g) Cost for retrieval by the Orbiter is for extra orbit days only, based on shared flight and opportunity retrieval.

h) Two days extra orbit time are allocated for transfer operations.

i) STS charges, real year dollars:
  - $2785/kg mass
  - $866,300/extra day on orbit
  - EVA $288,610

j) Free Flyer charges, real year dollars:
  - Basic spacecraft with 5kw power is $3M/month, or $0.75M/weel,
  - Additional power at $6975/kw-day
  - No charge for stay time while waiting retrieval.

2) Cost calculation

a) STS

2600 kg x $2785 = $7,241,000

2 days x $866,300 = $1,732,600 (transfer from Orbiter)

2 days x $866,300 = $1,732,600 (retrieval)

2 x $288,610 = $ 577,220 (EVA)

b) Free Flyer

3 weeks x $0.75M = $2,250,000

15kw x 21 days x $6975 = $2,197,125

Total Cost $15,730,545

Cost per kg $262,175

b. Flight 2 (1991)

1) Assumptions, same as for Flight 1 except:

a) Crystals grown - 100 kg

b) Crystal growth payload mass delivered to and retrieved from the free flyer is 4400 kg.

2) Cost calculation

a) STS

4400 kg x $2785 = $12,254,000
2 days x $866,300 = $ 1,732,600 (transfer from Orbiter)
2 days x $866,300 = $ 1,732,600 (retrieval)
2 x $288,610 = $ 755,220 (EVA)

b) Free Flyer

5 weeks x $0.75M = $ 3,750,000
15kw x 35 x $6975 = $ 3,661,875
Total cost $23,708,295
Cost per kg $ 237,082

3. <u>Space Station</u>

a) Flight 1 (Early mission-1992)

1) Assumptions

- a) 20 kw power available for crystal growth.
- b) Take up two furnaces, use only one for growing 20kg/week, for five weeks. 100 kg total.
- c) Orbiter flight is shared.
- d) Crystal growth mass carried up by the Orbiter is 2550 kg. Volume delivered to the Space Station is 156 cubic feet.
- e) Crystals are grown in the Space Station.
- f) STS charges, real year dollars:
  -$2924/kg mass
- g) Space Station charges, real year dollars:
  -$7330/kw-day
  -$62,716/man-day for crew time
  -$5700/day use of berthing port
  -$8/cubic foot/day internal volume

2) Cost calculation
   a) STS
      2550kg x $2924 = $7,456,200
   b) Space Station
      Berthing port - 1 day x $5700 = $5700
      Power - 35 days x 20kw x $7330 = $5,131,000
      Volume - 156 cu. ft. x $8 x 35 days = $43,680
      Crew time - 10 days x $62,716 - $627,160
      Total cost $13,263,740
      Cost per kg $132,637

b. Flight 2 (mid-term mission-1995)
   1) Assumptions
      a) 40 kw power available for crystal growth.
      b) Take up one furnace, use another furnace carried up on previous mission for growing 40kg/week, for 12 weeks, 480 kg total.
      c) Orbiter flight is shared.
      d) Crystal growth mass carried up by the Orbiter is 5250 kg. Volume delivered to the Space Station is 150 cubic feet, with another 150 cubic feet on board, total of 300 cubic feet.
      e) Crystals are grown in the Space Station.
      f) STS charges, real year dollars:
         - $3385/kg mass
      g) Space Station charges, real year dollars:
         - $8460/kw-day
         - $72380/man-day for crew time
         - $6580/day use of berthing port
         - $9/cubic foot/day internal volume

   2) Cost calculation
      a) STS
         5250kg x $3385 = $17,771,250
      b) Space Station
         Berthing port - 1 day x $6580 = $6580

Power - 84 days x 40kw x $8460 = $28,425,600
Volume - 300 cu. ft. x $9 x 84 days = $226,800
Crew time - 24 days x $72,380 = $1,737,120
Total cost $48,167,350
Cost per kg $ 100, 349

c. Flight 3 (end of period - year 2000)

For comparison purposes this is a repeat of the Flight 2 profile.

1) Assumptions
   a) 40 kw power available for crystal growth.
   b) Take up one furnace, use another furnace carried up on previous mission for growing 40kg/week, for 12 weeks. 480 kg total.
   c) Orbiter flight is shared.
   d) Crystal growth mass carried up by the Orbiter is 5250 kg. Volume delivered to the Space Station is 150 cubic feet, with another 150 cubic feet on board, total of 300 cubic feet.
   e) Crystals are grown in the Space Station.
   f) STS charges, real year dollars:
      - $4320/kg mass
   g) Space Station charges, real year dollars:
      - $10,800/kw-day
      - $92,400/man-day for crew time
      - $8400/day use of berthing port
      - $12/cubic foot/day internal volume

2) Cost calculation
   a) STS

      5250kg x 4320 = $22,680,000
   b) Space Station

      Berthing port - 1 day x $8400 = 8400
      Power - 84 days x 40kw x $10800 = #36,288,000
      Volume - 300 cu. ft. x $12 x 84 days - $302,400
      Crew time - 24 days x $92400 = $2,217,600

Total cost	$61,496,400
Cost per kg	$ 128,117

4. Space Station with Attached Dedicated Module

In this configuration there is a module dedicated to those activities that require very low acceleration rates. The module is attached to the Space Station with a presurized tunnel to handle the crew and equipment traffic in a shirt sleeve environment. The connecting tunnel will be designed to absorb any acceleration forces originating in the basic Space Station.

In analyzing the cost of using the dedicated module it appears that the cost should be the same as for use of a laboratory in the basic station. Therefore, the missions costed under Space Station should be representative.

5. Space Station-serviced Free Flyer

a. Mission. 1995

This mission is the same as Mission 2 under Space Station except that the growth occurs in the free flyer instead of the Space Station.

1) Assumptions
    - a) 40 kw power available on the free flyer for crystal growth.
    - b) Take up one furnace, use another furnace carried up on previous mission for growing 40kg/week, for 12 weeks. 480 kg total.
    - c) Orbiter flight is shared.
    - d) Crystal growth mass carried up by the Orbiter is 5250 kg. Volume delivered to the Space Station is 150 cubic feet, with another 150 cubic feet on board, total of 300 cubic feet.
    - e) Crystals are grown in the free flyer
    - f) STS charges, real year dollars:
        - $3385/kg mass
    - g) Space Station charges, real year dollars:
        - $8460/kw-day
        - $72380/man-day for crew time

- $6580/day use of berthing port
- $9/cubic foot/day internal volume

h) Free Flyer charges, real year dollars:

- Basic spacecraft with 5kw power is $3M/month, or $0.75M/week.
- Additional power at $8460/kw-day

i) Each EVA cost $350,000

2) Cost calculation

a) STS

-5250kg x $3385 = $17,771,250

b) Space Sation

Berthing port - 1 day x $6580 = $6580

Volume - 300 cu. ft. x $9 x 84 days = $226,800

Crew time - 24 days x $72,380 = $1,737,120

c) Free Flyer

12 weeks x $0.75M = $9,000,000

Power - 84 days x 40kw x $8460 = $28,425,600

EVA - 13 x $350,000 = $4,550,000

Total cost $61,717,350

Cost per kg $ 128,577

6. Additional Notes on Cost Data

a) Orbiter transportation cost from May 1982 STS Users Handbook, $718/1bm in 1980 dollars for shared flights of domestic commercial users. Inflation at 8% in 1981 and 5% thereafter.

b) Extra days on orbit for the Orbiter at $300,00/day 1975 dollars, or $558,600/day in 1982 dollars.

c) Space Station cost rates are from Boeing, based on their mid-term report to NASA. Those rates included amortization of the cost of the Space Station, and were in 1982 dollars. The rates have been cut in half to eliminate the Space Station amortization and inflated to real year dollars for each case.

d) Free flyer cost rates for the basic spacecraft are based on telephone information on the planned leasecraft,and are not to be considered as official data from Fairchild. The electric power rates are the same as provided by Boeing for the Space Station.

e) EVA cost rates are from the STS reimbursement guide, $60,000 to $100,000 in 1975 dollars. The higher number was used and inflated to real year.

f) Since the Orbiter rates are for a flight and return, the basic rate was used for those missions where return is on another flight, however no additional charges have been shown for the return flight.

The following conversion factors were used for inflation to real year dollars.

1975 $ x 1.862 = 1982 $
1982 $ x factor = year

Factor	Year
1.477	1990
1.55	1991
1.629	1992
1.71	1993
1.79	1994
1.88	1995
1.91	1996
2.078	1997
2.18	1998
2.29	1999
2.4	2000

7.2.1.2 Communications Missions and Communications Equipment Analysis (RCA Astro-Electronics, Princeton, N.J.)

FINAL REPORT

Communications Missions and Communications Equipment Analysis

for

Space Station Needs, Attributes and Architectural Options Study

Prepared for
Boeing Aerospace Company
Seattle, Washington

Purchase Contract CC0131

March 1983

RCA Astro-Electronics
Princeton, New Jersey

1.0 COMMERCIAL COMMUNICATIONS SATELLITES

1.1 Background and Summary

Communications satellites at geostationary altitudes have been used commercially for approximately fifteen years. (A good brief summary appears in Reference 6) Most of these systems have been of the fixed service type where channels are provided between ground stations with large antennas to support the needs of specified customers. These channels may be operationally dedicated to specific customers full time or may be time shared among several customers. Generally, the coverage provided by the antennas on the satellite is over a large area rather than over small regions using fixed or steerable narrow beams. Since the only bands currently used are C(6/4 GHz) and K (14/12 GHz) bands and there are severe limitations on the proximity of satellites using these frequencies, the total traffic handling capability of all potential satellites of this type is beginning to be strained by desires of customers. Hence, there is considerable interest in investigating new approaches - which may require larger satellites. The availability of a space station to support the assembly and deployment of such large satellites is therefore of interest. Also of interest are the possibilities of more economical designs and longer life for the satellites as well as shorter replacement times by using space station services.

Two other types of satellites are now becoming of more interest. The first are the direct broadcast satellites (DBS) which will provide direct service to homes of either wideband signels (e.g., television) or narrowband broadcasts (e.g., radio). Current plans for domestic DBS systems call for a dedicated satellite to broadcast to each time zone. Thus a system for the U.S. could have four operating satellites plus a number of spares for replacement at scheduled intervals or as needed so as to limit any interruption in commercial service. There are likely to be several such systems operating simultaneously each providing its own unique complement of programs. Potential for using the space station to simplify replacements of DBS satellites was also deemed worthy of further study.

Satellites to provide service to mobile surface or airborne systems are now under investigation. Operational systems are not expected before the mid 1990's (Reference 1) and the number of such satellites will be limited. Specific requirements for such systems were not used in the considerations of this study.

The purpose of this part of the Space Station Needs, Attributes and Architectural Options Study was to determine if the potential capabilities of a space station could be applied to commercial communications satellite systems. Specifically the goals were:

(1) To identify and evaluate space station functions which could be beneficial to communications satellite development and operations

(2) To identify those communications satellite missions and systems concepts which could take best advantage of the station

(3) To determine the impacts on spacecraft and payload design for the missions/systems in (2) above

(4) To estimate rough order-of-magnitude incremental costs to the communications satellites, and

(5) To determine the requirements imposed on the space station for these missions.

RCA Astro-Electronics was selected to perform this study because it has been a major developer of commercial communications satellites for over 10 years and has been designing, building, testing and launching all types of satellites since 1958. RCA developed the Relay satellites for NASA in the 1960's, launched its first commerical communications satellite, RCA SATCOM 1 in 1975, and since then has built or is building advanced communications satellites for five different customers. Among them, RCA is now developing the first direct broadcast satellite for the Space Television Corporation, a division of Comsat-General.

The results of this study are incorporated in the following four subsections of this report. The benefit studies, item (1) above, and the mission analysis, (2) above, are reported in Sections 1.2 and 1.3 respectively. The impacts on satellite design, cost estimates, and space station support needed are combined for reconfigurable satellite concepts in Section 1.4 and for large multibeam satellites, in Section 1.5. These two missions were evaluated to be those which could take best advantage of a space station.

The major results of the study can be summarized as follows: Potentially beneficial functions of space stations to commercial communications satellite systems fall into five different categories. Thirty-four such functions were evaluated. Of these, twelve were classified as technology testing functions, i.e., proving out a function or measuring some phenomena which might be applicable to many different communications satellites of the future. Four functions related to the assembly and/or deployment of larger structures (e.g., antennas and arrays) then can be accommodated on current satellites. Eight functions demonstrate advantages of the station for pre-transfer orbit checkout, test and adjustment after launch to the station using the space shuttle. Finally, two categories of in-orbit servicing of communications satellites were examined. Four of these functions could be performed in low orbit at the station, while six functions should be performed at geostationary altitude where the satellites operate. The thirty-four functions were evaluated and placed into three ranking categories. 13.5 (allowing for borderline cases) functions were ranked as "good", 13.5 as "fair" and 7 as "poor" uses of a space station for commercial communications satellites. The best of these were:

- Large angenna assembly and/or deployments
- Zero-G technology testing of several types
- Preparation of spacecraft for transfer from low to geostationary earth orbit
- Reconfiguring payloads of spare satellites in orbit, and
- OTV utilization for transfer or refueling

Three specific types of missions are representative of communications missions which might best use a space station. First, the space station would be useful for systems using several satellites simultaneously with less than one spare-in-orbit for each satellite. The spare could be kept in orbit attached to or near the station and could be reconfigured to meet the requirements of a specific satellite when needed. Manual feed manipulation, switching and testing at the station could simplify the design and permit rapid replacement. The second mission takes advantage of the most important capability of the station - the ability to be able to assemble or deploy very large structures. For communications satellites this opens up the possibility of antennas much larger than currently considered. Large antennas permit the use of many feeds to allow simultaneous service over many narrow beams, thus allowing a high level of frequency reuse. For example, a C-band system with 25 meter antennas (8-10 times current size) would be feasible in a natural evolution from today's systems. The third mission would not be an operational communications system, but rather the use of the station as a platform for testing new communications hardware and techniques for handling, deploying, and servicing spacecraft or their subsystems in space. This mission would naturally seem to be a NASA mission, but it might be supported by a consortium of communications satellite companies or of contractors who build satellites. The mission could consist of fully scheduled experiments or could take advantage of launch space when available to send up individual experiments. Only the first two mission types received detailed analysis in the study.

The concept of reconfiguring a communications satellite antenna requires design changes to permit use of the interchangeable feed horn arrays and feed networks. These units would need precise positioning capability, locking mechanisms, and protection when not in use. Testing would initially take place on the ground, but verification of antenna patterns would be required in space. A limited near-field measurement program is proposed. On-board special purpose devices as well as modifications of existing station hardware (e.g., spacecraft positioner) would be required to provide the test targets and scanning capabilities. Station manpower and hardware would be used for both the reconfiguration and test procedures. Estimates were made for the incremental costs of the satellite modifications, special space station hardware required, station manpower needs and unique test hardware. Assuming 6-8 DBS systems and 8 reconfigurable fixed service systems, Table 1.1-1 shows the estimates of recurring costs per satellite in 1983 dollars. Non-recurring costs are estimated at 3-4 M$ for the design of the interchangeable units per system. Tolerances on these costs are estimated at 25-50%.

TABLE 1.1-1. RECURRING COST INCREMENT ESTIMATES FOR RECONFIGURING COMMUNICATION SATELLITE

Item	Cost Increment (M$)
Satellite Antenna Assembly Modifications	4
Space Station Operations (Manpower)	3
Manpower Training	0.15
Space Station Hardware (amortized)	0.1
Systems Test Target (amortized)	0.07
Total (rounded up)	7.4

The large multibeam satellites are really new designs which can be considered economically and technically feasible because of the potential availability of the space station for assembly and/or deployment of large structures. A C-band satellite with a 25 meter antenna to cover the CONUS with 210 beams of 0.2 - 0.3 degrees beamwidth each has been selected as typical for this mission. Seven frequencies would be used, thus giving a frequency reuse factor of 30. Since such systems would be basically new, full program cost estimates were made rather than estimates of cost increments. Two systems of two satellites each were assumed. Table 1.1-2 shows the cost estimates per satellite, again in 1983 dollars and with tolerances estimated at 25-50%.

TABLE 1.1-2. COST ESTIMATES FOR MULTIBEAM COMMUNICATION SATELLITES

Item	Cost (M$)	
	Non-recurring	Recurring
Spacecraft Bus Transponder System Antenna System	245 50 150	40 25 35
Subtotal: Satellite:	445	100
System Unique Station Hardware Shared Space Station Hardware Space Station Operations (Manpower) Manpower Training		1.3 1.9 35 0.1
Subtotal: Space Station		38.3
Total (Rounded off)*	445	140

(Cost of using the OTV is not included)

1.2 Potential Benefits Available Using Space Stations

1.2.1 Space Station Capabilities

For the purposes of this commercial communications satellite benefits study, only two orbits were considered for space stations: 28.5° inclination low altititude and geostationary. Even with this limitation, it was further recognized that the low altitude station would be implemented first and that there would undoubtedly be a long delay (perhaps, 10 years or more) between the first availability of a low altitude station and the availability of a geostationary station. With an estimate of the early to middle 1990's for the start of utilization of the first limited capability station, studies of benefits either at or initiated from low altitude were concentrated on.

To support commercial communications missions, the space station and its associated elements should provide capabilities for six general types of functions:

(1) Long term equipment tests or development of operating procedures for new technology, either specific subsystems or new, general concepts

(2) Deployment and/or assembly of large elements of a satellite and operations tests of those elements before transfer to geostationary orbit.

(3) Transfer of the satellite and/or servicing tools to geostationary orbit.

(4) Maintenance and servicing functions of operational or to-be-operational satellites.

(5) Refurbishing/reconfiguring of spare or old satellites

(6) Facilities, utilities, data acquisition and handling, and manpower to suport these operations.

Specific requirements for the space station capabilities available for these missions were assumed to be:

A. Orbit - Initially a low inclination (28.5°), low altitude (300-500 km) orbit with frequent or dedicated-load STS launches. Future geostationary platform could support more, regular on-orbit servicing.

B. Work Areas or Docks - Mechanical operations need large volumes for deployments and assembly and associated handling, alignment, and distortion measuring equipment. Electrical subsystem manipulations (especially on RF equipment) need areas for more precise work with isolation from RFI/EMI as much as possible. Docks should be able to handle full spacecraft.

C. On-Board Tools - Must include manipulators for remote operations with large modules as well as tools to support manual assembly and deployment assistance activities. Vernier adjustment tools and measurement devices may be required for manual antenna feed adjustment. Tanks for liquid propellant plus plumbing, nozzles, etc. would be required if spacecraft fuel is to be loaded at the staion; equipment would also be required for dynamic balancing after loading.

D. On-Board Test Equipment - Special test equipment for communications payload hardware test would probably be supplied with the payload to verify operability. Unique processing and display subsystems may be provided, but standard interfaces with station communications and data handling subsystems could also be required.

E. Data Handling, Display and Communications - General purpose equipment should be available to reduce the needs for STE above (D). Communications of test results to the ground or of test control parameters or procedures to the station would use station facilities.

F. Auxiliary Equipment - OTV's and teleoperators would be useful for transfer to geostationary orbit and for positioning other free-flyers, such as antenna targets, near the station (if they are to be used). The OTV would be equipped with fuel tanks and/or manipulators for module replacement as necessary to service the spacecraft at GEO.

G. Utilities and environmental controls and monitors for work stations.

H. Manpower - Both payload specialists and support technicians would be required with EVA capability.

I. Warehousing - Storage of replacement elements and fuel would be required.

1.2.2 Identification of Useful Functions

Approximately fifty potentially useful functions of space station were identified in all areas relating to communications satellites, 34 of which were considered of sufficient interest for evaluation. This group includes spacecraft bus mechanical and housekeeping support subsystem assembly, servicing and testing functions, and also the benefits of new or improved communications payload concept testing, servicing and refurbishment. The functions were defined and evaluated by RCA Astro-Electronics systems engineers, communications payload designers, and spacecraft and subsystem design and test engineers. Communications satellite program planners were also interrogated and particiated along with representatives from RCA Americom, a common carrier which purchases and uses communications satellites. The 34 difference benefits were categorized into five groups: technology testing, large structure assembly and deployment, pre-transfer checkout and assembly, in-orbit servicing at the space station, and remote in-orbit servicing at geostationary orbits.

Definitions of the functions considered in each group are given below.

1.2.2.1 Technology Testing Functions

(1) Concept tests of designs for deployment of large structures - Space stations could be used to deploy much larger antennas and arrays than are currently in use on communications satellites. Deployment mechanisms of several different designs must be evaluated in space before they can be used on commercial programs.

(2) Thermal distortion impacts on large antennas and testing of manually or automatically controlled adjustments - Here also, order-of-magnitude growth in antennas requires testing before use. Possibly also significant could be the determination of the extent to which basic systems design is affected (e.g., beamwidth of spot beam could be changed, perhaps corrected by steerable array).

(3) - (6) Comparisons of operations and performance at zero-G with measurements and computer simulation modules used on the ground.

(3) Fluid motion - Different shapes and plumbing are anticipated for propellant tanks, pipes and nutation dampers for future spacecraft. All communications satellites require transfer to synchronous altitude with a number of different attitude and spin modes and different percentages of capacity utilized. Fluid motion observations may be needed to verify or correct the models.

(4) Thruster plume shape and contamination measurements - Monitoring of effects of different configurations to help in selection and in designing protective shields as necessary.

(5) Thermal louver operations - Monitoring to assess performance. However, current design techniques and models are considered good.

(6) Dynamic impacts of spin on different configurations - Current models and techniques have proven quite accurate; hence not a good application.

(7) Testing of OTV servicing and handling functions - An orbital transfer vehicle will be a major new tool available to be used with the space station. It may have other capabilities besides the transfer of satellites to operational orbits, for example, on-orbit fuel loading or some functions of a limited remote manipulator. Hence, test of all its potential capabilities is necessary before use.

(8) Recovery operations and hardware - Since recovery of satellites during nearby tests or from operational orbit is an integral part of the STS/space station program, testing of operations and hardware (e.g., refolding and latching systems) is necessary. However, many of the concepts should already have been proven for the shuttle program.

(9) - (11) Life tests on solar cells, external coatings, and resistance of electronics equipment to radiation - Subsequential data already exists in this field, especially for solar cells. For the other two items, there might be some limited benefit for new components or materials or to confirm accelerated tests conducted on earth.

(12) Space charge/discharge effects - This is an important area that is still being heavily investigated. However, significant testing should be done at geostationary altitude.

1.2.2.2 Large Structure Assembly and Deployment

(1) Manual assembly and deployment assistance for large antenna and arrays - Very large antennas (> 20 meters in diameter) are of increasing interest for obtaining spot beams and, in conjunction with an appropriate feed structure, for obtaining well-defined radiation contours. Deployment of antenna system could also include feed deployment in order to obtain long focal length system. Larger solar arrays would be useful for more powerful direct broadcast satellites, for active array antennas. Space station support may be the most reasonable approach to incorporating such large elements in communications satellites.

(2) Antenna system reconfiguration - Beam switching and/or feed displacement could be performed manually in order to adapt satellite to operation in alternate orbital positions. Reconfiguration may be performed on satellite during initial ascent, or satellite may be returned from orbit by OTV.

(3) Installation and adjustment of beams and weights to improve inertia - This could be useful for spin balancing, but there are potential safety problems.

(4) External mounting of transfer propulsion system - If solid AKM continues to be used, it can be installed at the space station. If it can be shipped separately from the spacecraft, it could be mounted externally (length is no longer a problem), and it could easily be jettisoned after it burns, thereby reducing on-orbit weight and hence, hydrazine weight.

1.2.2.3 Pre-Transfer Checkout and Assembly

(1) Antenna Pattern Measurements and Adjustments - Primarily concerned with feed horn alignment which would be adjusted manually to assure the desired pattern. This is becoming an increasingly critical problem as feed arrays increase in complexity. Use of remote targets on an OTV or teleoperator would be complex to operate and control. Near-field measurements with targets attached to station with motion control for scanning and computer corrections of near-field data may be necessary.

(2) Removal of auxiliary launch support structure - Large spacecraft may have to be provided with stiffeners to survive STS launch environment. If properly designed these elements could be manually removed and the spacecraft made lighter at the space station. For commercial satellites, lower weight can mean longer life or margin for increased capability.

(3) Loading of liquid fuel - With a space station, the potential exists for carrying the fuel to the station separately and loading the fuel on the spacecraft there. Balance verification would be required after loading. Use of this concept for many spacecraft could result in substantial savings and could also open the possibility of later refuling.

(4) Spin table use for solid rocket systems - Spin up required for such systems could be provided at the station.

(5) Attitude control system test - Same comments as for 1.2.2.1 (6).

(6) Electrical ground path testing of array and thermal blankets - This probably can be done adequately on the ground.

(7) Manual removal of protective covers - Astronaut technicians can remove or release protective devices, thus eliminating the weight and complexity of automatic controls.

(8) Check and repair of thermal blankets - Visual inspection after the severe environment of launch and simple repairs seem quite reasonable to accomplish.

1.2.2.4 In-Orbit Satellite Servicing at the Station

(1) - (3) Reconditioning recovered satellite to become spare

(1) Refueling - This is a necessary function to provide adequate capability for long life on orbit (Section 1.2.3 (3)).

(2) Replacing RF hardware and switches - Possibly replaceable RF hardware includes antenna feed horns and array networks, power amplifiers, associated power conditioners, receivers, and some signal processing equipment. However, the satellite must be designed to be modular, and the modules must be accessible. There would be some corresponding weight penalty, but it could be offset by reduction in on-board spares and switching. This function is probably useful for selected items.

(3) Replacing batteries, solar panels and blankets - Current designs don't point to the need for this, but there is the possibility that some replacements (e.g., batteries) might be planned for in future designs.

(4) Orbit transfer using an OTV - This is a basic concept that is expected to be available with the space station. It could permit larger communications payloads on the satellites and elimination of the need for some integrated propulsion capability.

1.2.2.5 Remote Satellite Servicing at Geostation Orbits

(1) - (4) Using an OTV

(1) Refueling to extend life - This would permit initial ascent with limited stationkeeping fuel supply. The weight saving can be devoted to increased satellite performance. However, one must compare relative costs of launching the tanker directly from Earth vs. launch from low orbit. The satellite design must be compatible with refueling concept.

(2) Full fueling on orbit - This could substantially reduce weight (see comments for (1)). However, system is completely dependent on the existance of a "tankersat".

(3) Component replacement - This would have to be limited to relatively simple operations, even if a manned OTV is available. However, design could be planned to accommodate such operations. Redundancy reductions would be possible.

(4) Cleaning and deployment aid operations - This concept (e.g. cleaning of arrays, optical elements and manually or "robotically" aiding deployments) would not offer enough savings to be worth the risk.

(5) - (6) Remotely from LEO station

(5) Control and/or periodic energy transfer for stationkeeping - This "way-out" concept would take advantage of future energy transfer techniques (RF or laser-beam) to provide for low thrust stationkeeping. Application of this technique requires too much future development to be considered worth-while now.

(6) Telemetry, tracking and control functions (to supplement ground stations) - TT&C elements aboard satellite would allow reduction in present ground facilities (one ground station instead of two under present conditions). However, contacts would be limited, and the limited space station facilities should not be burdened with a task well done from the ground.

1.2.3 Summary of Benefits Evaluations

Table 1.2-1 summarizes the evolution of the benefits defined in Section 1.2.2 into three categories - Good (G), Fair (F), and Poor (P). In addition some general comments can be made about the economics and other concerns of commercial communications satellite companies for using space stations.

Communications satellite system costs could be affected by the availability of a space station, most clearly in the launch and stationkeeping activities. The use of an orbit transfer vehicle to carry the spacecraft to GEO and of reloadable liquid propellant tanks which could be smaller than those needed for a full 7-10 year mission could reduce long-term system costs. This would be especially so if these practices were used for many communications satellites, enabling the cost of the operations to be shared. On the other hand corresponding non-recurring, initial costs could be substantial. The same comments are valid for life-cycle costs for systems with very large antennas. In general, the increased capabilities of new communications satellites which are possible because of the availability of the station will require high, non-recurring investments, though over the long-term, they may provide lower costs for comparable traffic-handling capability. At this point, major investment by user companies is unlikely because of the uncertainties of the availability of the station and of the return of from the improved systems.

TABLE 1.2-1. EVALUATION OF SPACE STATION BENEFITS

Function	Rating
Technology Testing	
(1) Deployment Techniques - Large Structures	G
(2) Thermal Distortions and Adjustments	G
(3) Zero-G Measurements - Fluid Motion	G
(4) - Thruster Plumes	G
(5) - Thermal Louvers	F
(6) - Spin Dynamics	P
(7) OTV Functions	G
(8) Recovery Operations/Hardware	F
(9) Life Tests - Solar Cells	P
(10) - External Coatings	F
(11) - Radiation Resistance	F
(12) Space Charge Effects	F
Large Structure Assembly and Deployment	
(1) Antennas/Arrays	G
(2) Antenna Reconfiguring	G
(3) Booms/Weights to Improve Inertia	F
(4) External Propulsion Mounting	F
Pre-Transfer Checkout and Assembly	
(1) Antenna Pattern Measurement	F
(2) Removal of Launch Supports	G
(3) Loading of Liquid Fuel	G
(4) Spin Table Use for Solids	F
(5) Attitude Control Test	P
(6) Ground Path Tests	P
(7) Removal of Protective Covers	G
(8) Checkout of Thermal Blankets	G
In-Orbit Satellite Servicing at the Station	
(1) Recondition by Refueling	G
(2) by Payload Hardware Replacement	F
(3) by Power Component Replacement	P/F
(4) Orbit Transfer Using OTV	G
Satellite Servicing at Geostation Orbit	
(1) Refueling to Extend Life	F
(2) Full Fueling on Orbit	F/G
(3) Component Replacement	F
(4) Cleaning and Deployment Aid	P
(5) Remote Energy Transfer	P
(6) TT&C Functions	P/F

The procedures and policies for using such a station must be worked out unambiguously for a commercial company to be willing to use it. Concerns are raised about:

- priorities and schedules in using the station
- the use of government or industrial employees for on-board technical activites
- safety and and industrial-security protection on-board the station or when using its associated facilities (e.g. a Teleoperator, Tankersat, or handling fixture)
- government incentives to use the station
- commitment to permanently maintain an operational station plus ancillaries
- and other regulations or policies for this use

All of the concerns associated with commercial use of the STS are greatly magnified for a space station because of its longer life, increased size and capabilities, and potential simultaneous use by many more users.

Insurance requirements and contracts for system payments based on performance evaluations are also likely to be greatly modified. Again, this would be required because of schedule and performance risks due to the involvement or possible interferance of many user organizations and people, both on the station and in-space but associated with the station.

In general, commercial operations are conservative and have a clear requirement to make a profit. Also there is no obvious, urgent need in current communications satellite plans for the improved capabilities potentially offered by space stations. Hence, commitments to use such stations are likely to be made by commercial organizations only after it is more certain that space stations will be built and their use will be regulated in a defined manner.

1.3 Business Opportunities and Missions

Of the various possible uses for the space platform, those involving satellite reconfiguration and the erection of a multibeam satellite having a large antenna are retained as having the greatest promise.

1.3.1 Reconfigurable Satellite

Two types of satellites are considered: direct broadcast satellites (DBS) and the more conventional communications satellites which provide for a large number of both up and down links over a wide geographical area.

Typically a comprehensive DBS system can be assumed to consist of four satellites providing broadcast coverage to the four Conus time zones from four orbit locations. Satellite failure may be handled by maintaining a pair of satellites in orbit, one satellite providing backup for the Eastern and Central time zones and the other providing for the Mountain and Pacific time zones. Each spare satellite is equipped with two sets of switchable feed horns and their corresponding feed networks required to assure the coverage pattern corresponding to a particular time zone. Two spare satellites are required rather than a single one because it is not possible to provide the four sets of horns that would be required to cover any one of the four time zones.

Rather than provide two satellites in orbit, it would be possible to maintain one spare satellite in storage on a manned, low-orbiting platform. This satellite would not be equipped with feed horns and their feed networks, which would be stored separately on the platform. There would be four different feed horn/network assemblies available, and the appropriate one would be installed on the spare satellite when failure or continuing degraded performance of an orbiting satellite occurred. Rapid replacement of a failed satellite can thus be assured by a single satellite stored on the space platform rather than two satellites in orbit. This saving would be approximately 50M$, to be offset by the increased costs incurred as described in Paragraph 1.4.2.

As the year 2000 is approached, it appears likely that 6 to 8 DBS satellite distribution systems will be in place. There would thus be 24-32 satellites in orbit at a given time. While the present type satellite is designed for a seven year life, it can be assumed that considerations such as the possibility of refueling, upgrading or antenna pattern reconfiguration would make it attractive to replace in-orbit satellites every four years. The yearly replacement rate would then range somewhere between 6 and 8 satellites.

For DBS systems we have seen above that one may gain the cost of one spacecraft for every four in orbit. For conventional communication satellites the gain to be made is not discerned as easily. In order to assure a certain back-up capability in the event of failure, an operator will typically lease a number of channels on a preemptive basis at a lower rate than is charged for a prime channel ($75,000/mo. vs. $100,000/mo. for example).

Assuming a typical comsat operator has four active spacecraft in orbit at a given instant, one quarter of his available capacity must be leased at the lower rate to guarantee prime channel users. This would amount to a revenue loss of 7.2M$ per year for 24 channel satellites. Assuming satellite replacement every eight years at a cost of 30M$/satellite and 28M$/launch leads to a financial standoff. However, the future value of the preemptible channel will probably diminish seriously as channel availability increases. Assuming it goes to half it present value, the financial advantage of having a ready replacement available would be on the order of 20-30M$ over the eight year period.

Insofar as platform traffic is concerned, it can be noted that 2 degree spacing would allow for the positioning of approximately 80°C and K band satellites over the range of longitudes corresponding to Conus coverage. This does not include DBS satellites which have a separate downlink frequency band. It is assumed that 8 U.S. operators will occupy 32 positions. Assuming satellite replacement every six years leads to a replacement rate of 5.3 satellites/year to be handled by the platform.

Total replacement rate is thus concluded to be 11.3-13.3 satellites/year for the two types of satellites considered.

1.3.2 Multibeam Satellite

The increased demand for in-orbit transponder capacity has already caused satellite operators to expand from C (6/4 GHz) to K (14/12 GHz) band operation. Foreseeing the eventual saturation of K band capacity, NASA is following the lead of other countries and has started experimental work necessary to commercial exploitation of the 30/20 GHz bands. The expansion to higher frequency bands is not without its cost, however, and one non-negligible aspect is the uncertainty in transmission quality at these higher bands due to the effects of precipitation. It would, therefore, be highly desirable to increase significantly the usable capacity of the 6/4 GHz band where such effects are negligible for all practical purposes. Such an increase (>10) may be obtained using a large multibeam satellite which would provide Conus coverage with a matrix of spot beams, each having a 3-dB beamwidth on the order of 0.2 - 0.3 degree. Frequency reuse would be made possible by the spatial separation between beams of like frequency. A repetition factor of seven may be considered feasible, where hexagonal clusters of beams having seven different frequencies would be repeated over the coverage area. Conus coverage by 210 beams for example, would correspond to 30 clusters and a frequency reuse factor of 30.

A single such satellite could provide Conus coverage or, alternatively, a pair could provide East and West coverage with a laser or millimeter wave link crossconnecting the two satellites. While such a large satellite would nominally handle a correspondingly large traffic load, the ground installation needed to assure a satisfactory radioelectric link could be of quite modest proportions. Since the satellite would incorporate such features as message demodulation and baseband switching of its digital traffic, it would tend to approach the concept of the switchboard in the sky. It would be necessary of course that the level of switching carried out be reasonably compatible with existing terrestrial facilities, but it can be seen that the tendency would be to pass from the ground network to the space link at the earliest point possible. There would be a significant economic justification for developing the communications network in this sense.

It would appear reasonable to assume that two such multibeam systems would exist in parallel for competitive reasons and to alleviate the effects of a possible, though improbable, catastrophic failure in one of the systems. This would result in two to four such satellites in orbit in the 2000 and immediate post 2000 time frame. Since experience has shown that communications satellites are unlikely to fail in a catastrophic fashion once they have been successfully put into operation on orbit, it would seem unlikely that an in-orbit back-up would be required. Such satellites provide a great deal of capacity and the gradual failure of individual channels would, for example, tend to increase the waiting time for individual subscribers wishing to gain access to the channels. It would thus be reasonable to assume that the replacement satellite would be launched from the ground at a scheduled date and then stored for a moderate period of time (several weeks or months) before final ascent to geosynchronous orbit.

1.4 Impacts of Communications Satellite Changes - Reconfigurable Satellites

1.4.1 Satellite Concepts

Design changes would not involve a fundamental change in satellite configuration. The feed horn array and the antenna feed networks would be designed and manufactured as a single package which would be mounted on the spacecraft in a predetermined position in the general vicinity of the satellite antenna focal point. The interchangeable horn/feed network unit would require relatively precise positioning accuracy (on the order of 5 to 10 thousandths of an inch for a C-band satellite). This mechanical keying could be assured by preloaded pins which would enter tapered holes in the installed unit. During storage, pins would be protected by a cover device which would also provide protection to open waveguide ports. The dimensions and weight of the interchangeable unit would vary somewhat depending on the particular spacecraft application; a typical set of values would be 300 x 200 x 500 mm. with a sea-level weight of 30 lbs. A simply operated locking device would be provided to maintain the unit in its position on the satellite.

It is assumed that with the horn assembly locked in place, there will be little need for further position or alignment adjustment. This would be verified by appropriate ground tests during engineering development of this capability. In the event that some mechanical adjustment capability should be required, that would complicate the design of the spacecraft but not to an undue extent.

In any case it would be necessary to make some verification of the antenna pattern resulting after installation of the set of horns. For these purposes a limited near field measurement program would be carried out. The satellite, with its antenna assembly in operating configuration, would be placed on a positioning device functionally similar to those presently used for antenna pattern measurement on the ground, and the measurements would be made while mechanically sweeping the satellite before a calibrated transmit/receive sensor. A hybrid scan operation with the test target on a gantry for translation relative to the spacecraft would permit 2-dimensional scans. The procedure for placing and accurately aligning the satellite on the positioning device would be adapted to the limited manipulative capabilities of space platform technicians. It would appear most desirable to avoid a precise positioning procedure by:

(1) Providing the satellite, the test targets, and the positioners with appropriate reference surfaces and prepositioned keying devices which would assure fairly accurate initial alignment.

(2) Providing a method for measuring the amount of residual misalignment, perhaps using accurately located laser beams on the test range and mirrors on the satellite.

(3) Introducing measured misalignment as a correction in processing of pattern measurement data.

1.4.2 Satellite Cost Impacts

It is assumed that use of the low-orbiting platform would be foreseen when a satellite family was still in a design phase. Thus, required modifications to typical design features would be incorporated from the start. The added costs incurred by inclusion of features described in 1.4.1 would not be a major item. As a maximum they may be estimated at one-half percent of the cost of the basic satellite. As an offset it should be noted that each satellite would be simplified by the elimination of the switchable beam coverage option. A second set of feed horns with its accompanying feed network and commandable switcher would thus be removed. For present purposes it can be assumed that the net effect on the cost of the satellite itself could be neglected. This does not include the separate additional feed horn/network assemblies to be provided. Each one would cost approximately 1M$. Assuming the cost of all four assemblies to be attributed to a given satellite, its cost would increase by 4M$. To this must be added the costs for special hardware for test and the costs incurred in use of the space platform.

1.4.3 Space Station Needs

The station will be used for acceptance and storage of the satellite from the STS as well as for test, actuation and launch.

Costs atributable to use of the space platform depend on the duration of active use of the platform's facilities and on personnel needs. Two principal usage periods may be foreseen:

(1) Reception and Storage of Incoming Satellites

It is assumed that this operation will require three technicians over a one day period.

(2) Activation and Launch of Stored Satellites

Personnel (time) requirements may be estimated as follows:

- Personnel required to move satellite from storage position and place it on positioning device (1/2 day):

  1 Technician to operate manipulator device

  2 Technicians to secure manipulator to satellite and to assure satellite location on positioner.

- Personnel required to install horn/feed network assembly (1/2 day):

  1 Technician

- Personnel required to carry out antenna range measurements and pre-launch satellite checkout (1 day):

  1 RF Technician

  1 Technician to operate positioners

  1 Data Processing Technician

- Personnel required to move satellite from positioning device to launch area (1/2 day):

  Same as the first item above.

- Personnel required to mate satellite with OTV and to effect launch to geosynchronoous orbit (1/2 day):

  3 Technicians

Thus it would be seen that each satellite requires a total of about 3 technicians over a period of 4 days for receiving, reconfiguring and relaunch activities. A total period of one week will be assumed to allow for possible contingencies such as possible periodic checks while the satellite is in storage.

It is assumed that that maintenance costs for a 10 person platform would be on the order of 60M$/person/year. One week of activity by 3 technicians would thus amount roughly to a cost of 3M$ per satellite.

Training for the personnel to perform the special tasks associated with the reconfigurable satellites should require about 2-4 weeks per person or 6-12 man-weeks total per team per satellite type. Assuming 2-3 team changes per year, each team will require this training for each satellite. Even including instructor costs and amortized costs of writing procedures, the total additional training cost per satellite should be less than 100K$.

Special equipment would be required on board the space station in order to test the reconfigured satellites. As noted above in Section 1.4.1, a hybrid scheme is suggested to provide two degrees of motion for scanning the test probe (receiver/transmitter) relative to the spacecraft. A space station 3-axis positioner would be modified with, if necessary, additional control equipment and a superstructure to mount the communications satellite. A additional gantry would be provided for mounting and controlling the RF target motion. The two devices provide scan control in orthogonal directions. The RF target or probe would be unique for each type of satellite; it is assumed that each probe is used four times and costs approximately 250K$.

Table 1.4-1 summarizes the cost of the special equipment shared among reconfigurable communications satellites.

TABLE 1.4-1. SHARED SPECIAL EQUIPMENT COSTS (RECONFIGURABLE SATELLITES)

Equipment	Cost (M$)
3-Axis Spacecraft Positioner*	2
Manipulator*	1
Gantry and Control Electronics	4
Alignment Measurement Gear	0.5
Computer*	0.5
Software	0.25
Total Shared Special Equipment	8.25

*It is assumed that the platform would require these equipments for other purposes. The amount represents an incremental cost required to satisfy satellite reconfiguration needs.

Assuming a 5 year life, the yearly cost would amount to about 1.7M$. Paragraph 1.3.1 indicated that expected usage would be on the order of 13 satellites/year. Cost per satellite would round off roughly to 150K$.

Insofar as initial investment in the platform is concerned, that has not been included. It is assumed that this would be considered as part of a many faceted national investment in space.

1.4.4 Cost Summary

The estimated costs for reconfiguring a communications satellite at a space station can be summarized by tabulating the data in Sections 1.4.2 and 1.4.3. Table 1.4-2 shows the recurring costs per satellite assuming that one reconfiguration takes place for each satellite. In addition, there are non-recurring costs for the design of the flexible system of network/feedhorn assemblies. Since each of the assemblies uses a similar concept, the design costs need really only be applied to one assembly. Using a factor of 3-4:1 as typical for the ratio of non-recurring to recurring costs, one obtains non-recurring cost increments of 3 to 4 M$ per system.

All costs are estimated in current (1983) dollars. Tolerances should be added to the estimates since they are based on preliminary concepts. Reasonable tolerances are on the order of 25-50%.

1.5 Impacts of Communications Satellite Changes - Multibeam Satellite

1.5.1 Satellite Design Concepts

Initially it is assumed the satellite antenna will have a diameter of 25 m. This provides a 4 GHz beam of approximately 0.2 degrees, which is consistent with an expected pointing error of 0.02 degrees. Larger antenna size and correspondingly narrower beams may be envisaged as expected pointing errors are decreased.

TABLE 1.4-2. RECURRING COST INCREMENT FOR RECONFIGURING COMMUNICATION SATELLITE

ITEM	COST INCREMENT(M$)
Satellite Antenna Assembly Modifications	4
Space Station Operations (Manpower)	3
Manpower Training	0.15
Space Station Hardware (amortized)	0.1
System Test Target (amortized)	0.07
Total (rounded up)	7.4

The size of the antenna and the accompanying satellite structure requires that either automatic deployment, manual erection or a combination of the two be employed. It is felt that the last of these options is the most attractive. Automatic deployment would not require manual resources and would best be carried out directly at geosynchronous altitude. However, any malfunction admits no corrective action, and very extensive proofing of quite complicated mechanisms must be carried out. In view of the limited manipulative skills to be expected of platform personnel, it would appear most efficient to rely on the automatic or semiautomatic deployment of certain subassemblies such as the basic boom structure and the antenna framework. These subassemblies would then be joined manually, these functions being of a simple, prekeyed nature. Thermal barriers would then be applied to the assembled spacecraft in structural areas shown to be sensitive to the effects of thermal distortion. Antenna measurements would then be carried out and final judgements made in the position of the feed assembly with respect to the antenna structure.

With regard to power requirements, it should be noted that Conus coverage using 210 beams has been estimated in 1.3.2. It can be assumed that many beams would cover regions of low traffic density and, consequently, would be used in a time-shared or scanned mode. Assuming that no more than 70 beams would be active at any given instant, and that each active satellite channel provided 20W output from a solid-state power amplifier, a total solar array output of 6 KW would be required. This would correspond to an array area of approximately 700 sq. ft.

1.5.2 Satellite Cost Impacts

This satellite, because of its size, can be considered to be a new system rather than a modification of existing communications satellite designs as was the case for the reconfigurable satellites. The availability of a space station makes it possible to consider the development of such large satellites. Various other studies (References 1-5) have considered similar large communications satellites and identified cost ranges of 400M$ to 500M$ non-recurring and 100-150M$ for the recurring costs per satellite.

In order to obtain estimates for the payload for the multibeam satellite, we have selected as typical the total costs of a large communications platform as presented in Reference 5. This study gave the following overall estimate:

	Total Spacecraft	Payload
Nonrecurring Cost (M$)	445	200
Recurring Cost (M$)	100	60

We then used the results of the other studies to arrive at the breakdown for the transponder system and antenna which are the key elements of the multibeam system.

- Transponder System Costs

  On the basis of the 30/20 GHz studies (References 1,2,3) it can be seen that transponder system development costs fall in the range 35 to 50 M$. We will choose a value at the higher end, 50M$, for this cost. Production (quantities of 3 or 4) costs seem to vary from 20 to 45M$. We will choose 25M$ or a reasonable value, it being 1/2 the development cost

- Antenna Costs

  Assuming the payload (P/L) consists basically of antenna and transponder systems, and subtracting transponder system costs given above yields the following:

  Development Cost (M$): 150
  Production (M$): 35

  It should be noted that development costs are estimated to be substantially larger than for the transponder. This does not seem unreasonable since basic techniques to be used in the transponder system are known. The load carrying capacity in the shuttle is such that it would not appear that extraordinary efforts need be made in terms of weight economy in implementation functions (demodulation, switching). There are, thus, fewer uncertainties associated with development of the transponder. On the other hand, the antenna has many unknown factors.

- Summary

  Table 1.5-1 thus summarizes the multibeam satellite costs.

TABLE 1.5-1. MULTIBEAM SATELLITE COST ESTIMATES

Item	Costs (M$)	
	Nonrecurring	Recurring
Spacecraft Bus	245	40
Transponder System	50	25
Antenna System	150	35
Total Satellite	445	100

1.5.3 Space Station Needs

It would be most effective if the space station were configured in a fashion such that antenna, boom and solar cell deployment could be carried out with these subassemblies in their final relative positions. This implies that the platform would be furnished with a reconfigurable structure which could be adapted to various such uses.

In order to carry out antenna near-field measurements, it would be necessary to provide a sensor which moves in two orthogonal directions or set of sensors with only translational freedom. Moving the spacecraft is not suggested since it would not appear desirable to mount this large structure on a positioning device. It is estimated that the costs of a single degree-of-freedom gantry plus associated support equipment for this program would break down as follows:

ITEM	COST (M$)
Gantry	4
Alignment Gear	0.5
Computer Usage	0.5
Software	0.25
Superstructure (to support fixed spacecraft)	1.25
Total	6.5

All of these costs could be shared among the two multibeam systems (2 satellites each) which are assumed for the future.

In addition, for each system it is assumed that there is a unique array of targets (estimated at ten, spaced linearly on a fixture to be moved along the gantry) for each system. At about 0.25 M$ per target, this array would cost 2.5 M$ per system.

An all-purpose manipulator which would position the various subassemblies prior to their manually-aided deployment would also be required. It is assumed that this capability exists on the station and that modifications necessary for these systems would be less than 1M$. An orbital transfer vehicle (OTV) would be used for transfer to geostationary orbit. No estimates are included here for the cost of its use.

Thus, shared hardware costs of 7.5M$ would be divided among four satellites, and unique system hardware costs of 2.5M$ would be shared between two satellites, giving approxixmately 1.9M$ and 1.3M$ per satellite respectively.

It is assumed that a 3 man crew could accomplish assembly, test and launch of the spacecraft in the following periods of time:

Antenna subassembly	2 weeks
Boom subassembly	1 week
Solar arrays	3 days
Spacecraft assembly	3 days
Application of thermal shields	3 weeks
Test and adjustment	3 weeks
Mate to OTV for launch	2 days

Assuming as before (Section 1.4.3) that manpower costs on the station are 60 M$/person/year, then the total in-flight manpower costs would be about 35 M$ per satellite. Similarly as before, training costs are estimated as less than 100 K$ per satellite.

1.5.4 Cost Summary

The estimated costs for a large multibeam satellite which takes advantage of the capabilities of a space station can be summarized by tabulating the data of Section 1.5.2 and 1.5.3. These costs are in 1983 dollars, and as before reasonable tolerances are on the order of 25-50%. Table 1.5-2 summarizes the cost per satellite.

TABLE 1.5-2. COST ESTIMATES FOR MULTIBEAM COMMUNICATION SATELLITE

Item	Cost (M$)	
	Non-recurring	Recurring
Spacecraft Bus	245	40
Transponder System	50	25
Antenna Aystem	150	35
Sub-total: Satellite	445	100
System Unique Station Hardware		1.3
Shared Space Station Hardware		1.9
Space Station Operations (Manpower)		35
Manpower Training		0.1
Sub-total: Space Station		38.3
Total (Rounded off)*	445	140

*Cost of using the OTV is not included.

1.5.5 References

(1) "18 and 30 GHz Fixed Service Communication Satellite System Study", Hughes Aircraft CO., Apr. 1979, NASA CR 159627.

(2) "Requirements Determination to Demonstrate 30/20 GHz Communication System - Task I Completion Report" Hughes Aircraft Co., 19 June 1980.

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(4) "Large Space Systems Technology - 1980, Volume I, Systems Technology", NASA Conference Publication 2168, Second Annual Technical Review, Hampton, VA, Nov. 1980.

(5) "Geostationary Platform System Concepts Definition Study - Final Review", General Dynamics/Comsat, Report No. GDC-GPP-79-008, 15 July 1980.

(6) Growth and Status of Commercial Communications Satellites, NASA Lewis Research Center, October 5, 1982.

7.2.1.3 Space Station Needs, Attributes and Architectural Options Subtask on Bioprocessing

(Battelle, Columbus Laboratories)

FINAL REPORT

on

SPACE STATION NEEDS, ATTRIBUTES AND ARCHITECTURAL OPTIONS

SUB-TASK ON BIOPROCESSING

to

BOEING AEROSPACE CO.

December 23, 1982

by

Kenneth E. Hughes

BATTELLE
Columbus Laboratories
505 King Avenue
Columbus, Ohio 43201

TABLE OF CONTENTS

LIST OF TABLES

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INTRODUCTION

Boeing Aerospace Company is participating in a NASA study (Contract No. NASW-3680) to anticipate space station needs for long-term, orbiting research and production facilities. One area of particular interest, and the subject of this report, is the processing of biologically derived materials---a field commonly called bioprocessing.

As part of the above study, Boeing asked Battelle's assistance in contacting industrial firms having current product lines and new development areas which might gain advantage from space processing. The intent was to identify attributes that a manned space station must have to satisfy the requirements for space-based processing of biological materials.

Statement of Work

The following tasks were agreed upon and initiated by Boeing's Purchase Contract No. CC 0181, dated November 3, 1982.

1. Contact at least fifteen biotechnology companies to assess their interest in using a Space Station.
2. Identify technical areas with potential value for commercial space-based processing of biological materials.
3. Provide at least four completed User Mission Data Forms.
4. Provide at least two Business Opportunity Descriptions.

The provision of items 3 and 4 were of course contingent upon the disclosure of concepts by the biotechnology companies.

BACKGROUND

NASA has had a long-standing interest in the processing of biological materials and has sponsored research since about 1970 in this area. Significant ground-based research on separation processes, particularly electrophoresis,led to preliminary flight experiments on Apollo, ASTP, and Skylab missions. Experiments and flight equipment were also devised for sub-orbital rocket flights.

The first commercial project for space bioprocessing is a joint endeavor between NASA and McDonnell Douglas/Ortho Pharmaceutical. The latter company is a division of Johnson & Johnson Products, Inc. It is hoped that the success of recent flight experiments on the Shuttle Orbiter will encourage other firms to begin commercial development of space processing.

METHODS

Battelle's Office for Biomedical Space Research* maintains current files on space research in the life sciences with particular emphasis on biological materials processing. Contact-lists of potential industrial and academic participants in space research are also maintained. These contacts stem from Battelle's current and previous research for the biomedical industry, and from our previous efforts in space bioprocessing (1,2,3).

Companies were usually contacted at a relatively high level of management (Vice President R&D, Director of Corporate Development, etc.) in order to ascertain the corporate attitude toward space research. Subsequent conversations were held with designated research staff as appropriate.

Since data on new bioprocessing concepts was not available from contacted firms early in the program, Dr. Harvey Willenberg of Boeing Aerospace Co. requested a supplementary task involving the preliminary definition of equipment requirements for two technical areas.

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* see functional description in the appendix.

- Continuous-flow electrophoresis
- Collagen fibrillogenesis

Suggested equipment lists and procedures for these two processes are included in this report.

RESULTS

For the purpose of this report, Bioprocessing is defined as the in vitro study or manipulation of chemical and growth processes involving materials of biologic origin. Traditionally, these materials have included molds, yeasts, bacteria, viruses and mammalian cells. Primary emphasis historically has been on the processes of separation, cell culture, and fermentation.

More recently, these manipulative processes have come to be known as "biotechnologies". The relatively new developments in genetic engineering are included. These processes may be divided into (1) growth systems, (2) biochemical processes, (3) separation systems, and (4) fabrication techniques.

In ground-based bioprocessing, gravity is often a major influence, becoming evident in

- fluid hydrostatic pressure
- natural convection flow
- settling of suspended particles
- gravity drainage of films
- stressing of gels under their own weight.

On the other hand, a sustained low gravity environment may offer the following advantages (4).

- reduced (practically eliminated) natural convection
- verification of complicated fluid-flow models
- reduced or eliminated settling of particles
- potential for containerless processing.

These advantages could translate to (1) three-dimensional cell culture systems without disruptive mixing to maintain suspension, (2) improved bioreactors, (3) higher throughput, higher resolution electrophoretic separation in low-viscosity systems, (4) improved polymerization of biopolymers, such as collagen, (5) improved microencapsulation processes, and (6) containerless processes for specialized applications such as free-casting of polymeric materials.

Industrial Contacts

Contacts were initiated with 19 biotechnology firms from a list of 38 potential candidates. Table 1 lists the companies contacted (with names and phone numbers) and the present status of the discussion. In several cases, additional follow-up would be desirable in order to keep communication open. Battelle would be pleased to assist in the continuation of this task if desired.

TABLE 1. INDUSTRIAL CONTACTS

	Company	Attitude*	Status
(1)	Abbott Labs., Inc. Dr. Ringler, Pharmaceutical R&D (312) 937-5011	o	x
(2)	American Hospital Supply Jeff Rondione, Medical Specialties (714) 975-1800	+	→
(3)	Bristol Labs. David Johnson, V.P. Development (315) 432-2712	o	x
(4)	Burroughs-Wellcome S. Winston Singleton (919) 541-9090	+	x
(5)	W. R. Grace Paul McSweeney (301) 531-4083	o	x
(6)	Kendall Co. W. O. Elson, Health Products Research (312) 381-0370	-	x
(7)	Kodak Kenneth Kennard, Bioscience Div. (716) 722-0395	o	x
(8)	Eli Lilly Samuel L. McCormick (317) 261-3826	-	x
(9)	3M Dale P. DeVore (612) 733-5260	+	→
(10)	Mallinckrodt George Vermont (314) 982-5350	-	x
(11)	Merck, Sharp & Dohme James Largo, V.P. for Process Devel. (201) 574-6084	not determined	

TABLE 1. (Continued)

	Company	Attitude*	Status
(12)	Miles Laboratories Ronald Weiss (219) 262-7450	+	→
(13)	Norwich Eaton Pharmaceuticals Frank F. Ebetino (607) 335-2611	+	→
(14)	Ortho Pharmaceuticals Richard Serbin (201) 524-0957	+	Joint endeavor
(15)	Owens-Illinois Roger Ritzert (419) 247-5000	+	→
(16)	G. D. Searle Paul D. Klimstra (312) 982-7867	+	→
(17)	Travenol Labs., Inc. Wayne Custead, V.P. R&D (312) 965-4700	o	x
(18)	Wyeth Labs. H.P.K. Agersborg, V.P. R&D (215) 878-9500	not determined	
(19)	Biospace, Inc. J. Richard Keefe (216) 354-6369	+	→

* Key to codes:

Attitude toward space processing

+ positive
o indifferent
\- negative

Status

+ idea submitted
→ under consideration
x no concepts at this time

Equipment Needs for Bioprocessing

Biological substances exist in aqueous-based fluid systems derived from living systems, and their behavior and viability are very sensitive to their environment. Hence, fairly strict environmental control is necessary to maintain these substances, whether cells, organelles or extracted materials. Generally, it is desirable to maintain a temperature of 4-40°C, although certain procedures can be used to freeze-quench blood cells and other materials in liquid nitrogen with little detrimental effect. Temperatures above 40-50°C denature many proteins, so usually must be avoided.

In certain processes, such as cell culture, fairly exact control must be maintained over pH, temperature, dissolved gas concentration, replenishment of reactants, and removal of waste products. Principal equipment types anticipated are:

- electrophoretic separators
- incubators
- refrigeration equipment
- storage reservoirs
- pumping and filtration devices
- high surface area gas exchangers
- recirculating nutrient systems
- close-tolerance environmental control systems
- detection and analysis systems

- dehydration and freeze drying equipment
- centrifuges
- optical and electron microscopes (SEM-TEM)
- photographic equipment (still and elapsed time)
- programmable process control
- data acquisition systems
- mechanical testing apparatus

Many of these items are needed in the two example systems which are conceptually described below.

Continuous Flow Electrophoresis

From the literature, it appears that continuous flow electrophoretic separation may be the most promising technical area for development of commercial space processing. Extensive work on electrophoresis has been supported by NASA at Beckman Instruments (5), McDonnell Douglas (6), and General Electric (7), as well as at several university laboratories. The present Joint Endeavor Agreement (8) between NASA and McDonnell-Douglas/ Johnson and Johnson (OrthoPharmaceutical Division) is a direct benefactor of this background research. Recent success of the company's electrophoresis pharmaceutical processing system will lead to more elaborate payload concepts (9), and possible space station applications.

Continuous flow electrophoresis as presently envisioned for space station use would probably involve the following procedures and equipment:

PROCEDURE	EQUIPMENT
1) Store buffer and sample materials.	Refrigerated compartments and reservoirs (4°C).

2) Heat and transfer buffer (recirculate if possible). Cell culture prior to separation may be desirable.	Pump, filter, heat exchanger, pH control, temp. control (nominal 37°C), replenishment system, flow sensors
3) Inject sample stream	Calibrated-flow pump
4) Apply power	Usually several hundred volts DC, cool buffer to counteract joule heating effect
5) Detect separation events	Light scattering or light absorbtion (laser or fiber-optics)
6) Collect sample	In-line sample detector, collection reservoir (temp. controlled 4°C), fluid-flow valves
7) Acquire data	Microprocessor
8) Analyze results (if man-tended)	Microscope, cell analyzer

Collagen Fibrillogenesis

The following additional data is supplied on the process of collagen fibril growth (polymerization) as presently envisioned in the space station. This work could involve process experimentation, as well as the production of materials, providing that flight experiments on the Shuttle Orbiter (not yet performed) prove the feasibility of the concept. Batch or continuous processing may be possible.

PROCEDURE	EQUIPMENT
1) Storage of buffer, collagen solution, cross-linking agents	Refrigerated compartments and reservoirs (4°C)
2) Prepare collagen solutions	pH, temp. control (4°C) spectrophotometer, ultracentrifuge
3) Load apparatus	pump, filter, flow sensor.
4) Polymerize collagen monitor turbidity	heat exchanger, environmental control (20-40°C), light absorbtion equipment, laser light scattering
5) acquire data	microprocessor
6) Fix collagen gels	UV irradiation, perfusion by glutaraldehyde, or freeze quench with liquid nitrogen.
(optional) Dehydrate gels	heat and partial vacuum may be required.

Gelled materials may be recovered as fixed in step no. 6, or may be dehydrated for easier storage.

7) Analyze gels (if man-tended)	Resin embedment kit, thin-sectioning device, optical and electron microscopes

Pancreatic Cell Separation

One of the more useful processes expected to benefit from electrophoretic separation in space is the preparation of purified strains of pancreatic beta cells. These cells exist naturally in the islets of Langerhans, the insulin producing bodies within the pancreas. The islets comprise <2 percent of this organ but produce all insulin (11). The specific cells responsible for insulin production exist on the periphery of the islets

Islet cell transplants for the treatment of diabetes were pioneered by Dr. Paul E. Lacey (12, 13) at Washington University in St. Louis. The basic procedure involved dissolving the pancreatic structural collagen with the enzyme collagenase, and separating out the islets of Langerhans. Islets were transplanted into the portal vein leading from the intestine and toward the pancreas and liver.

Separation techniques mentioned in the literature include microdissection (14-16), sedimentation (17) and Ficoll gradient centrifugation (18, 19). A detailed search of the literature was not accomplished, but it is believed that these are the alternatives to electrophoretic separation as studied by McDonnell Douglas and Johnson & Johnson (6).

CONCLUSIONS

Based on the small and admittedly non-statistical sample of companies contacted in this study, Battelle draws the following conclusions.

A relatively small percentage of industrial scientists and a yet smaller group of management level staff appear to be interested in pursuing commercial space processing of biological materials. It appears that personal interest by individual scientific staff should not be construed as corporate commitment to space research. In fact, where persons previously involved in space research have left for other positions, it was found that the previous corporate interest simply dwindled. This could be due to either 1) a lack of technical continuity or 2) a lack of corporate financial commitment.

Attitude of the Industry

Generally speaking, most persons contacted conveyed a positive attitude toward the academic and scientific aspects of space research. However, industry's attitude (measured by this sampling) regarding commercial opportunities in space bioprocessing can be considered as indifferent and in many cases, negative. Especially at the management level, little if any advantage for processing in space is envisaged.

Our contacts seemed to suggest that if space manufacturing is to become a reality, the government must lead the way with significant basic background research on materials behavior in the weightless environment (10). NASA's attempt to offer incentives, such as their "Joint Endeavor" program have met with limited positive response from the pharmaceutical/medical products industry.

Additional Contacts

In several cases, additional follow-up with existing contacts would be desirable in order to keep communications open during the duration of Boeing's effort. Battelle would be pleased to assist in the continuation of this task if desired.

Additional contacts are recommended with the following companies and research institutions if time and funds permit:

(1) American Cyanamid
(2) Diamond Shamrock
(3) Dow Chemical
(4) Dow Corning
(5) DuPont
(6) Illinois Institute of Technology
(7) Midwest Research Institute
(8) Parke Davis & Co.
(9) Pfizer Corp.
(10) Research Triangle Institute
(11) Rohm & Haas
(12) Schering Plough
(13) Stanford Research Institute

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3) Hughes, K. E. Space life sciences pilot user development program for the midwest region. NASA Final Report, NAS 9-15504, July, 1978.

4) "Materials Processing in Space", Report of the committee on scientific and technological aspects of materials processing in space (STAMPS), National Academy of Sciences, 1978.

5) Strickler, Allen. Electrophoresis experiment design for space. NASA reports, NAS 8-28474, 1974.

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19) Najarian, J. S., et al. Isolation of Human Islets of Langerhans for Transplantation. Transplant Proc., Vol. 7, p. 611, 1975.

APPENDIX A

Description of Battelle's Office for Biomedical Space Research

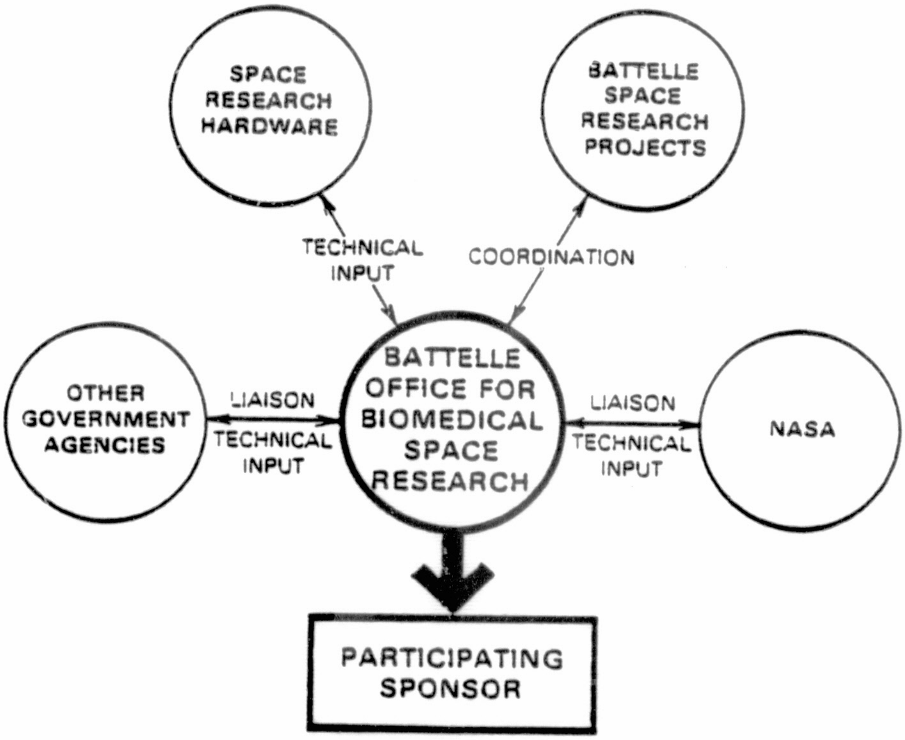
OFFICE FOR BIOMEDICAL SPACE RESEARCH

A special project funded by Battelle enabled us to establish a new capability for life sciences research in space. Contacts were established with NASA concerning several areas of mutual interest. Concurrently, Battelle established a centralized coordinating organization, the Office for Biomedical Space Research, for directing and integrating activities in the three primary areas of space-based research:

- Ground-based preliminary research
- Space research facility equipment development
- Development of flight experiments.

This Office was charged with the responsibility of maintaining liaison with NASA and other government agencies, receiving technical input from organizations developing space research hardware, and coordinating with other Battelle space research projects. Finally, the Office was instructed to develop means by which other organizations and companies could contract with Battelle in order to take advantage of new developments.

This biomedical space research coordinating office is an integral part of one of the most sophisticated and diversified biomedical research organizations in the United States.



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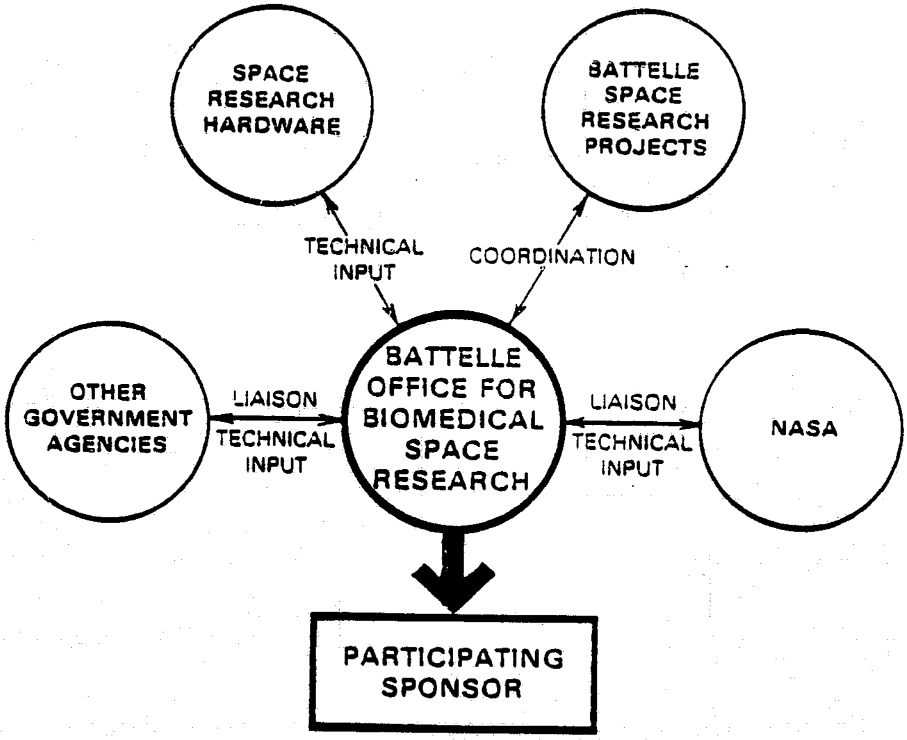


7.2.1.4 Aviation Maintenance Foundation Correspondence (Basin, WY)

AVIATION MAINTENANCE FOUNDATION
Post Office Box 739 • Basin, WY 82410 • Telephone: (307) 568-2466

March 14, 1983

Mr. Keith H. Miller
Senior Research Engineer
Mail Stop: 84-06
Large Space Systems Group
BOEING AEROSPACE COMPANY
P.O. Box 3999
Seattle, Washington 98124

Dear Keith:

Please excuse my delay in sending you the enclosed comments about the expansion of aviation maintenance technology training into spacecraft maintenance technology training. I have been on a travel schedule and only had the opportunity of this past weekend to put my thoughts down on paper for you.

The thought of working in space on, in or around a space station is tremendously exciting. Since you and I last spoke, I have talked with many educators in this Industry who would dearly love to become involved in the development of a spacecraft mechanic curriculum.

I hope the enclosed will be of use to you. I did not include much dialog regarding the areas of aviation maintenance training that would directly transfer to spacecraft maintenance training as I believe every area will have to be well evaluated. And, I'm certain upgraded. However, the format is there and works well. It would be from this base that we could develop an excellent training program.

Please keep me advised of your presentation to NASA. If it would serve any useful purpose, I will be happy to go to Washington either as a participant or as a morale supporter.

Again, thank you for allowing myself and the Foundation to be involved in this project.

Best Wishes,

AVIATION MAINTENANCE FOUNDATION

Richard S. Kost
President

RSK/nd
enc.

SPACECRAFT MECHANICS

THE BEGINNING OF A NEW AGE

BY
RICHARD S. KOST
AVIATION MAINTENANCE FOUNDATION

For the past many years, the Aviation Maintenance Foundation has been quite concerned about the next generation of aircraft mechanics. This concern was evidenced by the presentation of the first three "spacecraft mechanic licenses" to the astronauts of Skylab I in November, 1973, Captains Conrad, Kerwin and Weitz. These licenses were the result of the efforts of the Foundation in cooperation with the Federal Aviation Administration and the National Aeronautics and Space Administration. The three astronauts dramatically illustrated the need for space explorers to be able to maintain, service and repair what man sends into space. An unscheduled space walk was required to extend a malfunctioning solar panel and install a parasol required to shade the Skylab I vehicle when the airconditioning system failed.

In addition to being able to maintain, service and repair what man sends into space, the space explorers will have to be able to construct vehicles and platforms that cannot be sent into space in one piece. Such a necessity is apparent in the case of an orbiting platform, ie., a space station. In order to properly conduct any type of large-scale activity in space, a space station is a necessity. Such a space station will have to be large enough to accomodate several people with different types of skills. This means that the size of the space station will be too large to ship in one piece; it will have to be sent in pieces that will have to be assembled in space. The people who do the assembly will have to be well-trained and qualified. These spacecraft mechanics will do the actual bolting, welding and strapping of the space station as well as its continued maintenance.

These spacecraft mechanics will have to have several different skills at their command as they will be responsible for most all aspects of the physical plant of the space station. If a system breaks down, either inside or outside the space station, it will be the responsibility of the spacecraft mechanics to repair the malfunctioning systems. Also, any modifications to the space station will have to be performed while in orbit and it will have to be spacecraft mechanics who make the modifications. In essence, a succesful space program will have to rely upon the skills of dedicated spacecraft mechanics whose main responsibilities will be those of maintaining, servicing and repairing space machines built by man.

BACKGROUND

The concept of employing existing occupational skills in space exploration is viable and financially feasible. To develop new occupations for space exploration not only would be expensive, but would deny NASA the depth of experience resources that have been developed in over fifty years of aircraft maintenance training. It was on July 1, 1927, when the old Civil Aviation Agency (CAA) began certificating Airframe and Engine (A&E) Mechanics to assure the public of air safety with regards to aircraft maintenance, servicing and repair.

Since 1927, the Aviation Industry has been involved in the development of standardized regulations for the implementation of aviation maintenance curriculums. Currently, there are over 145 Aviation Maintenance Technician Schools training well over 12,000 aircraft mechanic students. The number of qualified instructors teaching these students exceed 1200. These numbers amount to thousands of man-years of curriculum development and implementation.

The existing curriculum for aircraft mechanic students, as defined by Federal Aviation Regulation Part 147, has been in effect for almost 13 years and while it is dated, does provide a good basis for the training of spacecraft mechanics. This curriculum base can be modified to be the basis of a curriculum for the training of spacecraft mechanics. The following is an outline of the Course of Study for aircraft mechanic students:

AIRCRAFT MECHANIC COURSE OF STUDY

1. GENERAL
   - A. Basic Electricity
   - B. Aircraft Drawings
   - C. Weight and Balance
   - D. Fluid Lines and Fittings
   - E. Materials and Processes
   - F. Ground Operation and Servicing
   - G. Cleaning and Corrosion Control
   - H. Mathematics
   - I. Maintenance Forms and Records
   - J. Basic Physics
   - K. Maintenance Publications
   - L. Mechanic Privileges and Limitations
2. AIRFRAME STRUCTURES
   - A. Wood Structures
   - B. Aircraft Covering

C. Aircraft Covering
D. Sheet Metal Structures
E. Welding
F. Assembly and Rigging
G. Airframe Inspection

3. AIRFRAME SYSTEMS AND COMPONENTS

    A. Aircraft Landing Gear Systems
    B. Hydraulic and Pneumatic Power Systems
    C. Cabin Atmosphere Control Systems
    D. Aircraft Instrument Systems
    E. Communication and Navigation Systems
    F. Aircraft Fuel Systems
    G. Aircraft Electrical Systems
    H. Position and Warning Systems
    I. Ice and Rain Control Systems
    J. Fire Protection Systems

4. POWERPLANT THEORY AND MAINTENANCE

    A. Reciprocating Engines
    B. Turbine Engines
    C. Engine Inspection

5. POWERPLANT SYSTEMS AND COMPONENTS

    A. Engine Instrument Systems
    B. Engine Fire Protection Systems
    C. Engine Electrical Systems
    D. Lubrication Systems
    E. Ignition Systems
    F. Fuel Metering Systems
    G. Engine Fuel Systems
    H. Induction Systems
    I. Engine Cooling Systems
    J. Engine Exhaust Systems
    K. Propellers

CURRICULUM DEVELOPMENT

It would not be practical to utilize the existing aircraft mechanic curriculum for spacecraft mechanic instruction without some major changes. Spacecraft mechanics would have little need for instruction in such areas as: wood, dope and fabric; aspirated engines (reciprocating or turbine); propellers; or other systems related to earthbound vehicles. The entire aircraft mechanic curriculum would have to be examined by a panel of experts. Those subject-areas of value would be modified for spacecraft mechanic training. While only half of the existing aircraft mechanic curriculum would be of use to a spacecraft mechanic curriculum, the instructional format has proven itself and readily can be adopted for spacecraft mechanic training.

In addition to the maintenance, repair and servicing courses that need to be taught to spacecraft mechanic students, the process of actually living and working in the hostile environment of space is absolutely essential. The actual instruction of living and working in space will probably be a separate, specialized course that all space workers will undergo. However, there should be a strong emphasis on space safety throughout the entire spacecraft mechanic training program. This emphasis should be coordinated with the curriculum on "Space Environment Safety" thereby providing a smooth transition from spacecraft mechanic trainees to qualified space workers. Additionally, each phase of spacecraft mechanic training should emphasize the necessary safety precautions peculiar to the individual spacecraft systems, ie., rocket engines, life support systems, etc.

As a means of reducing the expense of developing the needed curriculum for spacecraft mechanic training, NASA should appoint a Spacecraft Mechanic Curriculum Coordinator to work with them and Industry. The Aviation Maintenance Foundation has substantial expertise available in curriculum development and can provide the necessary coordination. Such coordination will bring together specialists from the Aviation and Aerospace Industries, Aviation Maintenance Technician Schools and goverment agencies (including NASA). The combined efforts of these specialists will provide the best curriculum available for the training of spacecraft mechanics. Once spacecraft mechanics actually begin working in space, their activities should be closely monitored to allow for continued improvement of the curriculum. This continuing improvement will provide for better space safety which, in itself, will help in the continued advancement in space exploration.

CURRICULUM IMPLEMENTATION

Once the spacecraft mechanic curriculum has been developed by the specialists and approved by NASA, a test-bed for the curriculum implementation should be selected. Since Aviation Maintenance Technician Schools already have a great majority of the equipment needed for proper instruction, two or three schools should be selected to begin the initial training phases. These initial phases will cover the theory of spacecraft maintenance as well as the integrated safety training. After the spacecraft mechanic students have completed their training in spacecraft maintenance, repair and servicing, they will transfer to NASA's own facilities. At these facilities, the spacecraft mechanic students will undergo the training needed for living and working in space.

An evaluation of the different test-beds should be made to determine which one is the most effective. Once this evaluation has been made, standardized curriculum implementation can be developed thereby providing an additional safety margin for space workers. It should be understood that there will be a necessity for standardization in several areas for the space workers' safety, ie., technical jargon, safety procedures, etc. Such standardization will have to be considered as the respective curriculums are developed.

SUMMARY

The prospect of living and working in space is an exciting one as well as a tremendous challenge. NASA has done well in its pioneering space exploration. The benefits of space stations are many and are within reach; many new industries will develop from what will be learned by continuous activity in space. However, it is now time for NASA to bring industry, as a whole, as a partner into space exploration. The use of existing aircraft mechanic training as a basis for spacecraft mechanic training is an excellent example of how industry can contribute to the space exploration partnership. Eventually, the relationship between industry and NASA will be transformed into one similar to that of industry and the FAA. The FAA promotes and regulates the Aviation Industry in the interest of improved air safety, but does a little actual experimentation. This does not mean NASA's role would be reduced to that of a policeman, but, rather, would allow NASA to concentrate on experimental programs while industry maintains and expands the existing ones. Industry is more aware of the needs of the public and can better respond to these needs than can NASA. Taxpayers' money should go to experimentation and pioneering efforts to develop new technologies rather than maintaining proven ones.

- END -

7.2.1.5 Materials Processing in Space and Applications for a Permanent, Manned Space Station

(Arthur D. Little, Inc., Cambridge, Mass.)

Materials Processing in Space
and Applications for a Permanent, Manned Space Station

Prepared for
Boeing Aerospace Company

Purchase Contract CC0071

March 1983

Arthur D. Little, Inc.
Cambridge, Massachusetts

CONTENTS

CONTENTS - con't

MPS HISTORY

Introduction

With the advent of the shuttle, the U.S. space program has reached a crucial juncture in its evolution. Not only the government, but industry as well must make decisions on the best ways to exploit current technological capabilities and select future directions. Such decisions are difficult to make. Space activities are no longer driven by "heroic" mission goals and their continuation has to be economically justified in a less expansive and more critical environment. The early space challenges were met in a climate of adventure and heroic accomplishment in which success was closely identified with issues of national prestige and for which funding was plentiful. Inevitably, that climate has changed, national priorities have been redefined and public interest has waned. It has become increasingly more difficult to stir the public imagination because the technical fallout and social benefits of the space program, most notably in the areas of communication, remote sensing, and weather satellites have been so successfully integrated into every day life that they are taken for granted.(1)

While the U.S. space program was drawing on a seemingly unlimited account, MPS was basically of scientific interest with potential but undefined industrial implications. When that account ran low, MPS was advanced by NASA as one of the vanguards of and justifications for a new thrust: namely, "space industrialization." Eventually, the overoptimistic projections for such items as "ball bearings" from space and promises made on behalf of MPS came into conflict with scientific methods and more realistic expectations. The result was an extensive re-evalution of the potential of MPS within the scientific community, government, and industry -a process which is still ongoing.(2)

Background

The conceptual framework and execution of the U.S. civilian space program has been dominated by political considerations from its inception. The program came into being as a response to the unexpected launch by the U.S.S.R. of Sputnik I on October 24, 1957. In 1958, perceiving the Soviet success as a threat to American security and technical prowess, Congress passed the National Space Act. This act created the National Aeronautics and Space Administration and empowered the agency to form a civilian space capability that would establish U.S. preeminence in "aeronautical and space science and technology and in the application thereof to the conduct of peaceful activities within and outside the atmosphere."

While the creation of space policy became a Presidential prerogative, most dramatically exemplified by President Kennedy's decision to accomplish a manned lunar launching within a decade -- the annual review and disposition of NASA's budget was a Congressional decision. Therefore, from its beginning, the space program was vulnerable to Congressional politics, and NASA administrators were highly sensitive to the impact on Congress of any adverse occurrences in their programs.

Starting with the Mercury program, the U.S. embarked on a series of manned space projects that culminated in the Apollo lunar landing. While the technical and management achievements of these "heroic missions" were remarkable, they established a mode of operation which had no reference to the process of scientific research. Moreover, since the U.S. space program was conducted in the open, it was mandatory to achieve both successful and safe missions. The required safety levels established for manned spacecraft added greatly to missions costs. Combined with success-oriented goals, the cost of launching payloads into orbits did not allow room for the trial and error normally associated with scientific experimentation on Earth.

By the mid-60's with the lunar landing still to come, growing social issues and the effects of inflation forced a re-evaluation of societal priorities and U.S. government expenditures. As a result, the budget for the space program was severely reduced. The only major project to survive the several years of debate and struggle to define an acceptable post-Apollo program was the space transportation system (STS) represented by the shuttle.

Throughout its development, the shuttle encountered lack of Congressional and public interest and technical difficulties which resulted in unplanned expenditures and necessitated a series of design compromises. Ultimately, with the civilian space program on the wane, the shuttle was approved by Congress because the U.S. Department of Defense (DOD) supported the STS program. However, DOD requirements had an impact on the shuttle design. The most dramatic impact was that the cargo bay would have to be large enough to accommodate military satellites. (The resulting 60 by 15 feet cargo bay volume meant that NASA had to devise means to fill the cargo bay volume. One approach was the small self-contained payload program or "Getaway Special" at a price of $10,000 in 1975 dollars.) As the shuttle development costs continued to escalate, the DOD's continued interest in the STS program and infusion of funds at crucial points were critical to the shuttle's successful development.(3)

The argument for the space shuttle, which made its development acceptable to Congress and the administration in the early 1970s, was that it would pay its way -- in tangible, economic terms as well as in "opening new frontiers". NASA is faced with the challenge of selling its programs on this basis to other federal agencies, to states and cities, to the military, to foreign nations and their agencies, and to the general public. Shuttle payload marketing has become a major undertaking. However, private industry as yet has not been willing -in fact has not been able -- to invest in a high-risk, long-payback enterprise such as STS. So far the only industry to take advantage of

STS has been the very profitable telecommunications industry which was built on the relevant technology created by government investments. By 1969, global communications by satellite was a routine operation. However, it must be noted that the commercial use of orbiting communications is now a much better defined and financially more attractive prospect than the use of space environment for MPS.

Material Processing in Space

That space with its unique environment could open new dimensions in the material sciences was recognized as long ago as the late 1960s when, in an attempt to learn how to use the microgravity environment effectively, several simple demonstration experiments were performed on the last few Apollo missions. Later, the experiments carried aboard Skylab, Apollo Soyuz, and Space Processing Applications Rockets (SPAR) provided an insight into the behavior of materials in freefall.(4)

Many plans were formulated, studies pursued, and experiments performed to explore MPS opportunities that might eventually be developed into "space-industry" operations.(5) These efforts have not yet reached maturity. In large part this abeyance is due to the lack of agreement about the direction and scope of the civilian space effort since the conclusion of the Apollo program. This lack of direction persists today, and as yet the U.S. has not formulated a policy to guide future space program activities. The U.S. space efforts have been characterized by changing plans and program directions, abandoned initiatives, and sudden shifts in emphasis that are responsive to perceived changes in policies and administrative and Congressional budget actions. Because these politically-motivated changes have occured in much shorter periods than the time needed to bring a major space program initiative such as MPS to fruition, the commitment to these programs by the scientific community and by industry, which must be enlisted to achieve success, has been attenuated and the effectiveness of program execution has suffered.(6)

Realizing that its MPS program was not being fully supported either by the scientific community or by industry, NASA and the National Academy of Science commissioned the Scientific and Technological Aspects of MPS (STAMPS) to study and evaluate the U.S. MPS program. The committee was critical of the MPS effort up to that time. They expressed the view that the approach that had been taken was too empirical and too hopeful of early beneficial results. They further noted that many of the Skylab experiments were insufficiently conceived and executed, resulting in ambiguous data. Recommendations stressed the need for more extensive ground-based research to serve as a basis for the evolution and assessment of investigations which would lead to a proper understanding of the role played by gravity in materials processes. Recourse to the weightless environment of space should be based primarily on the understanding and need in those specific cases identified from such a program. In addition, the first phase of the spaceflight program should be a demonstration of the new technology developed in the NASA program which should then be transferred to non-NASA entities for their use. The second phase, funded primarily by non-NASA users, should consist of a National Materials Laboratory in space to open the capabilities to all for a reasonable charge. Close ties between the materials communities and NASA were recommended in the form of peer review of all proposals, both ground-based and spaceflight, and the periodic peer review of policies and plans. NASA's Materials Processing in Space program was restructured on the basis of these recommendations, beginning with the earliest deliberations of the STAMPS Committee. An advisory committee was formed to provide guidance in future program planning and policy making consistent with the STAMPS Committee recommendations.(7)

Presently, NASA is proceeding cautiously with MPS. It knows that advances in fundamental knowledge are often stimulated by improvements in the ability to subdivide a complex system into individual components for study. Consequently, its first task has been to develop a thorough understanding and to determine, through a series of carefully chosen experiments, the important phenomena controlling microgravity processes, or the advantages to be gained by processing materials in space. Table-1 gives a chronology of major milestones in MPS in relation to the U.S. space program.

Western Europe followed the U.S. lead into space. With spectacular, manned space missions preempted by the U.S. and U.S.S.R., European plans and programs have placed more emphasis on long-term economic benefits. In the area of MPS, the Europeans have mounted endeavours exhibiting more program continuity and sense of purpose than the U.S. effort. According to a 1980 Government Accounting Office Report, it appears that they are also increasing the scale of their MPS activities relative to the U.S. efforts.(8)

MPS Funding

The yearly and cumulative funding for the U.S. MPS program is shown in Figure-1. The extrapolation of funding levels to FY 1986 is based on the NASA's Office of Science and Technology Application (OSTA) budget submission of 1981 shown in Table-2.

NASA expenditures have increased in the last several years in preparation for the STS era of the 1980s. However, most of these increases have been used for STS development, while resources allocated to materials research are still modest. The fiscal 1982 budget for materials science research is $23.6 million. These funds must support not only research on the ground and in orbit but also the development of research facilities and experimental hardware. (Funds are not available for mission-related costs of integration, launch, and operation.)

The budgetary plan, shown in Table-2 is considered by NASA to be the minimum required for an effective materials science program. It is reduced from previous requests which were based upon significantly higher funds to develop and demonstrate new processes. It supports a

TABLE 1

CHRONOLOGY OF SELECTED MILESTONES IN THE SPACE PROGRAM AND MATERIALS PROCESSING IN SPACE

Space Program

1957 - October 7: U.S.S.R. launches Sputnik 1, world's first artificial satellite

1958 - July: National Aeronautics and Space Act signed

- December: Project Mercury -- first U.S. manned space flight program

1961 - April 12: U.S.S.R. places the first human in orbit (Yuri Gagarin) and returns him safely to Earth

- May 5: first American (Alan Shepard) makes successful suborbital flight

- May 25: President announces the U.S. goal of placing a man on the moon by the end of the decade

- December: United Nations Treaty governing space activities signed

1962 - February 20: first American (John H. Glenn, Jr.) to orbit the Earth

1965 - March: Project Gemini flights begin -- Project achievements will include:

- flying in "shirt sleeve" environment
- first space rendezvous between spacecraft

TABLE 1

CHRONOLOGY OF SELECTED MILESTONES IN THE SPACE PROGRAM AND MATERIALS PROCESSING IN SPACE

(Cont'd)

Space Program	Materials Processing in Space
• first extravehicular activity • first docking of one space vehicle with another	
1966 - Personnel from NASA Marshall Space Flight Center visit manufacturing companies to determine industrial interest in space applications	
1968 - October: beginning of Apollo program	
1969 - July 16-24: U.S. launches Apollo II, first mission to land humans on the moon: Neil A. Armstrong; Edwin E. Aldrin, Jr.; and Michael Collins	1969 - NASA initiates first formal space processing program "Materials Science and Manufacturing in Space."
- August: The Space Task Report issued, recommending major new space initiatives--including the development of a reusable space shuttle	
1970 - March: President Nixon presents space message indicating limited space program in future	
	1971 - Jan.-February: Apollo 14: three "demonstration" MPS experiments performed in heat flow and convection, electrophoretic separation, and composite costing
1972 - January: President Nixon authorizes development of the space shuttle	1972 - April: Apollo 16: one MPS experiment performed in electrophoresis

TABLE 1

CHRONOLOGY OF SELECTED MILESTONES IN THE SPACE PROGRAM AND MATERIALS PROCESSING IN SPACE

(Cont'd)

Space Program	Materials Processing in Space
- December 7-19: Apollo 17, last flight in the Apollo program	- December: Apollo 17: one MPS experiment performed in heat flow and convection
1973 - May 25: First Skylab crew launched: Charles Conrad, Jr. (Commander); Joseph P. Kerwin (Science Pilot); and Paul J. Weitz (Pilot)	1973 - First Skylab crew perform material processing experiments
- July 28: Second Skylab crew launched: Alan L. Bean (Commander); Owen K. Garriott (Science Pilot); Jack R. Lousma (Pilot)	Second Skylab crew perform 11 material processing experiments
- November 16: Third Skylab crew launched: Gerald M. Carr (Commander); Edward G. Gibson (Science Pilot); William R. Pogue (Pilot)	August: European Space Agency contracts with NASA to build Spacelab for use with the shuttle
1974 - February 8: Third crew closes down Skylab and returns to Earth	1974 - Third Skylab crew performs five MPS experiments (Skylab provided 160 hours of MPS experiments)
1975 - July 15: U.S./U.S.S.R. Apollo-Soyuz is lauched	1975 - Apollo Soyuz provided 125 hours of microgravity processing (12 experiments)
	- December: First SPAR flight with MPS experiments
1977 - September 19: Soviets launch Salyut 6 space station (manned for 676 days)	1977 - STAMPS Committee Report evaluting U.S. MPS activities
	- November: NASA starts commercial materials processing in space program

TABLE 1

CHRONOLOGY OF SELECTED MILESTONES IN THE SPACE PROGRAM AND MATERIALS PROCESSING IN SPACE

(Cont'd)

Space Program	Materials Processing in Space
	1979 - August 14: NASA publishes "Guidelines Regarding Joint Endeavors with U.S. Domestic Concerns in Materials Processing in Space" in Federal Register
	- August 28: Joint Endeavor Guidelines announced in Commerce Business Daily
	1980 - Engineering model of Spacelab delivered to Kennedy Space Center
	- January 25: First Joint Endeavor signed between NASA and McDonnell Douglas Astronautics Company (teamed with Ortho Pharmaceutical Division of Johnson & Johnson Co.) to develop biochemical separation equipment
	- May 19: First Industrial Guest Investigator, TRW, signed with NASA
1981 - April 12: First launch of the space shuttle, Columbia (STS-1). John W. Young (Commander), Robert L. Crippin (Pilot)	1981 -
June 19: Ariane (L03) successfully launched by the European Space Agency	June 29: First Technical Exchange Agreement signed with John Deere Co. Second and Third Technical Exchanges signed with DuPont and International Nickel

TABLE 1

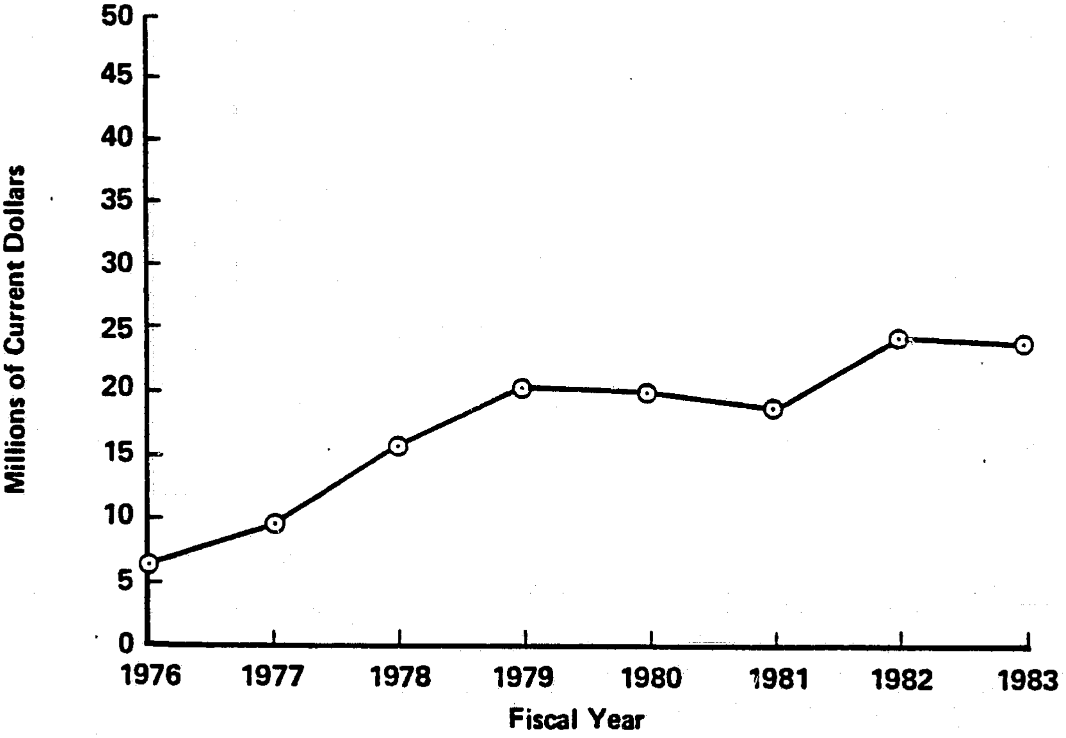
CHRONOLOGY OF SELECTED MILESTONES IN THE SPACE PROGRAM AND MATERIALS PROCESSING IN SPACE

(Cont'd)

Space Program		Materials Processing in Space
	1982	- January 20: Second Joint Endeavor signed with GTI, development of small metallurgical furnace for use in space processing of sample materials
		- March: Two MPS experiments carried on Mission 3 of shuttle. Monodisperse latex spheres (NASA Marshall Space Flight Center) and Electrophoresis system tests (McDonnell Douglas)
		- July: Monodiperse latex spheres reflown on mission 4 of shuttle. Demonstration successful.

FIGURE 1

ANNUAL U.S. BUDGET FOR MPS



Source: NASA

TABLE 2

NASA'S CURRENT FUNDING PLAN FOR MPS

	FY81	FY82	FY83	FY84	FY85	FY86
ADVANCED RESEARCH ACTIVITY	9.9	14.0	15.3	15.3	23.3	23.3
PAYLOAD DEVELOPMENT	7.5	9.0	8.7	8.2	4.6	15.0
EXPERIMENT OPTIONS	1.3	4.7	17.6	25.8	36.0	33.7
SPACE MATERIALS SYSTEMS	–	–	–	6.0	6.0	6.0
MPS TOTAL	18.7	27.7 (requested)	41.6 (requested)	55.2	69.9	78.0
		23.8 (actual)	23.6 (actual)			

SOURCE: NASA

a subcritical number of investigators and flight experimenters listed in Table-3. The payloads currently being developed on this budget are the Monodisperse Latex Reactor (MLR), Fluid Experiment System (FES), Vapor Crystal Growth (VCG) system, and in addition, the participating electrophoresis experiment. The Solidification Experiments System (SES), was recently eliminated. The program could be expanded to provide experimental facilities for a larger in number of investigators based on the planned expansion in budgetary resources.

TABLE 3

CURRENT INVESTIGATORS IN MPS

Discipline	Ground-Based	Flight Experiments
Crystal Growth & Solidification	16	8
Containerless	7	2
Chemical & Biological	7	1
Total	30	11

Source: NASA

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RATIONALE FOR MATERIALS PROCESSING IN SPACE

A. SCIENTIFIC FOUNDATIONS

The absence of gravity in orbit and its effects on the science and technology of materials processing are the bases for expectations that unique or improved products could be produced in the space environment. Other aspects of the space environment such as temperature, ambient vacuum, or radiation either have no significant effects on materials processing or their effects can be duplicated on earth.

The role of a low-gravity environment in materials science and technology was considered by the National Academy of Sciences Committee on Scientific and Technological Aspects of Material Processing in Space (the "STAMPS" Committee) in the 1978 report Materials Processing in Space. In this report, the Committee noted that the influence of gravity in most phenomena is well known. Gravity is, with rare exceptions, an insignificant force at the atomic and molecular levels. At the molecular level, only those phenomena associated with critical points, particularly in fluids, are likely to be altered detectably by a sustained low-gravity environment. As a consequence, no "breakthroughs" from the discovery of new physical phenomena are expected from spaced-based research. Instead, it will be the exploitation of the already well-known consequences of low-gravity on phenomena occurring in continuums of solids, liquids and gases which will result in economically significant innovative products from materials processing in space.

The STAMPS Committee report summarized the possibilities offered by a sustained low-gravity environment in statements carefully constructed to reference their scientific basis. The Committee summary, as supplemented by subsequent discussions, presents the following possibilities.

Reducing or practically eliminating buoyancy-driven natural convection for substantial periods of time. There are many technologically important, scientifically challenging processes which are so complex that the effects of buoyancy are obscured or cannot be controlled independently of other phenomena. Mathematical modeling of these processes would involve numerous simplifying approximations that would have to be experimentally tested. In those areas especially, where natural convection is believed to be deleterious, experiments conducted in low gravity might make a process more understandable and stimulate Earth-based materials developments. Space experiments may reveal other convection phenomena that ordinarily are masked by natural convection. The possibility of obtaining a product having uniquely useful properties is an incentive for performing such experiments.

Levitating and isolating larger samples for containerless processing. It is advantageous or necessary to isolate a liquid sample from container walls for a number of property measurements and basic processes. There are practical limits on sample sizes that can be levitated on earth. Furthermore, levitation is accompanied by convection. Low gravity has the potential advantage of allowing levitation of larger samples. This advantage may be partly offset by problems of positioning and manipulating the sample in a fluctuating background gravitational field and, if acoustic positioning is used, of contending with a surrounding gas. In a modified form of containerless processing, the size and shape limitations of partially supported liquid volumes, as in a floating zone crystal growth process, can be relaxed. The possibility exists of producing materials having unique properties by containerless processing in space.

Reducing or practically eliminating the gravity induced separation of mixtures consisting of materials having different densities. These effects extend to the avoidance of sedimentation of relatively denser particles or layers and to the buoyant rise of less dense particles or layers, and may be useful for scientific or technological purposes.

Using containment structures that would not survive on earth. Thin skins of a higher melting point material may be applied to act as a mold for a material to be processed at temperatures which melt or soften it. The lack of structural weight and hydrostatic pressure allows the fragile mold to retain its shape.

Testing experimentally the basic assumptions necessary in theoretical models of systems in which complicated patterns of fluid density variation are inherent. There are fundamental physical processes, solidification and combustion, that couple transformation and transport phenomena and unavoidably generate both density gradients and density-gradient-driven convection. Density gradients are complicated in that they never permit totally stable stratification against buoyancy-driven natural convection in the earth's gravity. Natural convection tends to interfere with planar, spherical, or other simple symmetries in those experiments where physical theories can most incisively be tested and demonstrated. This occurrence is important where complex nonlinear phenomena exists and theory predicts that a material system may behave in more than one way. In these circumstances, careful experiments in low gravity can advance scientific understanding.

Investigating molecular-level forces in macroscopic systems. One example of this possibility is that the low-gravity environment provides opportunities to study the van de Waals forces involved in the adhesion/cohesion between liquid/solid phases. Since these forces fall off rapidly with distance, gravitational forces mask attempts to study them in terrestrial experimental systems of macroscopic scale.

B. COMMERCIAL INTEREST

MPS technology is designed to exploit the scientifically-based opportunities described above. For example, in a low-gravity enviroment, the formation of large-particle-size monodisperse latex spheres of potentially commercial value will rely on the absence of sedimentation to keep the latex spheres in suspension as they grow from a polymerization process. Foamed metal with a uniform entrapment of bubbles could be produced because suppressed buoyant forces are large. Defect-free crystals of electronic materials with uniform properties could be produced by the floating zone process because density gradient-driven convection in the molten zone is absent and there are lesser restrictions on the size and shape of crystals. These examples illustrate the possibilities which have sparked interest in MPS as a commercial enterprise. Section V contains a discussion of other possibilities for MPS.

There are three potential commercial benefits of MPS:

1) Advances in the science and technology of materials processing would benefit terrestrial processing methods.

2) The demonstration of products with unique and valuable properties produced in space experiments would provide a powerful spur to the development of earth-based, alternative production methods.

3) The production of unique material products in space ultimately could lead to a space-based materials processing industry.

The economic justification for MPS is based on the development of marketable products or processes which are derived from any of these aspects. The products or processes which survive economic evaluation as conventionally applied to a new product opportunity will form the basis for successful businesses. Materials that will be produced in space in the near future, would be of low-volume but high-value. Large factories or mills producing huge quantities of materials, as is the case on Earth, are projected to be constructed in orbit in the more distant future when extraterrestrial materials taken either from the moon or asteroids may conceivably be mined and processed for use in space applications.

CURRENT PROGRAMS IN MPS

A. THE U.S. PROGRAM

The goals of the current MPS program were enunciated in their present form in 1978 after the evaluation of the STAMPS committee, discussed above. The flight opportunity to which the current MPS program has been directed is the shuttle and its payload, the joint NASA/ESA orbiting laboratory, Spacelab.

1. Current Research

In 1977 NASA issued an Announcement of Opportunity for experiments to be flown on Spacelab 3, currently scheduled to fly in September 1984. The selected experiments are concentrated in the seven materials processing areas shown in Table 1. Specific experiments selected for shuttle/Spacelab flight are shown in Table 2.(1) Their goals are mostly scientific; that is, they concentrate on the identification and understanding of basic process mechanisms and gravitational influences on these mechanisms. The experimental systems that are being prepared to accommodate experiments in these areas are listed in Table 3.(2) Three to seven years of ground-based research will precede each space experiment. The only other Announcement of Opportunity soliciting research projects for using the Fluid Experiment System developed for Spacelab was issued in 1980 and a few ground-based research projects have been sponsored since 1977.(3) Accordingly, the U.S. program proceeds on a truncated research base.

2. Spacelab 3 Experiments

Spacelab 3 will be the first U.S. MPS mission using the shuttle orbiter. Its primary objective is the acquisition of science data in low-gravity experiments. Spacelab 3 consists of a Spacelab long module and a Multipurpose Experiment Support Structure (MPESS) (see Figure 1). The MPESS, which attaches to the Shuttle cargo bay space will provide a multipurpose framework that can support a large spectrum of experiment hardware. This mission will encompass three discipline areas: Life Sciences, Materials Processing, and Environmental Observations.(4)

Spacelab 3 will fly a variety of MPS experiments. The selection is not yet final but some appear certain. This mission will be the first flight of the Fluid Experiment System (FES) and the Vapor Crystal Growth System (VCGS). The FES will explore solution crystal growth to obtain basic data about crystal-growing processes and to produce improved crystals by the elimination of convection currents. The FES incorporates systems to observe crystal growth, fluid con-centration and temperature fields. The FES will use precise control of the crystal, solution, and growth chamber temperature to maintain control over the crystal-growth process.

TABLE 1

MATERIALS PROCESSING IN SPACE PROGRAM — CURRENT AREAS OF RESEARCH

- Crystal Growth and Solidification
  - Solid Solution IR Detectors (HgCdTe, PbSnTe)
  - Vapor Growth (HgI_2, Alloy Type)
  - Solution Growth (Growth Environment vs. Morphology)
  - Float Zone (Marangoni Convection, Radial Segregation, Interfacial Stability)
- Metallurgical Materials and Processes
  - Immiscible Alloys
  - Magnetic Composites
  - Metal Foams
  - High Growth Rate Solidification
  - Solidification at Extreme Undercooling
- Composites
  - Casting of Dispersion Strengthened Alloys
  - Solid Electrolytes with Dispersed Alumina
  - Particle Pushing by Solidification Interfaces
- Glasses
  - Glass Fining
  - Laser Host Glasses
  - Optical Glasses with Unique Properties
  - Metal Glasses
- Chemical Processes
  - Monodisperse Latexes (Polystyrene Microspheres)
  - Stability of Foams and Suspensions
  - Colloidal Interactions
  - High Temperature Properties of Reactive Materials
  - Diffusion Controlled Synthesis
- Separation Sciences
  - High-Volume, High-Resolution Electrophoresis Cell Separation
  - Protein Purification by Continuous Flow Isoelectric Focussing
- Fluid Studies
  - Non-Buoyancy Driven Convections
  - Wetting and Spreading Studies
  - Role of Convection in Processes (Electrokinetic Separation, Electroplating, Corrosion, etc.)

Source: NASA

TAB. 2

EXPERIMENTS SELECTED FOR FLIGHT IN SHUTTLE/SPACELAB

Growth of Solid Solution Crystals	R. J. Naumann	NASA/MSFC
Semiconductor Materials Growth in Low-G Environment	R. K. Crouch	Electronics Devices Res. Brnch-LaRC/NASA
Vapor Growth of Alloy-Type Semiconductor Crystals	H. Wiedemeier	Rensselaer Polytechnic Inst.
HgI_2 Crystal Growth for Nuclear Detectors	W. F. Schnepple	EG&G, Incorporated
Solution Growth of Crystals in Low G	R. B. Lal	Alabama A&M University
Aligned Magnetic Composites	D. Larson, R. Pirich	Grumann Aerospace Corporation
Containerless Preparation Preparation of Advanced Optical Glass	R. Happe	Rockwell International
Liquid Miscibility Gap Materials	S. H. Gelles	S. H. Gelles Associates Columbus, Ohio
Large-Particle Size Monodisperse Latexes	J. W. Vanderhoff	Lehigh University
Aggregation of Human Red Blood Cells	L. Dintenfass	University of Sydney

Source: NASA

TABLE 3

MPS PROGRAM EVOLUTION

Research Discipline Operations to Benefit from Low Gravity	Experimental Payloads Shuttle/Spacelab Payload Development	Spaceflight Modes Materials Experiment Operation	Potential Commercial Applications
Crystal Growth Processes • Diffusion Controlled Growth Phenomena • Vapor Growth Phenomena • Solution Growth Phenomena • Epitaxial Growth Phenomena • Floating Zone Growth Phenomena	Fluids Experiment Sys. (D)* Vapor Crystal Growth Sys. (D) Analytical Float Zone Sys. (B) Solidification Experiments Sys. (D) Float Zone Processing Sys. (A) Epitaxial Crystal Growth Sys. (I) High Gradient Furnace (A)	Orbiter Middeck Spacelab Module Spacelab Pallet Materials Experiment Assembly Materials Experiment Carrier (Power System — Free Flying)	Infrared Detectors Nuclear Detectors Solar Cells Doped Semiconductor Chips
Solidification Processes • Microsegregation Phenomena • Macrosegregation Phenomena • Dispersion Phenomena	Solidification Experiments Sys. (D) Fluids Experiment Sys. (D) High Gradient Furnace (A)	Orbiter Middeck Spacelab Pallet Spacelab Module Materials Experiment Assembly Materials Experiment Carrier (Power System — Free Flying)	Dispersed Composites Directionally Aligned Materials Castings Solar Cells Eutectic, Peritectic, and Multiphase Alloys Metal Foams Superconductors Miscibility Gap Alloys

TABLE 3

MPS PROGRAM EVOLUTION (Cont'd)

Research Discipline	Experimental Payloads	Spaceflight Modes	Potential Commercial Applications
Operations to Benefit from Low Gravity	Shuttle/Spacelab Payload Development	Materials Experiment Operation	
Fluid and Chemical Processes • Gravity Driven Convection Phenomena • Non-g Driven Convection Phenomena • Drop Dynamics • Segregation and Flocculation Phenomena • Sterochemical Phenomena	Monodispersed Latex Reactor (D) Fluids Experiment System (D) Polymer Latex Reactor (A) Combustion Facility (A) Drop Dynamics Module (D)	Orbiter Middeck Spacelab Module Materials Experiment Carrier (Power System — Free Flying)	Polymers Monodisperse Latexes
Biological Separation Processes • Electrophoresis Phenomena • Isotachophoresis Phenomena • Counter Current Phenomena • Isoelectric Focusing Phenomena • Cell Culturing Phenomena	Isoelectric Focusing System (B) Electrophoresis System (A/I) Fluids Experiment System (D) Bioprocessing System (A) Fluids Experiment System (D)	Orbiter Middeck Spacelab Module Materials Experiment Carrier (Power System — Free Flying)	Purified Hormones, Enzymes, Vaccines Purified Products of Live Cells: Blood Fraction Cell Cultures to Produce Immunologic Products

TABLE 3

MPS PROGRAM EVOLUTION (Cont'd)

Research Discipline	Experimental Payloads	Spaceflight Modes	Potential Commercial Applications
Operations to Benefit from Low Gravity	Shuttle/Spacelab Payload Development	Materials Experiment Operation	
Vacuum Processes • Vapor Deposition Phenomena • Vapor Crystal Growth Phenomena • Outgassing and Sublimation Phenomena	Wake Shield Demonstration (A) Electromagnetic Containerless Processing System (A) Space Vacuum Research Facility (A)	Space Shuttle Materials Experiment Carrier (Power System — Free Flying) Wake Shield Free Flyer (Power System)	Purified Metals Vacuum Deposited Solar Cells
Containerless Processes • Nucleation and Solidification Phenomena • Vapor Crystal Growth Phenomena • Bubble Motion & Control Phenomena • Mixing and Shaping Phenomena • Extreme Undercoding Phenomena	Acoustic Containerless Experiments System (1-axis) (D) Drop Dynamics Module (D) Acoustic Containerless Processing System (3-axis) (B) Electromagnetic Containerless Processing System (A) Electrostatic Containerless Processing System (A)	Spacelab Pallet Spacelab Module Materials Experiment Assembly Materials Experiment Carrier (Power System — Free Flying)	High Index of Refraction Glass Fiber Optics Optical Wave Guides Laser Host Glass Microspheres, Fusion Targets Bulk Glassy Electromagnetic Materials Ultrapure Metals Variable Index of Refraction Glass Lenses Super Alloys Superconductors Property Measurements (High Temperature, Reactive Materials)

*Legend: A — Under Feasibility Study; B — Under Preliminary Design; D — Under Design and Development; I — Under Industrial Consideration

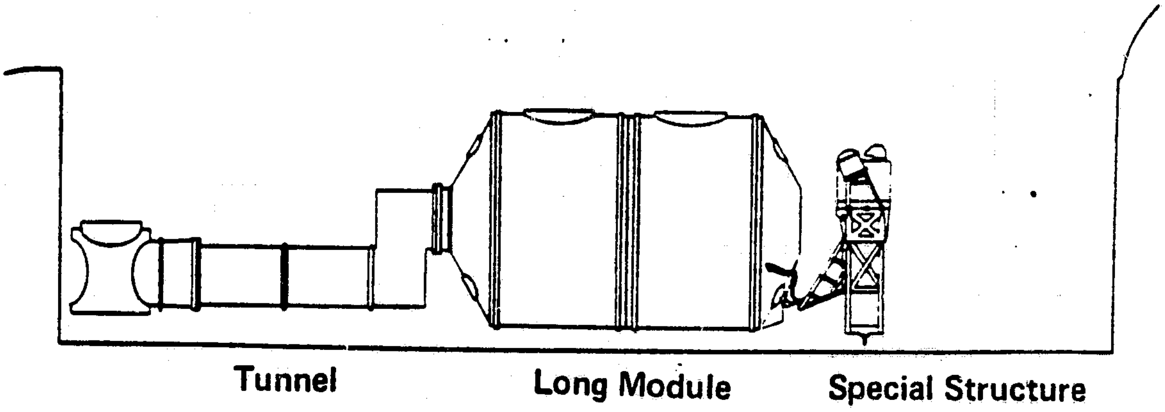


FIGURE 1 SPACELAB 3 PAYLOAD CONFIGURATION

The Vapor Crystal Growth (VCG) system will be used to grow a large, single crystal of mercuric iodide that is relatively free of mass load strain defects and physical property inhomogeneities. A mass of mercuric iodide source material is affixed to the side of a glass crystal-growth chamber. The chamber contains a seed crystal mounted on a string. The temperatures of the source material, growth cell, and string are adjusted to cause the source material to vaporize and redeposit on the seed crystal. The payload specialist's skill in operating the equipment will be a key factor in the success of both these experiments.

A Reimbursible flight of another mercuric iodide crystal growth expriment is being sponsored by CNES, the French space agency.

Another key materials experiment is the Drop Dynamics Module (DDM). The DDM uses acoustic fields to position and excite drops of water and/or silicone oil. Three orthogonal views of the drops are recorded on 16-mm film. The objective of the experiment is to perform tests to validate theoretical predictions of the behavior of drops in this environment. Information obtained in this experiment could be applied to the processing of small, hollow spheres of near-perfect geometry for laser fusion targets. The DDM occupies a double rack in the pressurized module.(5)

3. Low-Gravity Test Facilities

The facilities for low-gravity experimentation that NASA has available or is planning are shown in Figure 2.

a. Drop Tower

Economical simulation techniques, ground-based facilities, including drop tubes and drop towers, have been developed to provide low-cost, functionally flexible and readily available low-g test facilities. The NASA/MSFC operates two drop tubes: one of 100-foot length and one of 300-foot length. These facilities provide between two and four seconds of low-g time. The 300 foot drop tower employs a free-falling aero-dynamic container within which experiment packages are mounted for zero-g tests. Reference 6 gives a description of these facilities.

b. Aircraft

By flying parabolic trajectories, short periods of low gravity can be achieved with aircraft. The NASA/Johnson Space Center KC-135 aircraft has been used for several years to obtain low-g material science data and equipment verification. This aircraft can accommodate a relatively large experiment package which may be either automated or manually operated; the KC-135, low-g operating periods are, typically, 15 to 30 seconds and are useful for some solidification studies and preliminary experiments in other areas, such as containerless processing where the processing times available are sufficient. More recently, the NASA/Dryden Flight Research Center F-104 aircraft has been used for MPS

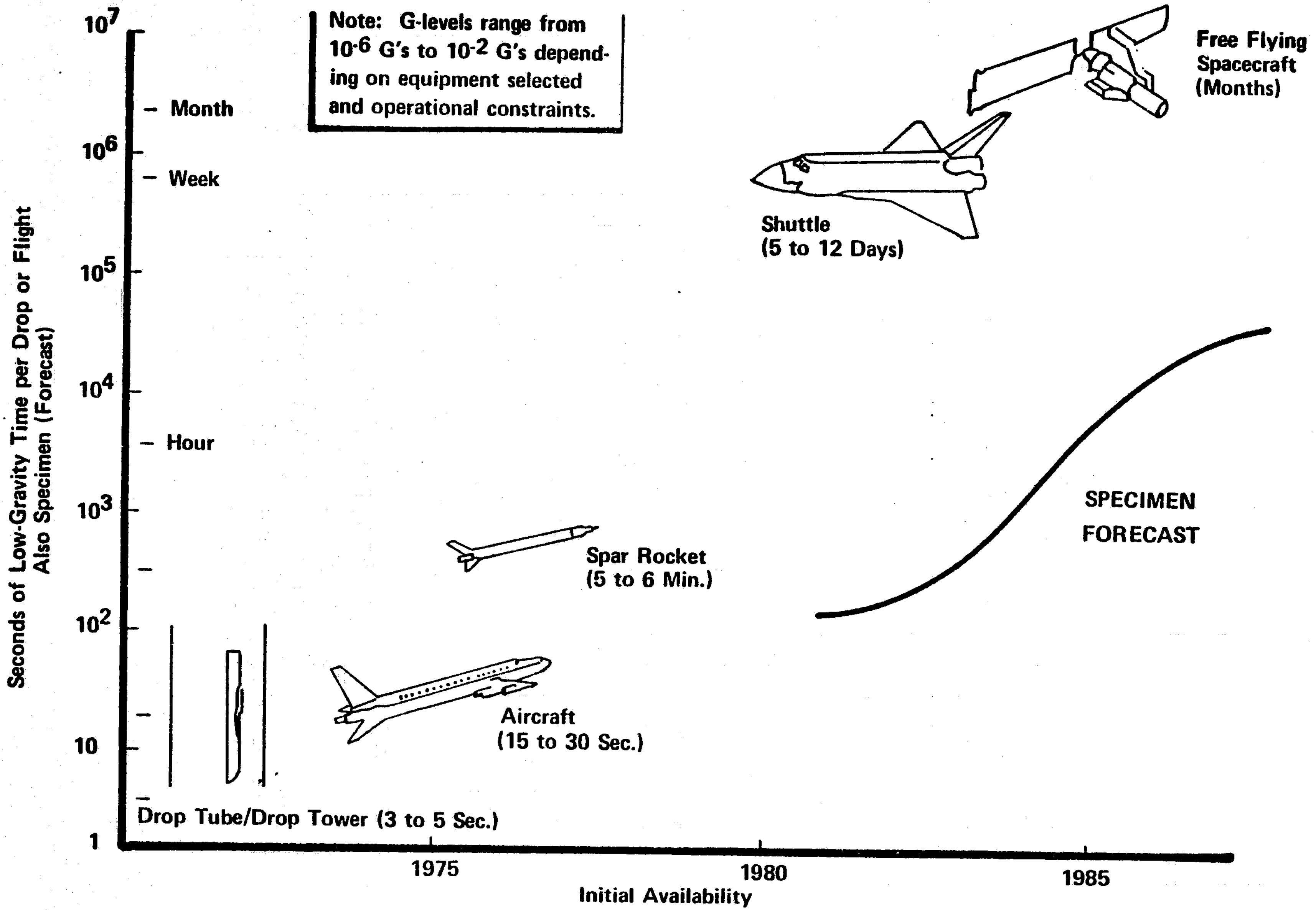


FIGURE 2 LOW-GRAVITY CAPABILITY

preliminary experiments. This aircraft accommodates small, automated experiments and can achieve 30 to 60 seconds of microgravity time. Reference 7 describes the aircraft low-gravity capability.

c. Sounding Rockets

Since 1974, NASA/MSFC has employed sounding rockets called, Space Processing Application Rocket (SPAR), to provide short-duration (4 to 6 minutes) flights for investigators to pursue their research in low-gravity phenomena and to develop concepts and techniques to be used later in shuttle flights.

The low-gravity environment on SPAR has been found to be an excellent interim tool for meaningful research in materials science. Although, the short duration, limited energy supply, and harsh launch environment, including spin-up and spin-down, providea a real challenge for experiment design, the sounding rocket program has accommodated a large number of experimenters interested in conducting materials research under low-gravity conditions. Many of the theoretical concepts to be validated on the shuttle have been screened in tests using SPAR. Considerable experience has been gained in developing and testing new hardware through the SPAR program. One result has been a development of significant inventory of off-the-shelf hardware that can be used to conduct longer duration experiments which will be flown on a space-available basis during shuttle operations. SPAR, as originally planned,was to continue to be an important experimental capability in the MPS program for several years. However, due to funding limitations, the SPAR program has had a 2-year hiatus. SPAR 10 is expected to fly January 1983. The current NASA five-year plan calls for a SPAR flight every other year. This plan, however is subject to future budget reallocations. Reference 8 gives a more complete description of the SPAR program and facilities.

d. Space Transportation System (STS)

The STS (space shuttle) is the primary vehicle for MPS experimentation during the decade of the 80's. The STS is a transportation facility or carrier providing space environmental capability for several kinds of experiment packages for nominal periods of time, initially, five days, later extending to as much as 30 days. Experimental facilities to be carried on the shuttle include: self-contained packages on the Orbiter middeck, The Materials Experiments Assembly (MEA), Spacelab module, and Spacelab pallet (Figures 3 through 5, respectively). The shuttle is also the means for putting a free flyer into orbit and resuppling it. The major advantages that the shuttle/Spacelab offers the experimenter are increased volume ($0.95m^3$, double rack) weight (425 kg, double rack) and time (up to seven days, subject to timeline restrictions) for experiments. It also provides power (an average of approximately 500W for a single experiment) and offers a shirtsleeve environment for Payload Specialists to assist in the test operations. A complete description of the capabilities of the shuttle/Spacelab is given in Reference 9.

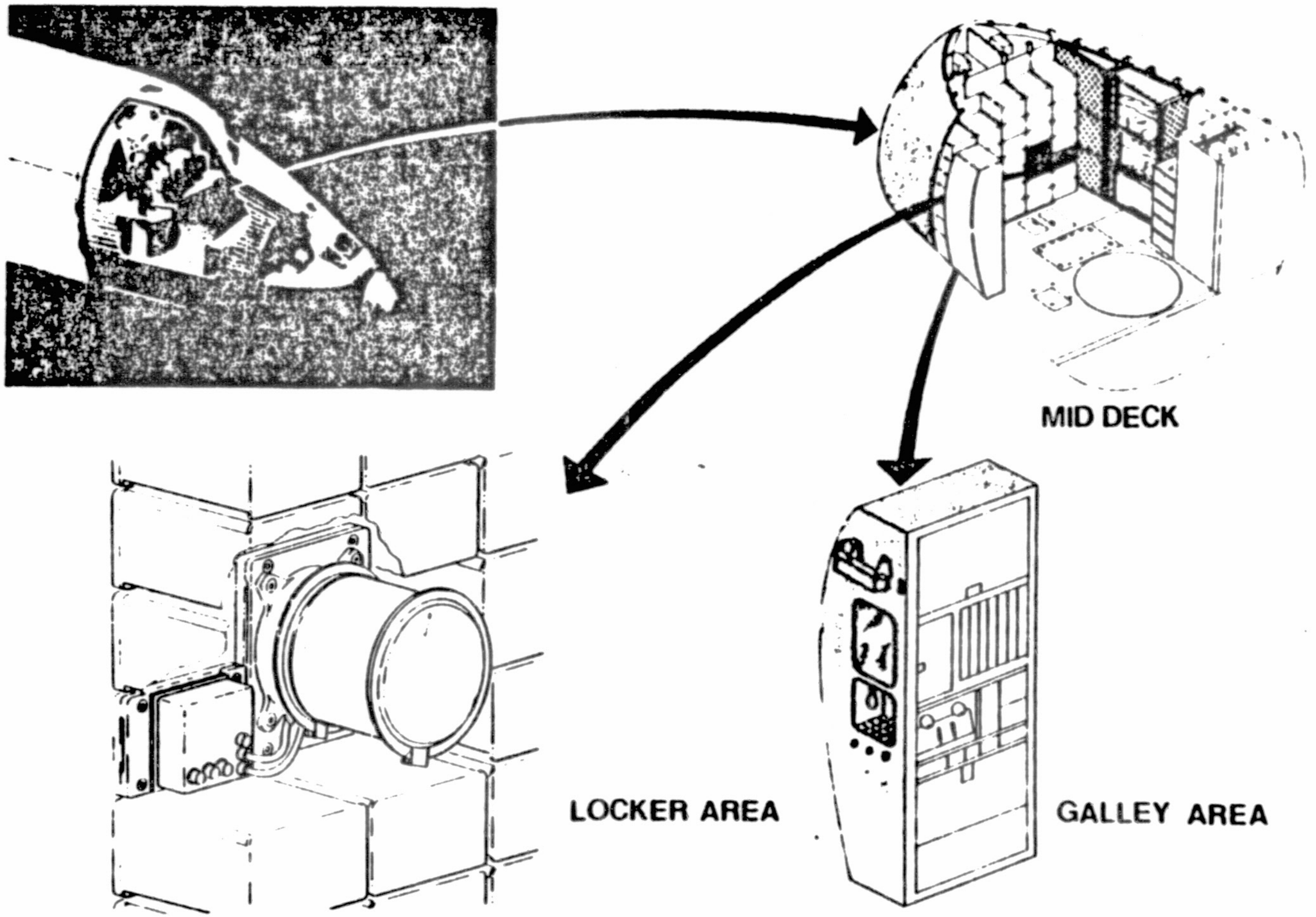
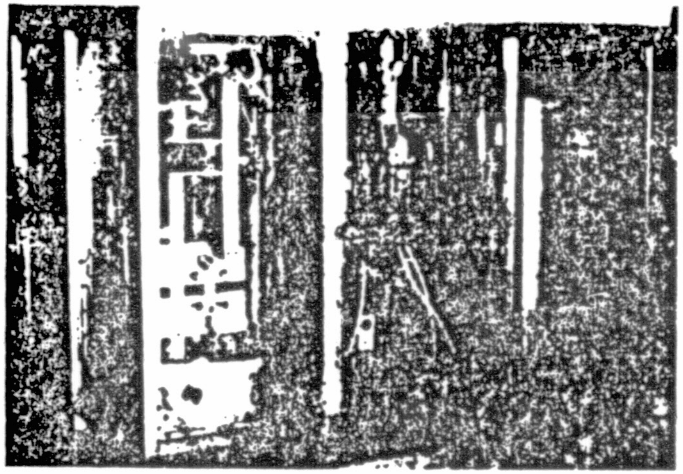
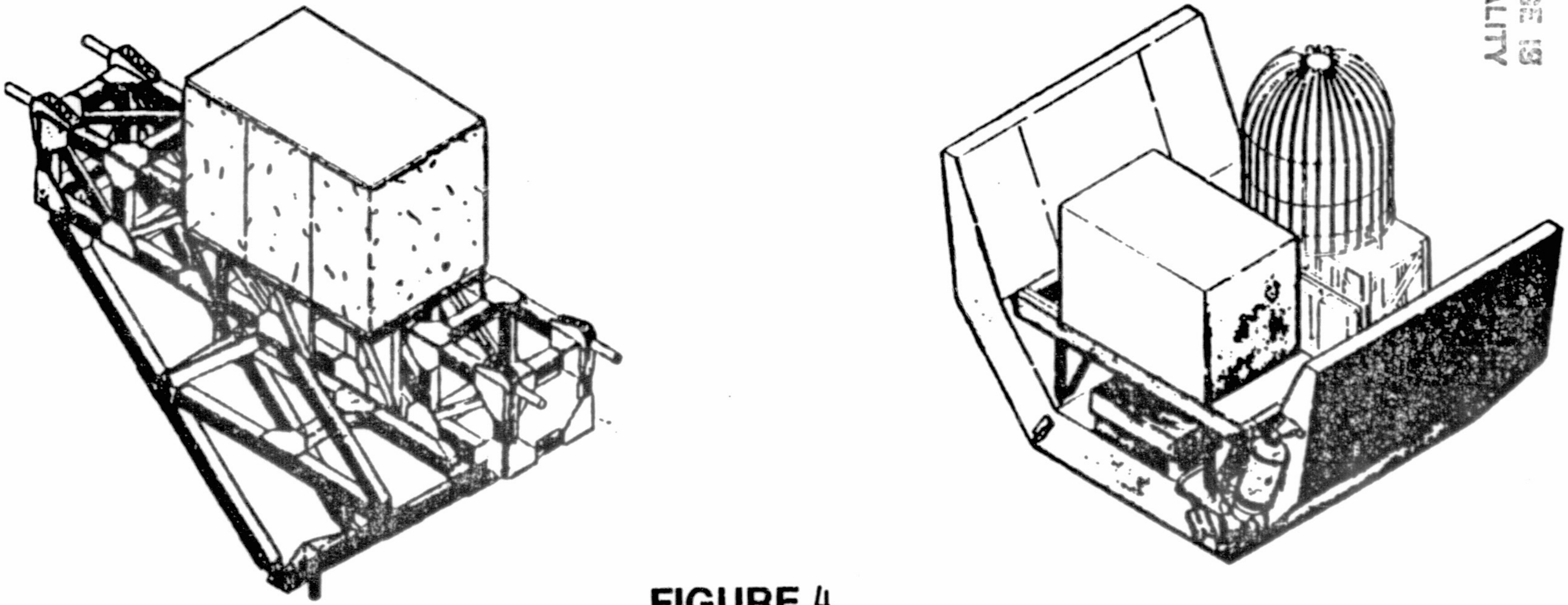


FIGURE 3 ORBITER MID-DECK ACCOMMODATION

MATERIALS EXPERIMENTS ASSEMBLY (MEA)





MEA ON MPE SUPPORT STRUCTURE

MEA ON PALLET

FIGURE 4

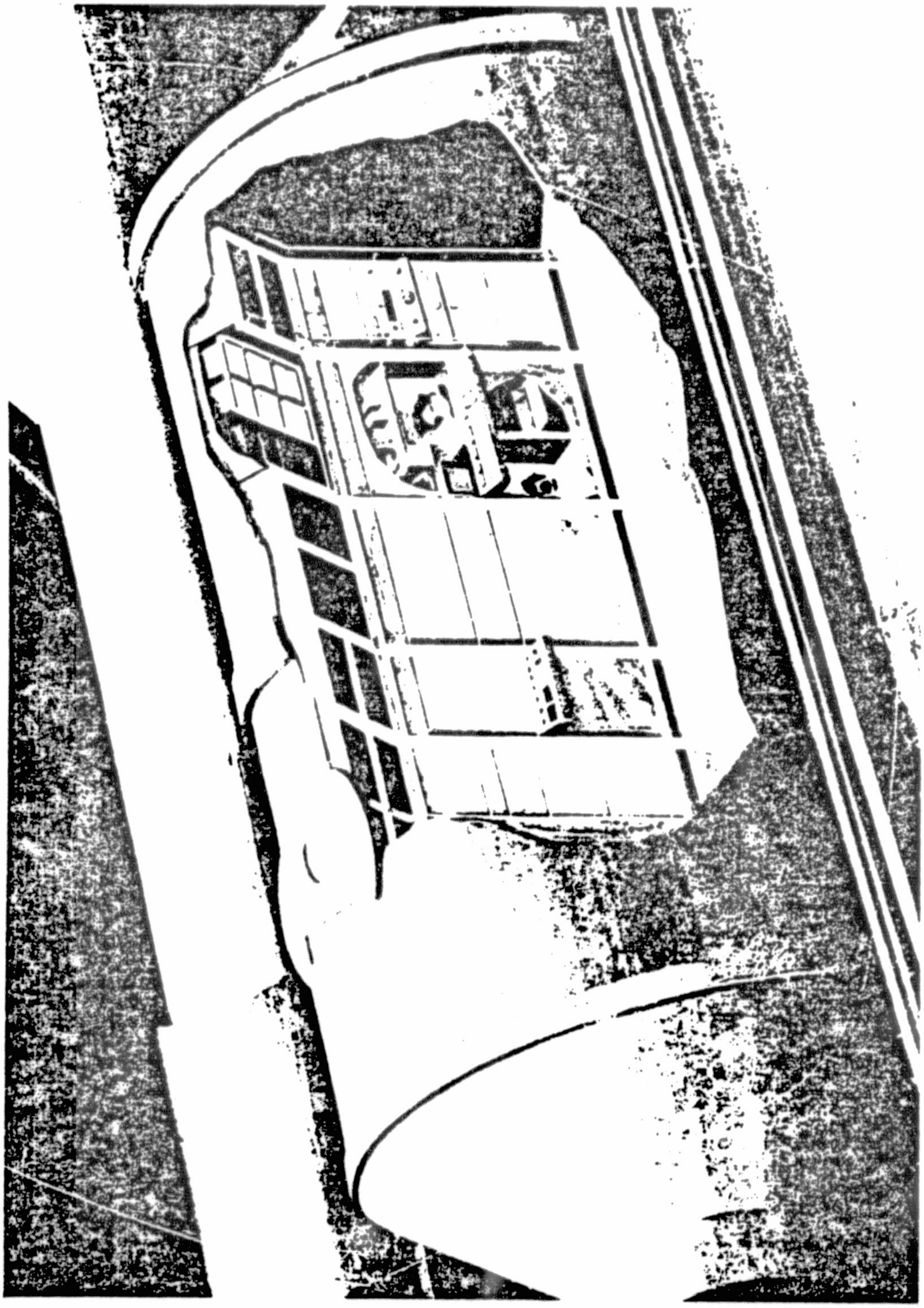


FIGURE 5 SPACELAB 3 MPS EXPERIMENTS

e. Free-Flyer

Various studies have indicated that to achieve economy of operations for MPS will require a free-flying satellite. NASA's MPS Program is planning to develop such a satellite, the Materials Experiment Carrier (MEC) (Figure 6). This automatic, unattended free-flyer will provide the long duration of low-g needed for continuous processing. The shuttle can serve as the transportation vehicle to place the free-flyer into orbit, to supply it with raw material and to pick up finished products. This operation requires teleoperator manipulation and maneuvering of raw material and product packages. Various versions of increasing capability have been studied (References 10, 11, and 12). The first flight of the minimum version is scheduled for a mission four years after initiation of the design study. It is to be supplied power from a 25kW power module. Neither the MEC nor the power module have yet been funded.

4. Results

MPS experiments have built on an evolutionary development of the facilities described in this chapter. Drop tower tests, in spite of the fact that their microgravity environment is only 4 seconds long, proved to be of considerable value in the verification of experimental concepts and the development of apparatus flown in Skylab. The use of KC-135 aircraft flying parabolic (keplerian) trajectories provided order of magnitude increase over drop tower microgravity periods. The extended time permitted researchers to verify the functioning of several Skylab experiments. Sounding rockets (SPAR's) further extended the ability to prepare and test experiments at a time when manned space flight opportunities were not available. The two major opportunities for actual space experimentation were provided by the Apollo Program and Skylab. The Skylab experiments on solidification and crystal growth in space constituted the first extensive demonstration of materials processing in space. However, while many of these experiments gave promising results, their interpretation remained somewhat ambiguous, and the Committee on Scientific and Technological Aspects of Materials Processing in Space (STAMPS) concluded that they were too hastily conceived and lacked adequate ground based precursor experiments and instrumentation.

NASA has since 1978 adopted the STAMPS Committee's recommendations, and to date has had two successful MPS demonstrations on STS3 and STS4: the monodisperse latex spheres and the McDonnell Douglas joint endeavor electrophoresis experiment. Still MPS is in its early R&D phase. Near zero-g experimentation time has been only a total of 8 hours spread over a period of 16 years and approximately 50 experiments. Substantial results are, therefore, meager. From the lessons of Skylab, NASA has embarked on a program requiring careful ground-based scientific research prior to space experimentation and working groups of investigators from many disciplines and institutions were formed in individual research areas to cooperatively attack common problems. The benefits of this approach were bearing fruit when funding limitations and corollary changes in program plans have erroded the enthusiasm and commitment of the scientific community to the MPS program.

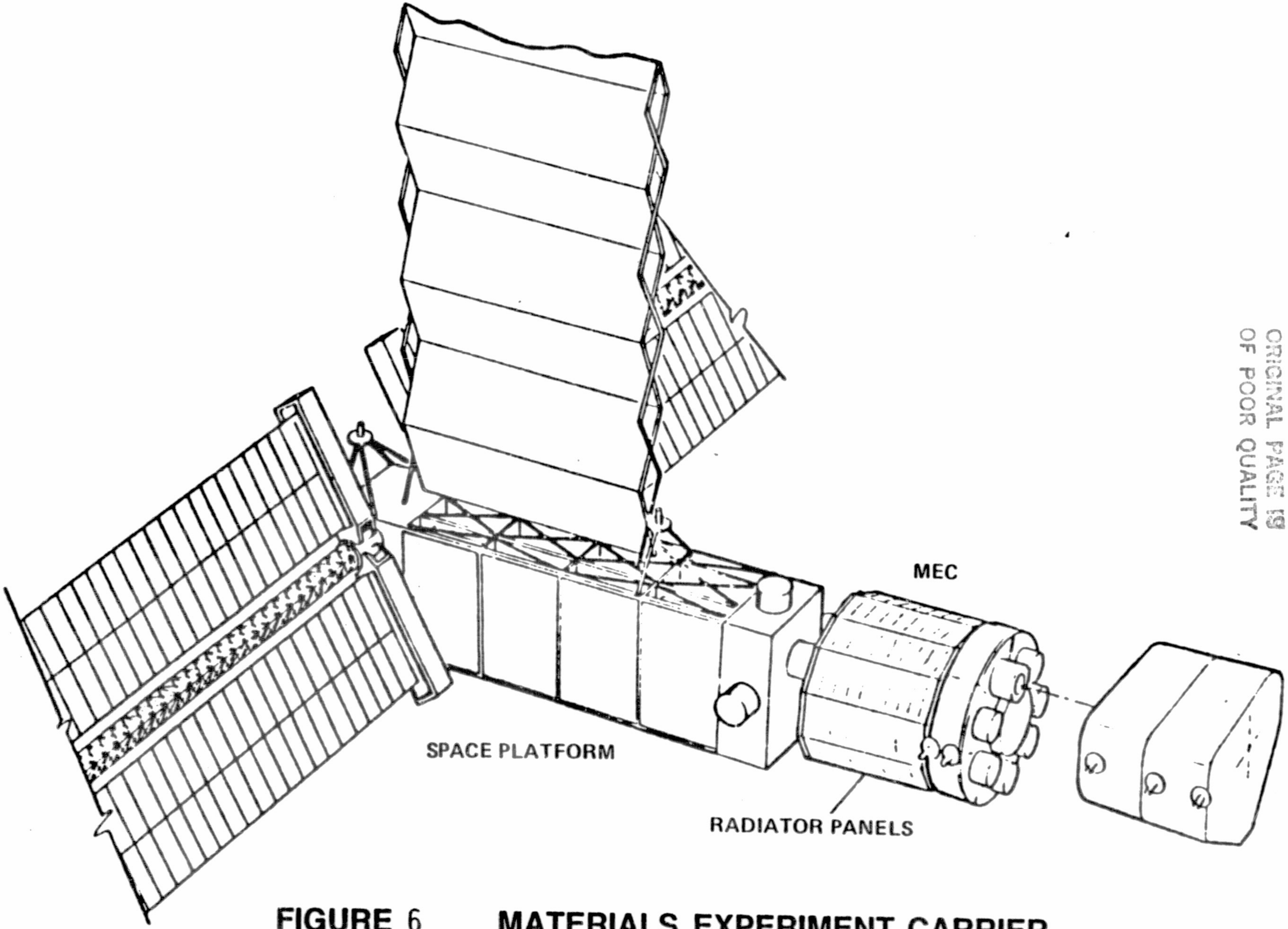


FIGURE 6 MATERIALS EXPERIMENT CARRIER

5. The Future of MPS

Limited government funding could have serious adverse effects on U.S. progress in materials science and on the development of a competitive position in MPS. For example, according to NASA and others interviewed in the course of the Government Accounting Office study cited previously(13):

- A few early commercial applications, such as those being pursued in NASA's joint endeavor programs, are likely to be discovered. While these discoveries are critically needed to demonstrate commercial potential, much basic research in materials science is yet to be funded that would establish a broad scientific base for identifying a wide range of commercial applications. This research begins with extensive preparation, experimenting and testing on the ground, as well as designing, developing, and testing related facilities which will house the experiments in space.
- Most of this early, basic research must be funded by the Federal Goverment or it may not be funded at all. Due to the high risk, high cost, and lengthy payback periods, private industry cannot commit significant resources.
- Hardware needed for follow-on work planned to begin in 1984, will require 2 to 5 years to develop, test, and integrate into Spacelab. Development which should have begun in 1979 or earlier was deferred and is likely to slow the pace of the materials research program by 1984 and beyond.
- Similarly, experiments which should have been funded already are being delayed. Only 14 U.S. experiments have been selected and funded, of which only 2 have been selected for flight, compared to 39 selected and funded by Europeans to be flown on the first Spacelab. The 14 U.S. experiments were selected in 1977. None have been selected since then. According to NASA officials, many worthwhile experiments cannot be funded, though NASA had planned to select 10 to 15 new experiments each year.
- New investigators cannot be brought into the U.S. materials science program due to limited funding. This lack of commitment frustrates many scientists in and out of the Government at a time when they believe more of the country's top scientists are needed in the program.
- Other industrial nations, most notably West Germany, France, Japan, and the Soviet Union, have made substantial commitments to materials science in space. At the current level of U.S. funding, early discoveries, which could lead to significant economic benefits, will most likely be made by other countries.

- Early flight opportunities for materials science experiments on Spacelab missions will be occupied predominantly by other nations' experiments. Because of low U.S. funding, no new U.S. experiments can be undertaken and no related hardware facilities are being developed with the result that for flights beginning in 1985, no U.S. experiments can be scheduled. In the meantime, European countries and Japan are proceeding with their plans and will likely request Spacelab space for additional materials science experiments beginning in 1985.(14)

- Continued low funding by the U.S. coupled with the higher emphasis and commitments by other countries, increases the need for specific international ground rules and agreements to provide U.S. accessibility to experimental results--an increasingly tenuous possibility as new discoveries with economic potential begin to surface and grow in number.

Thus, until specific products and processes are identified, adequate funding resources are committed, and legal barriers to private industry participation are removed, U.S. progress will be slow.

Most of the problems cited above are perceived by the scientific community, both here and abroad, as resulting from a lack of clearly defined national policies and the commitment to carry them out.

Those researchers in industry, academia, and Government who are most optimistic about U.S. prospects of materials research in space are deeply concerned about the growing emphasis and commitment by other countries to MPS. The concern is not that other countries are ahead now; rather, once the shuttle and Spacelab are operational and used by international competitors, their heavy emphasis and commitment could lead to technological and economic advantages which may be difficult to overcome--being "first to market" with new high technology products and processes.

These concerns, though somewhat overreactive, are not without justification. While the United States still remains preeminent in space activities, its lead has diminished. Whether the United States will maintain leadership depends largely upon events during the next 10 years - whether its position will be strengthened by a vital expansive space policy and more substantive financial commitment to assure future econimic and technological positions.

There are a number of options for future U.S. MPS budget, ranging from (1) eliminating MPS activities, through (2) the current reduced-level MPS program, to (3) an augmented MPS program that will support a realistic schedule to explore MPS opportunities.

B. EUROPEAN PROGRAM

The current European Program in MPS involves 11 nations in cooperative agreements within the European Space Agency (ESA). The 11 nations are Belgium, Denmark, France, Ireland, Italy, Netherlands, Spain, Sweden, Switzerland, United Kingdom and West Germany. Austria and Norway are observers. All the member states except Sweden are participating in Spacelab.

ESA provides the centralized planning and management needed for the enterprise. The member countries have national MPS programs of various magnitudes within which they support the research and development leading to flight experiments, the design and manufacture of flight experiment systems, and the design and manufacture of hardware elements of larger systems such as Spacelab. The Federal Republic of Germany and France have also mounted significant efforts independent of ESA.

1. ESA

a. Micro-Gravity Program

The micro-gravity program of ESA is the counterpart of NASA's MPS program. Starting in 1973, when planning for the Spacelab's initial mission started, a micro-gravity program was part of ESA's mandatory scientific program. In a mandatory program all its member states had to contribute to the cost of projects in proportion to their gross national products.

ESA does not fund experiments. It issues announcements of opportunity of available facilities for Space Experimentation and accepts proposals from institutions within its member states for most effectively using the space facilities that it builds. These proposals are evaluated by the Materials Science Working Group. The Materials Science Working Group was created in 1976 and was responsible for selecting the 39 European experiments for Spacelab 1 from among approximately 130 materials science and technology proposals. A primary requirement for any proposal's acceptance is its ability to demonstrate that it has already been funded by the regular sources of research support in its country.(15)

Table 4 gives a Spacelab 1 mission Science Summary. As the table shows, there will be 34 MPS experiments performed. Table 5 gives a breakdown of the experiments by Principal Investigators.

In 1981, ESA decided that its mandatory MPS program was overburdened. When it became apparent that support within ESA for the micro-gravity program was not sufficiently strong, ESA made it optional. In the past year, the agency has been trying to find enough voluntary support to make the program feasible. It recently succeeded by a very close margin. ESA's MPS program was $1.2 million in 1981. In January 1982, ESA announced an approved 4-year "microgravity program" budgeted at $52.4 million.(16)

TABLE 4

SPACELAB 1 MISSION SCIENCE SUMMARY

Discipline	NASA Investigations	ESA Investigations	Total
Atmospheric Physics/ Earth Observations	1	5	6
Space Plasma Physics	2	4	6
Solar Physics/ Astronomy/Astrophysics	2	4	6
Material Sciences	1	33	34
Life Sciences	7	9	16
Totals	13	55	68

Source: Sander: AAS–82–103.

TABLE 5

SPACELAB 1 EXPERIMENTS: MATERIAL SCIENCES AND TECHNOLOGY

Experiment No.	Scientific Object	Organization	Principal Investigator
1NT011	Characteristics of Bearing Lubricants	Shaker Research Corporation Ballston Lake, N.Y. (USA) and Marshall Space Flight Center, Huntsville, Alabama (USA)	Dr. C. H. T. Pan Dr. R. L. Gause, Ann F. Whitaker
1ES300	Material Sciences and Technology (35 Experiments)	ESA–Contractors	H. Steimle (DFVLR)
1ES332	Organic Crystal Growth	Technische Universität Kopenhagen (DK)	Prof. J. F. Nielsen
1ES333	Growth of Manganese Carbonate	Universite Pierre et Marie Curie, Paris (F)	Prof. A. Authier
1ES338	Mercury Iodide Growth	Laboratoire d'Electronique et Physique Appliquee, Limeil-Brevannes (F)	Dr. C. Belouet

Source: Kappler, AAS-82-102

b. Spacelab

The first major scientific payload on the shuttle will be the European-built Spacelab. In return for building Spacelab, NASA will fly Spacelab 1 without fee. Spacelab 1 is scheduled to be flown in September 1983.

The Spacelab flight will carry six people: the two astronaut-pilots, two astronaut "mission specialists," and two scientists, one an American and the other a European. The scientists will fly after only a few weeks of training for the space flight. They will become the first "ordinary people" to go into space.

Europe began working toward its own orbiting space laboratory in the early 1970s after 10 countries pooled their space research resources in the European Space Agency. Spacelab was created to complement the U.S. STS program.

Spacelab was inspired by Skylab, the United States' orbiting laboratory and space station combination that was visited by three astronaut crews in 1973 and 1974, and by the Soviet Union's Soyuz space stations. Like the shuttle, ESA planners wanted Spacelab to be reusable. To make it versatile, its designers evolved a modular system of building blocks that can be assembled in various configurations according to the needs of future commercial, scientific, or military applications.

Spacelab's keystone is a large, drum-like instrument-packed pressurized compartment, 9 feet long and 12 feet in diameter. Ordinarily, two such drums would be joined end-to-end to form a large compartment to accommodate up to four researchers, who would live in the shuttle's forward quarters, enter Spacelab through a connecting tunnel, and work there in what the engineers and NASA officials describe as a "shirt-sleeve" environment. One unit, the core module, will contain computers and control system. The second unit, the experiment module, will provide additional room for equipment and work space. Spacelab's second component is a U-shaped open pallet for experiments that demand bulky instruments, like telescopes, or exposure to the vacuum of space. A third component, a barrel-shaped container called an "igloo," houses computers and other subsystems needed to control instruments mounted on pallets. Spacelab's components can be arranged in one of eight basic configurations, ranging from a standard version with a pressurized manned compartment and two pallets, to a simple manned compartment without pallets, or a string of pallets supported by an igloo but without the manned compartment. Once carried into orbit in the shuttle's cargo bay, Spacelab is to remain there during missions that can last up to a week and then return to earth.(17,18)

Contracts to build Spacelab were awarded by ESA according to which countries provided the most money. Since Germany paid 53 percent of Spacelab's $833 million cost, German companies were the major hardware contractors. Besides ERNO, the prime contractor, German companies built Spacelab's power systems and the life-support system. Italy financed 18 percent of the cost. An Italian aerospace company built the module's steel cylinders. France was the third biggest contributor with 10 percent - a French company received contracts for the electronic command system. In all, some 35 contractors and subcontractors were involved in the work. There were problems in building the orbiting laboratory. Initially, the need for engineers to communicate in a common language, which an Erno spokesman once described as "broken English," slowed work and led to misunderstandings. Also, suppliers failed at times to understand specifications, causing tieups when components had to be re-ordered.

However, European aerospace manufacturing experts also agreed after the project was well underway that Spacelab had enhanced the flow of high technology and expertise between Europe and the United States. For example, when European subcontractors were unable to solve complex software problems, a team of United States experts was called in to assist. ERNO officials said afterward that the cooperation sharply increased software management expertise in Europe.

The first Spacelab was delivered to Cape Canaveral in November, 1980, several months before Columbia's launch. It was put into service to train personnel and began undergoing tests. A second, operational version was delivered in December, 1981. By the time Columbia was launched, some 600 to 700 organizations had expressed an interest in using Spacelab, roughly 60 percent of them interested in materials testing. About 30 percent of these groups were from German industry. In 1980 NASA contracted to purchase a second spacelab, including pressurized module and five instrumentation pallets, for $183.9 million from the prime contractor, ERNO.

There are currently five dedicated missions planned for the Spacelab system before the end of 1985--Spacelabs 1, 2, 3 and 4 and the (reimbursible) German mission D-1. These missions exercise many of the configurations of the shuttle/Spacelab system (Table 6). All are European except Spacelab 3 which is a U.S. mission. The first two missions, Spacelabs 1 and 2, have as one of their prime purposes the validation of Spacelab's services and environmental standards while the subsequent missions are devoted to science oriented experiments. The Spacelab 1 mission configuration is shown in Figure 7.

As costs of the shuttle have risen, so has the price of sending Spacelab into orbit. Although NASA's pricing policies for shuttle charters are yet to be finished, Erno officials now calculate that each flight will cost about $65 million, necessitating a reduction of planned flights in the later 1980s from two per year to about one every two years, and raising the service and transportation costs of a typical experiment on Spacelab to as much as $1 to $2 million, more than any but the very biggest industrial organizations can afford. Without considerable government aid, Spacelab is in danger of being priced out of business.

TABLE 6

DEDICATED MISSION SUMMARY

Mission	SL-1	SL-2	SL-3	SL-4
Configuration	One pallet and long module	Three pallets, igloo, instrument pointing system	Special structure and long module	Long module
Launch Date	September 1983	November 1984	September 1984	September 1985
Number of Investigations	68	11	8	25
Discipline Areas (Note 1)	1, 2, 3, 4, 5	2, 3	1, 4, 5	5
Orbital Inclination (Degrees)	57	49.5	57	TBD
Orbital Altitude (km)	250	400	370	300
Payload Mass (kg)	3500	5000	3800	4100

1. Atmospheric Physics/Environmental Observations
2. Space Plasma Physics
3. Astronomy and Solar Physics
4. Materials Processing
5. Life Sciences

Source: NASA

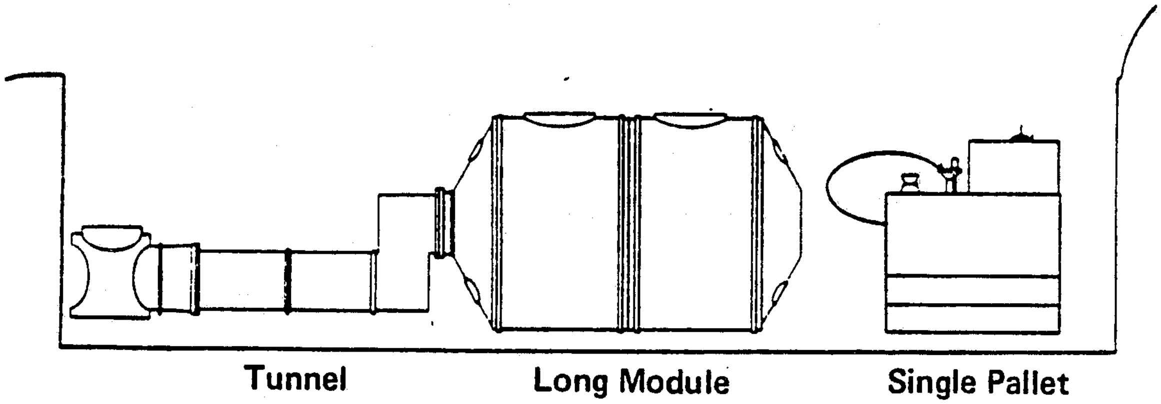


FIGURE 7 SPACELAB 1 PAYLOAD CONFIGURATION

c. Free-Flying Carrier

To increase the opportunities and capabilities for MPS experimentation, ESA is planning to develop small free-flying experiment carriers. The Free-Flying Retrievable Carrier was recently approved by the member states for deployment in 1986.

Among the reasons ESA is interested in a retrievable carrier are that the possibilities of micro-gravity experimentation in Spacelab are limited by the mission duration, the achievable micro gravity level, the available power, safety requirements for manned systems and, to some extent, by the outgassing of the shuttle-Spacelab system.

The Retrievable Carrier, is to have an orbital operation duration of several (2-6) months and a power supply of several kW, compared to approximately one week and 1kW for Spacelab. The micro-gravity quality of 10^{-5}g is continuously achievable by the Retrievable Carrier, whereas in Spacelab the micro-gravity environment is often disturbed up to 10^{-3}g by crew movement and Shuttle manoeuvers. Other advantages of the Retrievable Carrier are: potentially lower safety requirements (and associated lower costs) for an unmanned spacecraft which enable toxic products to be used, a cleaner environment, and a better vacuum in a 450-km orbit. Balanced against these advantages is the need to substitute robotics and pre-programmed intelligence for human interaction with the experiments.

The funding levels for the Retrievable Carrier is approximately $210 million for the next 5 years. Germany is expected to pay for about half.

2. Federal Republic of Germany

The German government has been actively supporting MPS through its Federal Ministry for Research and Technology. There is an understanding that until the first proof-of-concept missions on the shuttle have been evaluated, the risk involved in MPS will require special commitment by the government before industry is able to decide on investment and commercial utilization. Still German industry has actively participated in investigating materials processing in space through investment of their own funds. Man, Inc., is pursuing skin technology in which complex refractory metal alloys used for turbine blades are melted and resolidified in the space environment within an oxide skin. Volkswagen is working on new, immiscible-metal alloy systems.(19)

The West Germans are estimated to have spent $57 million on MPS experiments between 1978 and 1980 and $15.4 million in 1981. They are expected to spend $50 million between 1982-1985. Additional funds are available from non-federal sources.

The current program is pursuing space experimentation through the use of the shuttle/Spacelab and sounding rockets. Table 7 provides an overview of the evolution of the orbital systems for German materials processing activities.

The first experiments on Spacelab 1 use the German Materials Science Double Rack (MSDR). The experiment facilities include: (1) high temperature thermostat, (2) mirror heating facility, (3) isothermal heating facility, (4) capillarity measurement equipment, (5) cryostat, (6) fluid physics module, (7) gradient heating facility, (8) UHV chamber, (9) common support equipment.

The next German MPS mission on Spacelab is the D-1 mission. For this mission, Germany is chartering the entire capacity of Spacelab on a single Shuttle flight scheduled for April, 1985. Low-gravity experimentation in metal and electronic materials processing, in fluid behavior, and transport and physical chemistry phenomena are the prime objectives. Experiments in the fields of medicine, biology and botanics will also be included.(20)

The configuration of Spacelab in the D-1 mission is the Spacelab long-module with a payload complement in the cargo-bay of the shuttle. This payload complement may be accommodated either on a standard Spacelab pallet or on a Shuttle Pallet Satellite or Carrier. The latter (to be decribed) would permit experiments to be conducted independently of disturbing accelerations of shuttle and Spacelab during a free flying phase of the SPAS carrier. Investigations of the feasibility of this concept are still in progress, but the scientific community and the program management are strongly requesting this extension of the scientific capabilities of improved microgravity.

The payload elements which will be flown on the D-1 Mission and operated in the Spacelab Module are:

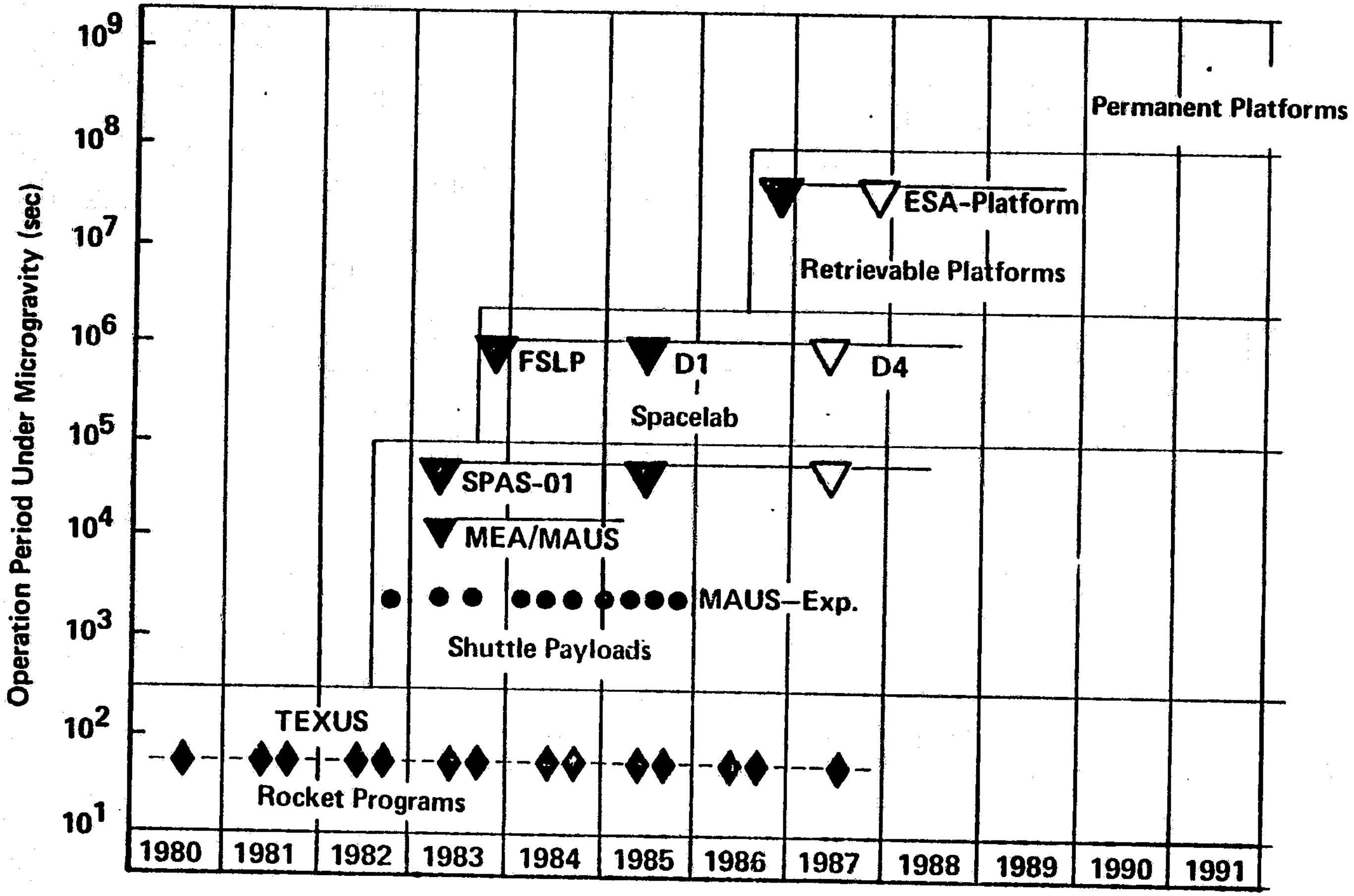
- the Material Science Double Rack (MSDR)
- the MEDEA laboratory for metallurgy and crystal growth experiments
- the Process Chamber for research activities in the area of fluid physics
- the ESA Biorack and
- the ESA Vestibular Sled.

In addition, a payload support structure in the cargo bay will carry such payload packages as:

- NAVEX: a communication and navigation experiment, and

TABLE 7

EVOLUTION OF ORBITAL SYSTEMS AND GERMAN MATERIAL PROCESSING ACTIVITIES



- the NASA MEA - Payload (Material Experiments Assembly)

The cost of the D-1 mission is estimated to be $65 million.

To accommodate simple, self-contained materials processing experiments, West Germany has the Material-wissenschaftliche Autonome Experimente unter Schwerelosigkeit or MAUS program. It provides economical opportunities for materials science experiments to be performed under microgravity in shuttle flights. The experiments packages and experiments are designed to be compatible with NASA's "Getaway Special" program. Under the MAUS program, twenty-five of these "Getaway Specials" have been purchased to date by German companies and government agencies.

The instrumentation of the autonomous MAUS payloads is contained in a cylindrical container which is identical with the NASA "Getaway Special" containers. The package provides the necessary resources for measurement and control of the experiment. The MAUS support modules are under development.

Another planned use for the MAUS modules is in the SPAS 01 mission of Messerschnitt-Bolkow-Blohm, Gmbh (MBB). SPAS 01 is designed to carry three MAUS modules. Its U.S. counterpart is the Materials Experiments Assembly. The MBB-Project SPAS-01 (Shuttle Pallet Satellite) is currently scheduled to be launched on Shuttle flight No. 7 in April 1983. Two mission phases are foreseen: in the first phase (one day) the payload is operated in the Shuttle Orbiter cargo bay. In the second phase (two days) SPAS-01 is deployed as a free-flying satellite and used for testing various approach and retrieval maneuvers. A planned cooperative flight of a NASA/German payload MEA/MAUS will provide another flight opportunity for three MAUS modules, and finally, some MAUS modules will be accommodated in the D-1 payload.

Germany also has an ongoing sounding rocket program, Technologie Experimente Unter Schwerelosigkeit (TEXUS) carried out in cooperation with Sweden. TEXUS provides a limited low gravity experiment capability similar to the U.S. SPAR program. Figure 8 illustrates the TEXUS payload concept.

3. France

The French program includes experiments on Spacelab-1 in crystal growth and fluid physics with some follow-on planned for Spacelab-3. French crystal growth and solidification experiments also flew on Salyut-6, the NASA sounding rocket program, and are planned for future NASA missions as mentioned previously. In general, the French effort is smaller and more scientifically oriented than the German activities. There is as yet little French industrial involvement in MPS for reasons similar to those expressed by U.S. industry.

Estimates are that France has spent $1-2 million on MPS to date and plans to spend about $2 million between 1982-1983.

SET-UP OF THE
PAYLOAD TEXUS

Payload Length:
4.5 m

Payload Weight:
360 kg

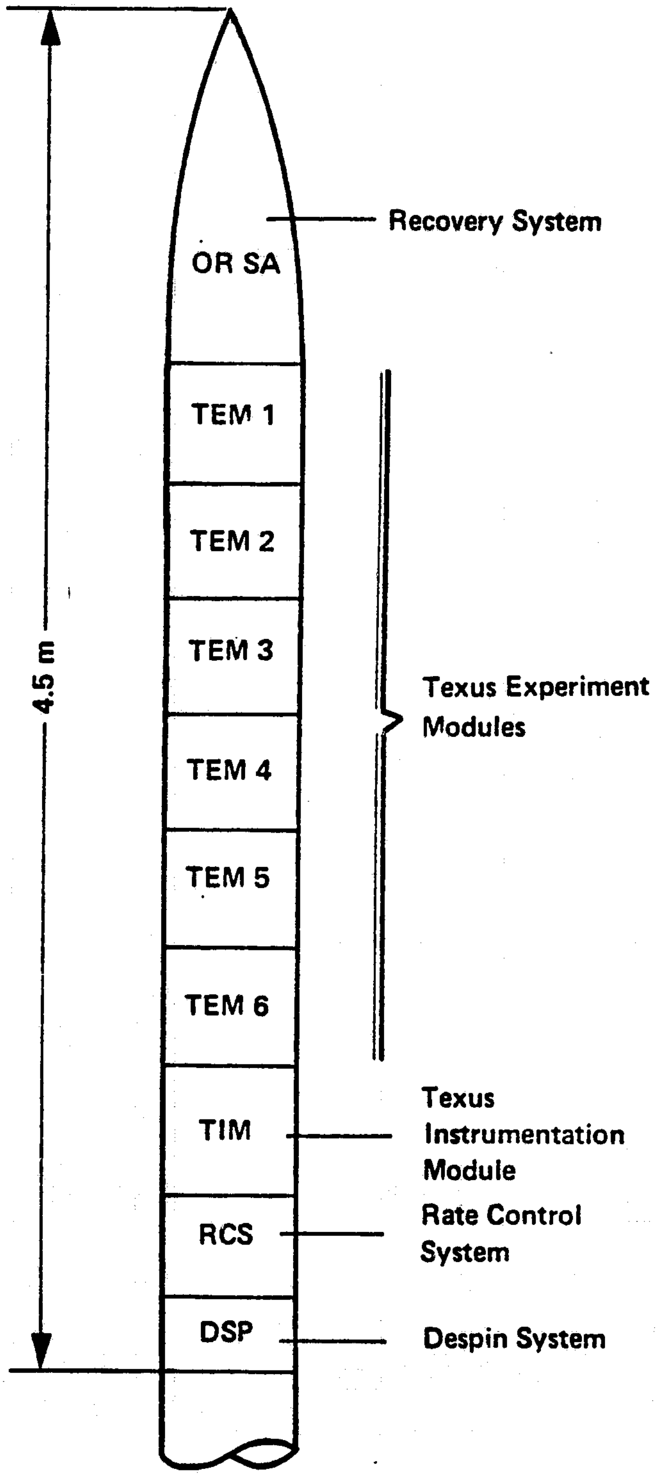
Maximum Altitude:
270 km

Micro-g Time:
360 s

Micro-g Quality:
10^{-4} g

Range:
Esrange

Recovery:
Parachute



Source: Gieger: AAS–82–105.

FIGURE 8 CONCEPT OF THE TEXUS PAYLOAD

The French Centre National d'Etudes Spatiales (CNES) is currently studying an unmanned space station named Solaris, which could be available in the 1990's. Among its many purposes, the Solaris would determine if there could be an automated solution for industrial materials processing in space. Plans are that the Solaris would be able to handle materials weighing up to two tons in its oven. Solaris would be orbited by an Ariane-4 launcher, operating for a lifetime of up to 15 years. Feedstock would be transported to the station by Ariane-launched unmanned spacecraft. Modules containing processed materials would be returned to Earth from Solaris via unpowered reentry vehicles. It is estimated that Solaris would cost $175.4 million. This cost would make it too expensive for France to undertake solely as a national program. The possibility of a joint European effort is currently being discussed.(21,22)

4. Other Countries

Other European countries with interests in MPS are Italy, Spain, Great Britain, Denmark, Sweden and Norway. The experiments from these countries center around basic fluid dynamics experiments in the fluid physics module (Spacelab-1) and small scale demonstration experiments in crystal growth and solidification. Interest at this time is academic in nature, with the development of scientific knowledge as the main goal.

Great Britain's history with MPS is particulary interesting. After enthusiastic support, the British have all but opted out of ESA's microgravity program on board the manned Spacelab. Originally the Department of Industry paid for Britain's share of the cost of Spacelab. However, today, officials in the department view the "profits" from microgravity research as long- term, making MPS "science" rather than "technology" and therefore a matter for the national research councils. Accordingly, the Department of Industry is no longer funding MPS research, leaving it to the research councils to decide how much they want to contribute to ESA's microgravity program. The Science and Engineering Research Council (SERC) and the Medical Research Council decided to give only 1.3 percent in 1982 to ESA's microgravity program. The Science and Engineering Research Council and the Department of Industry paid for the preparation of zero gravity experiments for Spacelab 1. The SERC also paid Britain's contribution to ESA's mandatory scientific program, which included projects for equipment for life science experiments in microgravity. Britain plans no further MPS experiments after those to be carried out on board Spacelab 1.(23,24)

C. SOVIET PROGRAM

The Soviets have been flying space experiments routinely on the Salyut-6 laboratory since the summer of 1978. During an initial 14-week period, about 40 different materials were prepared and returned to Earth for analysis. These specimens were processed in two furnace systems, SPLAV-01 and Kristall, which were designed to a standard set of requirements common to existing terrestrial furnaces. Subsequently, some 20 to 30 additional specimens have been processed, some for Soviet block countries and France.

In all the Soviets claim to have performed 1,600 experiments and brought back 300 materials processing samples since 1977. (25). About a dozen of these materials have been reported in the open scientific literature and have included semiconductor crystals, amorphous chalcogenides, oxide glasses, and metal alloys. Most space processing research is carried out at the Space Processing Institute in Moscow where about 300 workers plan, implement, and analyze space experiments. The current Soviet leader of the space processing program is Dr. Validium Il'yushin, a world renowned materials scientist.

The Soviets place great importance on MPS. They perceive it as a way to overtake the Western nations in technological and industrial areas. Estimates are that the Soviet MPS program receives 3 to 4 times more funding than the U.S. MPS program.

The avowed goals of the Soviet space program include the building of a space platform and the development of a shuttle-type winged reusable manned spacecraft to access it. The implications on MPS of such a development could be very significant and inspire international competition motivated by economic considerations.

D. JAPANESE PROGRAM

The Japanese view MPS as a very promising means of insuring a competitive position in 10-15 years, but not as something with a "near-term" payback. MPS is part of their 15-year space development policy, however they have as yet no definite MPS program. Indications are that when an MPS program is put in place, it will be modeled on NASA's in its attempt to involve private industry in space commercialization.

MPS in Japan falls under the auspices of NASDA: the National Space Development Agency, which is the principal space agency involved in civilian applications and test programs and which launches development and tracking facilities. The Japanese plan MPS experiments in both the shuttle and the TT-500-A.

The TT-500-A is a small, two-stage suborbital rocket with recoverable payload sections. It provides approximately 7 minutes of microgravity (under 10-4G), comparable to the U.S. SPAR and German TEXUS. NASDA is planning two TT-500-A flights per year. An early launch in 1981 carried a metallic compound processing experiment, while an August flight evaluated semiconductor processing techniques.(26)

NASDA anticipates funding annual missions with Spacelab, inaugurating its use with a first material processing test (FMPT) in fiscal year 1985.

The FMPT will use half or one-third of the available space in the shuttle carried spacelab. A Japanese payload specialist will join shuttle crews to conduct the FMPT and later shuttle-based experiments. NASDA has requested $5.1 million for fiscal 1983 for its shuttle experiment preparation. (27)

Japanese industry, under the auspices of the Ministry of Trade and Industry is currently evaluating promising products through exploitation of the space environment. Once these products have been identified, either through Japan's own efforts or through a close observation of other countries' results, Japanese industry is expected to make investment in areas it considers promising, in keeping with Japan's practice of long-term development. The current symbiotic relationship between the Japanese government and industry make Japan a promising candidate for MPS leadership in the future.

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INDUSTRIAL PARTICIPATION

Social and economic benefits which may accrue from the emerging technology of MPS will result from application of the technology to marketplace needs. NASA can make significant contributions to the development of the technology base for MPS. However, NASA has no direct involvement in the processing of materials for commercial markets. Thus, to ensure that the technology base which NASA develops is useful, close coordination between NASA and prospective users of the technology will be needed. To foster effective working relationships with prospective users, the Commercial Applications Office, MPS Projects Office, at the NASA/Marshall Space Flight Center, was created to work exclusively with commercial interests. The project office is a liaison between NASA and the commercial community, serving as a source of information and assistance for prospective users, as well as a focal point for commercial interests and a channel by which industry views can be communicated to NASA. The project office works to clarify NASA's policies regarding commercial rights in intellectual property, liabilities, equipment-leasing, and pricing. Through this effort NASA expects to provide a simpler interface with industry and to develop a better understanding of the incentives needed to elicit industry initiatives and inventiveness to utilize MPS technology.(1,2)

A. INCENTIVES FOR COMMERCIALIZATION

To accelerate technological innovation based on MPS technology and to provide incentives for commercialization, NASA has initiated a program in which it will share the costs and risks of early investigations and projects in the field of MPS with industry as discussed in the "Guidelines Regarding Joint Endeavors with Domestic Concerns" published in the "Federal Register," August 14, 1979, pages 47650 and 47651.

1. Risk Sharing and Incentives

In these joint endeavors NASA and qualified industrial organizations enter into "constructive partnerships" as equals who have sufficient motivation toward common objectives to make independent commitments and to share in the costs, risks and benefits. Activities are selected across the spectrum of MPS to demonstrate that the low-g environment is a valuable tool for isolating and characterizing gravitational effects on ground-based material processes, or for actually producing unique materials in space for commercial application. Since market incentives are presently inadequate to bring about technological innovation based on low-g technology, under its joint activities program, NASA can provide certain tangible incentives such as: (1) providing flight time on the STS on appropriate terms and conditions, (2) providing technical advice, consultation, data: and use of facilities and equipment, and (3) entering into joint research and development programs where each party funds its own participation. Joint activities may range from exchanges of technical information and collaboration on low-g groundbased and flight experiments to joint projects (Joint Endeavors) to develop a marketable product.

2. Terms and Conditions

As stated in the NASA "Guidelines" the terms and conditions of joint efforts are negotiable, including such factors as the industrial organization's right to proprietary data and/or patent ownership, provisions for a form of exclusivity in special cases, and recoupement of NASA's contribution under appropriate circumstances. Until such time as normal market incentives provide a competitive and self-sustaining condition in the industry for materials processing in low-g technology, the incentives and negotiability of terms and conditions will be used as a stimulus to encourage the more technologically advanced, entrepreneurially inclined industrial organizations to pursue applications of low-g technology.

3. Form of Contract

Because NASA wishes to encourage industry in early commercialization efforts and the regulations for Government procurements are not generally compatible with an entrepreneurial endeavor, NASA does not anticipate sponsorship of commercialization work through procurement type contracts. Rather, NASA is pioneering a concept of negotiating an agreement for joint investigations and joint projects with industry on a case-by-case basis. Thus, the agreement can be tailored to the specific needs of an industrial organization for the specific investigation or project.

B. NASA/INDUSTRY WORKING RELATIONSHIP

NASA has developed three basic levels of working relationships with industrial organizations. These provide the flexibility needed to meet the wide range of needs encompassed by large organizations with strong research departments to small entrepreneurial firms that want to develop a product for the market. They also provide for incremental increases in understanding and commitment by the parties. In all cases, the Government does not fund any of the work done by an organization, but rather each party funds its own activities separately.

1. Technical Exchanges

For organizations interested in the application of low-g technology, but not ready to commit to a specific space flight experiment or venture, a Technical Exchange Agreement (TEA) has been developed. Under a TEA, NASA and an organization agree to exchange technical information and to cooperate in ongoing ground-based research and analyses. In this way, an organization can become familiar with microgravity technology and its applicability to market needs at minimal expense. Under the TEA, the industrial organization funds its own participation, and derives direct access to and results from NASA facilities and research, while NASA gains the support and expertise of the industrial research capability. The first TEA was signed in June of 1981 with Deere and Company, Moline, Illinois, for work on the effects of gravity on solidification mechanisms and cast iron alloys. Approximately fifteen other companies are actively considering TEA's, including a metal producer, an equipment manufacturer and a chemical company.(3,4)

2. Industrial Guest Investigators

Another joint activity is the Industrial Guest Investigator (IGI). The IGI arrangement is applicable to situations where NASA and an industrial organization share sufficient scientific interest such that the organization appoints one of its scientists to collaborate, at its own expense, with a NASA-sponsored Principal Investigator on a space flight experiment. Once the parties agree to the contribution to be made to the objectives of the experiment, the IGI becomes a member of the investigation team, thus adding industrial expertise and insight to the experiment. The first IGI agreement was signed in May of 1980 with TRW Equipment Division in Cleveland, Ohio, for work on solidification experiments.

3. Joint Endeavors

Joint Endeavors provide a mechanism for NASA to share in the cost and risk of early space projects. The first Joint Endeavor Agreement between NASA and McDonnell Douglas Astronautics Company was signed in January 1980, and illustrates the key features of the third type of working relationship. McDonnell Douglas will use the shuttle to develop and demonstrate the technology of continuous flow electrophoresis under low-gravity conditions and to ascertain the applicability of that technology to the production of pharmaceutical products. The agreement requires a substantial investment by McDonnell Douglas and its associates in each of three phases: (1) feasibility studies and planning, (2) flight experimentation and technology development, and (3) applications demonstrations. In return for McDonnell Douglas' promise to make results of the work available to the U.S. public on reasonable terms and conditions, NASA agrees to refrain from entering into similar joint endeavors or international cooperative agreements directly related to the development of commercial devices and processes which would compete with those resulting from the McDonnell Douglas endeavor. However, NASA is not precluded from selling flight time on the shuttle to any other organization wanting to conduct the same or similar experiments. Significantly, NASA will not acquire rights in inventions made by McDonnell Douglas or its associates in the course of the joint endeavor unless McDonnell Douglas fails to exploit the inventions or terminates the agreement, or unless the NASA Administrator determines that an emergency exists. Additional joint endeavors are being pursued. For example, detailed discussions have been held with a small business firm regarding electroepitaxial growth of semiconductor crystals. Agreements with small business concerns require attention to means for minimizing financial risk and controlling negative cash flow. Joint Endeavor Agreements offer significant prospects for commercial exploitation of MPS technology.

4. Current NASA/Industry Experiments

NASA has initiated discussions with key people in over 150 industrial organizations both large and small, and as a result several important MPS industrial research tasks are underway. Private companies do not publicly announce their interests and they usually request anonymity in their initial working relationships with NASA. However, the following agreements have been publicly discussed:

- A TEA has been arranged with Deere and Company in the field of solidification of metals;
- An IGI was formally appointed in May 1980 by TRW Equipment Division in Cleveland, Ohio, in the discipline of directional solidification; and
- A JEA was signed in January 1980, with McDonnell Douglas Astronautics Company (MDAC), developer of the biochemical separation equipment, who is teamed with Ortho Pharmaceutical Division of the Johnson and Johnson company. The equipment is being evaluated for isolation of materials such as hemophilic factor VIII for hemophilia, beta cells for diabetes, alpha-antitrypsin for emphysema, epidermal growth factor for healing burns, growth hormone for stress ulcers immunoglobulins for hepatitis, summatomedin for meat production, transfer factor for melanoma, and urokinase for blood clotting. This intial endeavor has been the subject of testimony to Congressional Committees in both the U.S. House and Senate.
- A JEA was signed with GTI Corp. on January 1, 1982. Under this agreement NASA will fly a multiple micro-experiment flight package (MMFP) to be developed for GTI by a third party. The MMFP will be a furnace with multiple subenclosures designed to perform and control several seperate experiments in solidification. GTI's role will be to serve as a broker between NASA and potential investors, customers, inventors, and hardware manufacturers.(5,6)

Other offers of cooperative agreements in various stages of discussion include:

- A TEA with a major metallurgical supplier on electrodeposition of materials,
- A TEA with a university research institute and a pharmaceutical company to evaluate purification of proteins in a new device,
- A TEA with a major electrical equipment supplier on dispersions of immiscible materials,
- A TEA with a nonprofit research institute to grow a biological material to assist in the repair of human tissue,
- A TEA with a new high technology oriented small business to develop semiconductors, and
- A TEA with a small materials research business to provide research samples to industry.

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MPS TECHNOLOGY

A. POTENTIAL BENEFITS

Materials processing technology will benefit from the utilization of space in three important areas: 1) the development of scientific understanding of phenomena involved in materials processing, 2) the production of sample materials in space that have special properties which will stimulate their manufacture on Earth, and 3) the manufacture of materials by processes which utilize the low gravity of the space environment to unique commercial advantage. MPS activities to date in the U.S. and Europe have emphasized experimentation to develop greater scientific knowledge. The reason for this emphasis is that the large costs associated with space experimentation can be justified most easily on the basis of the widely useful (if long term) results of scientific research. As shuttle operations become routine and space-related cooperative arrangements between government and industry become commonplace, the production of prototype materials and special materials manufacture will receive greater emphasis.

B. PROMISING PROCESSES OR PRODUCTS

The potentially beneficial applications of MPS have been under continual examination since the early 70's (References 1 through 28). References 14, 15, 23, 18 are particulary pertinent reviews. The most promising applications of MPS which have been identified in the last decade are given in Table 1. The most promising product-related applications for space processing before the year 2000, as distinguished from scientific research opportunities, are in four areas: 1) pharmaceuticals, 2) electronic materials, 3) glasses, and 4) metal alloys and composites. The technical limitations of the space experiment and processing facilities which (under current plans) are to be available in the next decade and the large costs associated with their operation will, in all likehood, limit commercial exploitation opportunities to the pharmaceutical and electronic materials areas. It is in these areas that products could have the minimum requisite value per unit mass ($2000/kg) needed to offset transportation costs and which have an existing market that can be satisfied by the small quantities that can be produced with the available space processing facilities.

Near-term (less than 10 years) activities of MPS in the glass and metal areas will be confined to research and exploratory development through the proof-of-concept phase, for these products are not sufficiently valuable (with the possible exception of gas turbine blades made by the "skin" technology method) to offset production costs. In addition, the processing requirements for these products demand large facilities and power supplies. In the areas of glass and metals, relatively inexpensive trial and error approaches made possible by plans by such companies as Fairchild Space and Electronics Company and GTI to fly furnaces on the shuttle will be undertaken to create sample materials

TABLE 1

MOST PROMISING COMMERCIAL APPLICATIONS OF MPS: CONSENSUS RESULTS

	Section V References	Date
Isoenzymes X-Ray Targets Transparent Oxides Crystals	No. 7	1973
Silicon-crystal ribbon	No. 12	1975
Organic Materials – Isozymes (also medical diagnostic) – Urokinase (anticoagulant) – Insulin (from human sources)	No. 20, No. 21	1978
Inorganic Materials – Large crystals (size and perfection) – Super large-scale integrated circuits – New glasses (including fiber optics) – High-temperature turbine blades – High-strength permanent magnets – Cutting tools – Thin-film electronic devices – Continuous ribbon crystal growth		

TABLE 1

MOST PROMISING COMMERCIAL APPLICATIONS OF MPS: CONSENSUS RESULTS
(Cont'd)

	Section V References	Date
Pharmaceuticals	No. 14, No. 15, No. 16	1981
– Antihemophilic		
– Erythropoietin		
– Pancreatic beta cells		
Electronic materials		
– Semiconductor crystals		
High-quality glass		
– Optical		
– Laser		
– Communications		
Crystal Growth and Solidification		
– Solid solution IR detectors (HgCdTe,PbSnTe)		
– Vapor growth (HgI_2, alloy type)		
– Solution growth (triglycene sulfate growth environment vs. morphology)		
– Float zone (Marangoni convection radial segregation, interfacial stability		

TABLE 1

MOST PROMISING COMMERCIAL APPLICATIONS OF MPS: CONSENSUS RESULTS

(Cont'd)

	Section V References	Date
Chemical Processes		
– Monodisperse latexes (polystyrene microspheres)	No. 14, No. 15, No. 16	1981
– Stability of foams and suspensions		
– Colloidal interactions		
– High-temperature properties of reactive materials		
– Diffusion controlled synthesis		
Separation Sciences		
– High-volume, high-resolution electrophoresis cell separation		
– Protein purification by continuous-flow isoelectric focusing		
Fluid Studies		
– Non buoyancy-driven convections		
– Wetting and spreading studies		
– Role of convection in processes (electrokinetic separation, electroplating, corrosion, etc.)		
Pharmaceuticals		
Electronic Materials	No. 9	1981
Glasses		
Metal Alloys and Composites		

TABLE 1 .

MOST PROMISING COMMERCIAL APPLICATIONS OF MPS: CONSENSUS RESULTS
(Cont'd)

	Section V References	Date
Metallurgical Materials and Processes — Immiscible alloys — Magnetic composites — Metal foams — High gradient directional solidification — Solidification at extreme undercooling	No. 14, No. 15, No. 16	1981
Composites — Casting of dispersion-strengthened alloys — Solid electrolytes with dispersed alumina — Particle pushing by solidification itnerfaces		
Glasses — Glass fining — Laser host glasses — Optical glasses with unique properties — Metal glasses		

having special properties. Methods would then be sought to produce these materials on Earth. Another important activity during this interim period is the scientific, step by step, logical examination of the commercial validity of space-based processes or products.

The near-term MPS commercial ventures in the U.S. presented in Table 2 illustrate the possible early fruition of the consensus choices for commercial applications. The first two items in the table are for products in the pharmaceutical and medical research areas. The third is, after silicon, a most widely used semiconductor material. The fourth venture is to provide a service for the self-contained processing of metallurgical specimens to customers seeking empirical evidence of exemplar material samples. The last entry in the Table 2 is another commercial venture which antcipates the need to provide functional services (power, climate control, data logging, communication, manipulation, etc.) to payloads which are to operate for some period of time in space. Electrophoresis processing units and material processing furnaces are examples of the MPS payloads to be serviced. The shuttle will provide the transportation needs for the free-flyer and its payloads. A memorandum of understanding to be followed by a Technical Exchange Agreement between NASA and Fairchild Space and Electronics Co. establish the basis for the implementation of this multi $100 million venture. The identification of other specific MPS commercial opportunities depends on the outcome of research and development.

C. STAGES IN MPS DEVELOPMENT TO COMMERCIALIZATION

Industry sectors and products within industries experience life cycles. The maturity of an industry reflects its degree of development, stability and, therefore, its predictability. The maturity of an industry is usually identified by four phases in the maturity cycle: embryonic, growth, mature, and aging. The classical pattern of sales over time is an S-curve with segments representing the four phases as depicted in Figure 1.

MPS is clearly in the early embryonic stage. Its passage into a growth phase depends on the development of competitive products for a receptive market. In the case of MPS, the passage is now keyed to the successful outcome of scientific and technological investigations. Moreover, the high investment levels, long time horizons, and high risks associated with MPS as a business opportunity reduce the possibility for investments by industry. Accordingly the early stages of MPS development should be largely sponsored by goverment. Development of strategies for involving industry are appropriate at these stages, but transfer of the leadership role in the development of MPS to industry should await the results of early scientific and technological investigations.

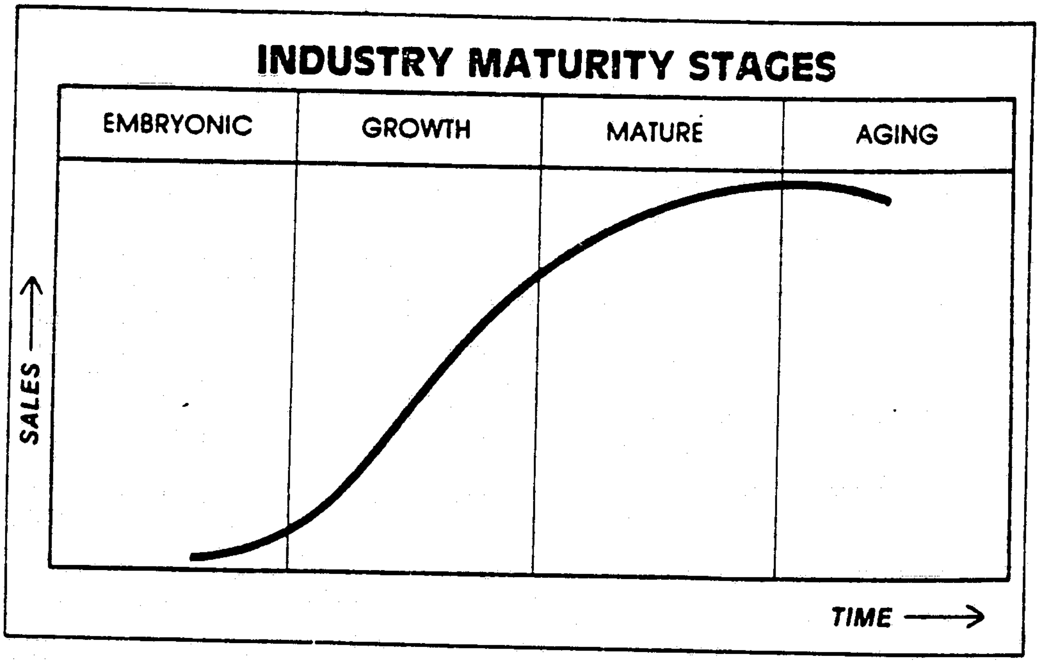
TABLE 2

NEAR-TERM MPS COMMERCIAL VENTURES

Product	Company	Required Facilities	Projected Operation Date
Monodisperse Latex Spheres	NASA	Shuttle	1983
Ethical Drugs	McDonnell Douglas and Johnson and Johnson	Shuttle/Free-Flyer	1987
Gallium Arsenide Crystals	Microgravity Research Associates	Shuttle	1987
Metallurgical Specimen Processing Service	GTI Corporation	Shuttle	Mid 1984
MPS Payload Services in Free-Flyer	Fairchild Space and Electronics Co.	Shuttle	1988

FIGURE 1

CLASSIC REPRESENTATION OF SALES OVER TIME



The MPS technology development process can be divided into five phases (1) investigation of concept, (2) validation of concept, (3) exploratory development of concept, (4) pilot commercialization, and (5) full-scale commercialization. The first four of these phases and part of the fifth lie within the embryonic stage of a maturing industry.

1. Investigation of Concept

The investigation of concept (IOC) phase is defined as one where the theoretical aspects of the physical phenomena embodied in an MPS concept are examined in a combined program of analysis and ground-based research. The necessary precondition for IOC is a good MPS concept. The concept may focus on means to enhance scientific knowledge or a way to obtain an improved, more valuable product. As a typical first step for an investigation, a theoretical model of the material system is developed. The model must include the effect of gravity among the other parameters which will determine the behavior of the system, and it is used to predict the results of experiments in space. Often the mathematical model of system behavior may be elaborate and computer simulations are employed.

Terrestrial experiments may be conducted to test various aspects of the concept by using similarity models which approximate the effects of low gravity. Tests in a drop tower, in an aircraft undergoing a period of "free fall", or in a sounding rocket may be used where the short test times that are available are sufficient to yield valuable information. A preliminary space experiment for validating the concept is also designed in this phase and a ground-based laboratory version with the configuration, instrumentation and controls necessary to demonstrate the required functions is developed.

IOC includes all efforts necessary to make a "go/no-go" decision on an MPS experiment. Unfavorable progress at any point may lead to the decision not to proceed to a space experiment. Much of the current MPS programs in the United States and European countries focus on the IOC phase. The STAMPS report deals exclusively with the IOC phase.

2. Validation of Concept

The validation of concept (VOC) phase involves all activities which are required for a test in space of the hypotheses developed in the IOC. The space experiment is conceived to perform several critical tests. For scientific investigations, the desired end product of VOC could be general information on material system behavior having wide application. In other cases, the experiment may be designed to produce a sample of a particular product with information on its properties and the environmental conditions in which it was produced.

A valuable product of VOC may be to provide the insights and identify the incentives necessary to reproduce it on Earth. Thus a particular space experiment may end with this perfectly satisfactory result.

The design, development, and construction of the experimental facilities required to carry out the space experiments are part of VOC. The rack-mounted experiment systems on Spacelab are examples of such facilities. A space carrier and platform for experimentation must be provided, but this provision is not considered part of VOC. A ground-based version of the space experiments facility may be built as part of VOC in order to rehearse the functional aspects of the experiment and to train its operators. Training of the personnel necessary to conduct the space experiment (in NASA's terminology, the mission and payload specialists) are also included.

3. Exploratory Development of Concept

The exploratory development of concept (ED) phase entails the additional space experiments necessary to define the operational range of variables which control the material system behavior in order to allow the selection of those that come near to optimizing the design of the MPS process system. The end product of ED is the information necessary for the design of a pilot plant and credible estimates of the costs involved in a space manufacturing business.

The space facilities needed for ED will go beyond those for VOC. More power, more time, more space than are available in the shuttle may be called for. A free-flyer in the nature of the U.S. MEC with robotic operators is one approach. Another approach is a permanent manned space station.

The opportunities which can be explored in and beyond the ED phases will be limited if the shuttle is the only available experimental facility. However, successful results from the limited opportunities provided by the shuttle will greatly influence the continuation of MPS . A broadly based continuation will require large investments to build free-flyers dedicated to MPS.

4. Pilot Commercialization

The pilot commercialization (PC) phase is the initial step towards mass production of materials in space and is performed on a small scale. New hardware is built and operated in accordance with the plans developed in the ED phase. The pilot commercialization phase uses a valid manufacturing process to produce products on a small scale and serves as a test bed for process optimization.

The sale of products to generate revenue will be possible for the first time during the PC phase. The definition and development of markets demand attention. The availability of facilities beyond the shuttle as described in the case of ED will be a necessary prerequisite for MPS to enter this phase.

5. Full-Scale Commercialization

Full-scale commercialization requires a manufacturing plant in space, supporting services and supplies, workers, products and a receptive market. It is a conventional business in all aspects except that the plant is located in space. The realization of a space manufacturing business depends on the success of all prior phases. The nature of the plant and its operations can only be outlined in concept at this time. Business success will depend not only on the success of MPS but also on more mature space technologies, especially in the area of space transportation. The normal sequence of development through full scale commercialization is illustrated in Figure 2.

D. ECONOMIC CONSIDERATIONS

Associated with the five phases in the development of MPS to commercialization are very important economic considerations. Decisions about the economic commitment to each phase will have to be made, as well as an overal economic commitment to a total program leading to MPS using the facilities of a permanent manned space station.

From the outset, there must be a proper understanding of the government's role in MPS funding and the point at which industry can be reasonaby expected to get involved in MPS commercialization. NASA has two successful previous commercialization efforts to look to for some guidance in the commercialization of MPS: the aerospace industry and satellite telecommunications. In each case the early stages of technology development were undertaken by the government. When the major unknowns were resolved, industry was willing and able to commercialize both technologies. At that point, any R & D industry put into these areas was motivated by market forces and the need to stay ahead of the competition.

MPS is at the very early stages of the first phase of a technology development process. As the scope of succeeding phases depend increasingly on what are presently as yet undefined results of preceding phases, it is only for the IOC, VOC and ED phases that meaningful plans can be generated at this time, and these plans will require repeated iteration as specific issues are better defined and more information is obtained. For the following development phases, only trends relating to the level of effort, transportation and space facilities, time for implementation, and associated funds can be anticipated. Since the time required to implement each of the IOC and VOC phases as part of an effective program is about five years, adequate time remains to anticipate developing needs and to establish firmer plans for the follow-on phases. Such a time frame, however, makes research in MPS a difficult investment from industry's point of view. The following discussion of the costs associated with an MPS program able to utilize a space station effectively is predicated on the assumptions that IOC, VOC, and even ED, are primarly government-funded.

The scope of the early phases is determined by the number of areas of research. The maximum limit to the scope of IOC will be set by the range of worthy research ideas proposed by scientists in response to the government's announcements of opportunity. Success is primarily determined by the ingenuity and skills of the scientists and engineers who participate. As the results of ground-based research emerge, the MPS program scope will be narrowed by a review and selection process to screen the projects which are selected for the VOC phase.

This approach maximizes the chance of success of an MPS program because it builds on a firm and broadly-based foundation for the follow-on activities. The IOC and VOC phases can also be designed to have educational and long-term value and to achieve technological advances that make the investment worthwhile even if tangible returns in the form of improved products are not realized over the near term.

The cost of space experimentation involved in the VOC and ED phases compared to the ground-based activities of IOC is a major economic consideration. Two chartered flights of the shuttle/Spacelab will cost about the same as all the ground-based activities leading up to them. However, by investing fully in the IOC phase the opportunities for success are maximized and perhaps this course of action can be justified on the "spin-off" effects alone.

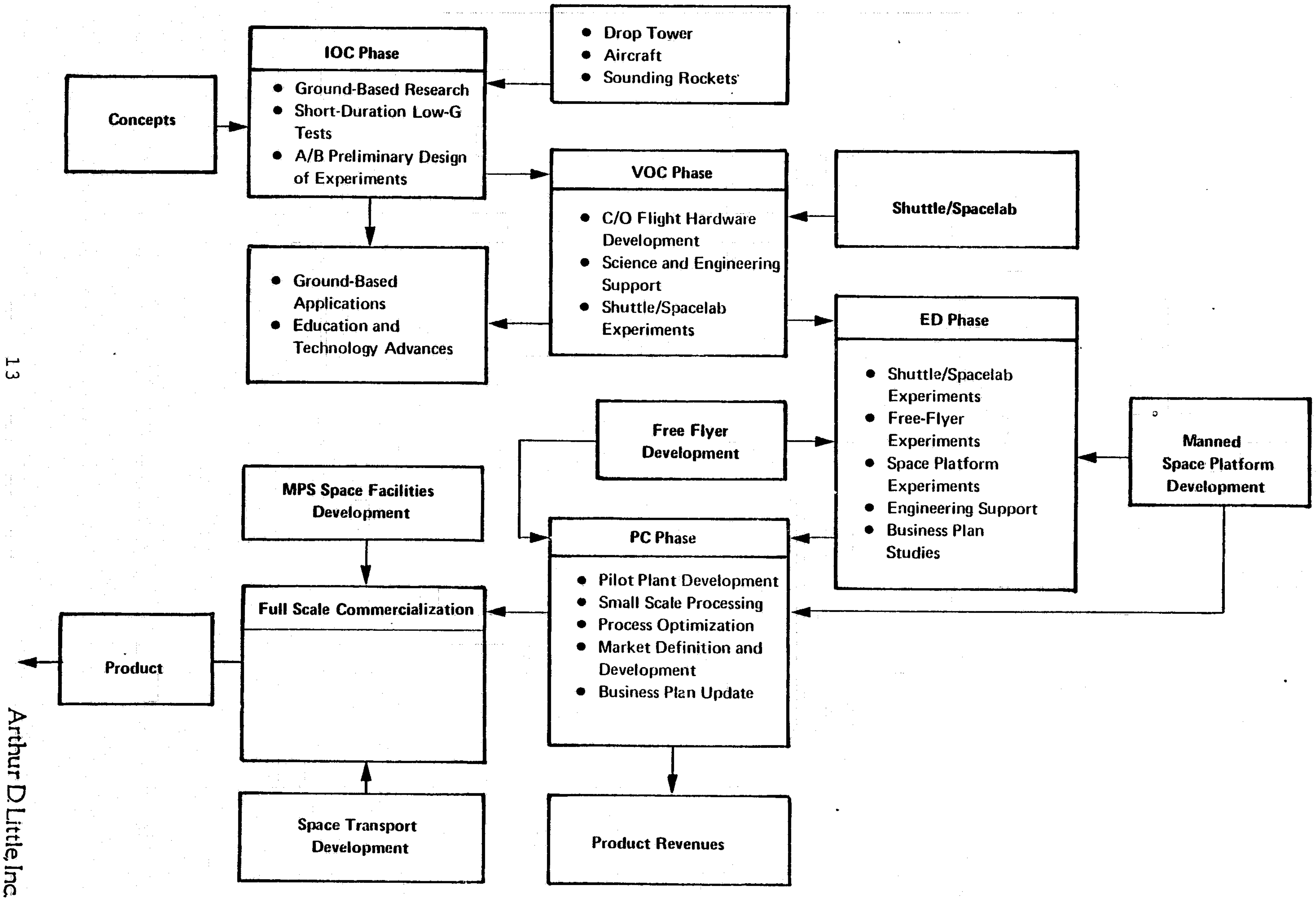
The plans and budgets for an MPS program to be presented assume that at every phase, the outlook is sufficiently promising so that a decision to proceed can be made.

1. IOC Phase

Ground-based Research. The intent is to engage in all the promising areas of research identified above. A plan to have 5 to 10 funded research projects ongoing every year in each of the 7 areas appears reasonable. Each project would have a minimum life of 2 years and a maximum life of about 5 years. The intial ground-based research phase would have a planned life span of 5 years. The commitment beyond this time would be contingent on the success of previously funded endeavours and the influx of newly proposed worthy ideas and concepts for MPS.

FIGURE 2

DEVELOPMENT PHASES IN MPS PROGRAM



The average annual costs for the ground-based research program is estimated to be $7.5 million. This estimate results from assuming that 50 projects receive funding at an average level of $150,000 per year for five years. The costs associated with the design, building and testing of ground-based experiments are included in these figures. They do not include additional pro-rated amounts applied for overall MPS program administration.*

Short Duration Low-G Tests. Test in a drop tower, in an aircraft undergoing a period of free fall, or sounding rockets are part of the IOC phase. Assuming that these facilities are available to MPS, a budget of $600,000 per year for operations in support of MPS ground-based research actvities is estimated. An additional $400,000 per year is budgeted to cover the design, building, and testing of experiments, bringing the total estimated cost to $1 million per year. Most of the costs are for sounding rocket experiments estimated to require two launches per year.

Preliminary Design of Space Experiments. When the ground-based research reaches a point where the science and technological requirements of the space experiment can be established, a preliminary design of the test systems to accommodate the space experiments is carried out. This effort is designated by NASA as the A/B Preliminary Design Phase. The output of this phase is the preliminary design and specification of the flight hardware associated with MPS experiments systems. This design undergoes another cycle before it becomes the basis for the manufacture of space hardware.

The design of each space experimental system is unique although some may be multi-purpose; that is, designed to accomodate a number of different experiments having similar facility requirements. The space experiments will be carried out aboard the shuttle in the mid-deck region, on a pallet, or in Spacelab, depending on their service requirements. The preliminary design of the average general purpose space experiment system for Spacelab costs about $500,000. A pallet-mounted or special purpose experiment is simpler and costs approximately $200,000.

In the first 5 years of the IOC phase it is reasonable to assume 13 experiments systems will undergo preliminary design. Of these 5 will be of the multi-purpose variety and 8 of the special purpose type. Using the cost estimates cited as a basis, the total cost of preliminary experiments design becomes $3.1 million. The time to complete a preliminary design is one year or less.

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* All cost estimates will be without MPS program administration burden.

2. VOC Phase

Flight hardware development. The VOC phase is triggered by the decision to proceed with space flight experiments. The flight hardware development, which is the dominant element of VOC, has 6 elements: 1) design development test and evaluation 2) hardware manufacture and construction, 3) ground-based integration and test, 4) integration with the shuttle, 5) experiment in space, and 6) post experiment evaluation. Each of the space experiments undergoes this development process, but some may be combined where the space experiments are to be carried out in the same general purpose space experiments system.

The process is very structured and starts with preliminary design and specifications resulting from IOC. Only minor changes in the starting design specifications can be tolerated, although they are entertained until a critical design review is held midway through the VOC cycle. The changes may be sponsored from results of ground-based research incoming from IOC whose duration overlaps that of VOC.

The experience of NASA's and ESA's MPS program is that the cost of the VOC is approximately $20 million for a general purpose experiment system. It is built to accommodate 4 or 5 experiments, but intended to accommodate many more. On this basis, a pro-rated budget cost for each experiment is $4 million. Special purpose flight experiments having less capability have an average budget cost of $2 million. The time to complete the development cycle of a general purpose experiments system is about 4 years. Two to four years are required for a special purpose flight experiment.

A plan for VOC would entail the design, development and construction of 5 general purpose experiments systems for Spacelab and 8 special purpose flight experiments for either the Spacelab and shuttle pallet or the shuttle mid-deck in the first 5 years of VOC. These estimates continue the assumptions made for the preliminary designs carried out in the IOC phase. Using the estimated unit costs previously cited, the total estimated cost of experiment development for the VOC phase is approximately $100 million. The costs would be distributed over 5 years.

Science and Engineering Support. Support for the science and engineering teams associated with the flight experiments would continue throughout the VOC phase. It is assumed that 13 flight experiments are active at all times during a 5 year period and $3 million per year is budgeted for the science and engineering teams involved with them, resulting in a total estimated cost of $15 million.

Training and Support of Payload Specialists. Training of a payload specialist force to operate the flight experiments in Spacelab is initiated and continued in the VOC phase. The budget is $2.5 million per year for a 5 year period, or $12.5 million.

Shuttle-based Experiments. Flight experiments will be carried out in Spacelab and in pallet segments aboard the shuttle. Three double racks and 6 single racks on Spacelab and 4 pallet segments will be occupied. Two shuttle flights will be chartered in the 5 year span. The cost of a charter for the time of these flights is yet to be established, but previously set prices are certain to be increased. Using the $65 million figure for the German D-1 charter as a guide, $100 million is assumed for a single shuttle charter. At three-quarters occupancy, the charter may be shared reducing the cost to $75 million per flight or a total of $150 million for 2 flights. These costs, although uncertain, are not likely to be overestimated. A striking feature of the estimated cost of the two shuttle charters is that it is about the same as the sum of all the other program elements leading up to these flights ($17.3 million).

Besides the orderly plan for research, development and flight experimentation presented above, maximum advantage should be taken of the opportunities presented by NASA's "Getaway Specials" and which may be available with GTI's or Fairchild Space and Electronics Company's self-contained thermal processor for simple and cheap trial and error experiments. Hundreds, perhaps thousands, of simple experiments designed solely to demonstrate the existence of a useful low-g phenomenon or a sample of an improved material can be conducted for the price of one fully instrumented, scientifically oriented flight experiment. From the statistics involved some rate of success can be expected from this type of experimentation.

3. ED Phase

Without a decision to build a new laboratory in space useful to MPS, no new hardware developments would be initiated for ED. The hardware designed and used for VOC studies would be modified to serve the purposes of selected experiments that enter this phase. These special versions would be built for dedicated service at a total cost estimated to be one half that of the VOC precursor, or $10 million and $1 million for the general and special purpose types, respectively.

Only a fraction of the experiment concepts which were selected as having technological promise will survive to this stage. Ten percent may be assumed as an upper limit. Accordingly, perhaps 5 of the 50 projects that entered into ground-based research will have the dedicated hardware built and the services provided for ED. The costs of continuing the technological development cycle with the shuttle has the cost of the rental of a succession of missions as a major element. Program support for payload specialists and continued support for the science and engineering teams must also be provided.

Although there will be a continuation of costs associated with the modification of the flight experiments systems and for the support of payload specialists and science teams, the total cost of the ED phase will be dominated by the schedule of chartered shuttle flights. Extrapolation of the need for chartered flights and hence funding level can only be conjectured at this time. Moreover, the decision whether to proceed with the development of a free-flyer dedicated to MPS or for a permanent manned space station to be used in part for MPS exploratory development will determine the future course of MPS. These decisions must be the result of considerable future study. For these reasons the extrapolation of the level of funding for the ED phase of MPS is deferred.

E. SUMMARY

The costs of a baseline MPS program have been developed. They are based on the experience to date and emphasize the ultimate use of the shuttle/Spacelab because that is what now exists. They have been presented to give perspective into the cost structure now associated with exploratory developments in MPS.

The projected baseline program in MPS carried through the IOC and VOC phases has a cumulative cost of about $300 million in a ten year period exclusive of the costs of overall MPS program management. A noteworthy feature of the costs of MPS is that two chartered flights of the shuttle/Spacelab dedicated to MPS experimentation will cost about the same as all the ground-based activities leading to them. Flight hardware development for MPS experimental systems is a next major cost item of about $100 million. One sixth of the total, or about $50 million, is spent on ground-based research and development. It is this component that is typical of R & D in materials processing on Earth. The baseline program projected is approximately an extrapolation of NASA's current effort and budget at 1979-1982 funding levels.

The development period to any economically viable products based on new technology typically takes about 20 years. A continuation of the MPS program for this period relies on a continual flow of new concepts into the IOC phase and a measure of success in the outcome of previous concepts as demonstrated in their VOC and ED phases. The continuation of MPS at near the levels indicated is believed to be necessary to entertain its future with respect to a manned space station. Over the next decade every effort should be made to involve U.S. industry in MPS and it would be expected that some of the program's costs would increasingly be shared by industry. However, funds for MPS development will still be required which do not meet the risk/benefit analysis of commercial business ventures and it is likely that the major portion and the leadership role will reside with the government for the next decade and beyond.

F. THE ROLE OF A MANNED PERMANENT SPACE STATION

By itself, MPS cannot generate sufficient justification for a permanent space station; however, without it the MPS program of development through the IOC and VOC phases will be, in large measure, dead ended as far as space-based materials processin is concerned. A few processes and proceedures such as electrophoresis separation of ethical drugs can be carried through the commercial phase with the services of the shuttle and dedicated free-flyers, but without a manned space station promising products requiring space facilities that are identified in developments using the shuttle/Spacelab cannot be carried to pilot plant demonstration and commercial production.

The STS facilities for MPS are mainly useful for the IOC and VOC phases. Even so they are limited particularly in respect to the small amounts of power and time available for experimentation. When one consideres the average time to bring a product based on new technology to markt is two decades on Earth without these constaints, a development even though these phases if limited to the shuttle facilities will be lengthly and expensive.

If a government commitment to a space station is made in the next few years, from the perspective of MPS, the space station can and should be viewed as a national laboratory for space R & D, utilizing the knowledge and equipments gained from Spacelab in the avenues for useful and economically space experimentation. The space station will act as the transition facility for allowing pilot commercialization and even full-scale commercialization. It can provide facilities extended in respect to power and time for experiments. It will provide the first model of a space manufacturing facility in which the needs for plant, personnel, equipment, transportation, maintenance, etc. are demonstrated. Constructed on the basis of a modular structure, the first element dedicated to MPS would borrow extensively from the Spacelab experience and would look much like a high-powered Spacelab. It would be modified and added to as results dictated. Seperate modules devoted to special commercial interests and which will allow the protection of proprietary right are envisioned to emerge.

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FLIGHT ACCOMMODATION NEEDS

A. RATIONALE

Materials Processing in Space (MPS) is at the early phase of an evolutionary development. At the time of a Manned Space Station MPS will be at verification of concept (VOC) and engineering demonstration (ED) phases. These phases will have had extensive ground-based research and (in many cases) shuttle/Spacelab investigation of concept (IOC) phases as precursors. In the period before the deployment of the space station there must have been at least 5 years of continuous commitment to IOC at a level of at least $30 million per year. Such a commitment would be adequate to support about 50 ground-based (IOC) research endeavors during one year. In the early years, from these 50 experiments, about 10 may be selected for flight and accommodation on the space station. In addition, a modification to these 10 experiments, or 10 new experiments, would take place each year. Therefore, approximately 20 planned experiments could be conducted each year. Should the MPS facility aboard the space station be made available to international participants, there would probably be a doubling of experimental activity.

The most important advantages of the space station over the shuttle/ Spacelab are that it would provide experimentation facilities with much more power and greatly extended time in space. The space station would also allow the presence of the human experimenter in space. Human experimenters are essential in the early phases of MPS development because it is only after a process has been reduced to a routine that automated manufacture can be considered.

The space station as a facility for MPS can be a national (or international) laboratory for continued research and development in materials that exploit the unique low-gravity environment of space. The early configuration and capabilities will be determined by the prior commitment to MPS and the experience gained through use of the shuttle/Spacelab. Because this commitment may justify only about 10 VOC and/or ED endeavors per year, the start-up of MPS activities aboard the space station should be designed accordingly. Success, even at this modest activity level however, will stimulate construction of new facilities as needed. The industrial infrastructure and technological capabilities that produced the space station should be adequate to meet the requirements for future expansion of MPS activities.

B. Technical Requirements

1. Basis

The following is a list of candidate, multi-purpose MPS experiment systems which may require accomodation in a space station:

- Solidification Experiment Processing System
- High Gradient Furnace Processing System
- Electromagnetic Containerless Processing System
- Isoelectric Focusing Separation System
- Float Zone Processing System
- Acoustic Containerless Processing System
- Electrostatic Containerless Processing System
- Solution Crystal Growth Processing System
- Vapor Crystal Growth Processing System
- Bioprocessing Systems
- Fluid Science Facility
- Combustion Science Facility
- Extraterrestrial Materials Processing Demonstrations

It is anticipated that these experiments would be conducted in an "open" laboratory environment. At the same time, however, certain commercial MPS efforts might have to be accommodated by the space platform. One example of such a commercial system would be Electrophoresis Operations. To insure the protection of proprietary research and production, the space station may have to be constructed to allow the attachment of laboratory modules that simultaneously could access the station's utilities and could guarantee privacy. These modules could either be rented or owned by the commercial sponsor. If owned, the space station's utilities could be rented or user charges levied.

2. Volume and Mass

The requirements for MPS laboratory facilities will be determined by the number of experiments, the scope of the federal and industry-funded MPS program, and decisions regarding international use of space station facilities. Assuming the continuation of a MPS program beyond shuttle/ Spacelab, 10 double (Spacelab) racks integrated into a Spacelab-like enclosure with climate control for payload specialists who work in a "shirtsleeve" environment could be required. The equipment could be housed in an expanded version of the cylindrical Spacelab module. Such a module, complete with climate control, waste heat, and electric services, but empty of experiments, would have a diameter of 4m and length of 10m, a volume of 126m^3, and a mass of 12000kg. Each double rack would have a mass capability of approximately 500kg. Other mission-dependent materials could have a mass of 2000kg. Therefore, the estimated total volume and mass for an initial version of a MPS facility on the space station is about 130m^3 and 19,000kg respectively. International participation agreements could double these numbers. (In the subsequent discussions laboratory facilities designed for both international and U.S. use should be multiplied by a factor of two). The arrangement of the axes of the basically cylindrical configuration of the facility would be determined by the appropriate match to the overall configuration of the space station.

3. Power

The limits to the availability of power (about 1.5 kW continuous) on the shuttle/Spacelab is currently one of the most constraining influences on MPS. Experiments with high melting point materials (most notably the electronic materials with a high commercial value) will dominate the power requirements of the MPS facility. A float-zone processing experiment is an example of an experiment requiring a large amount of power when designed to allow free, 360° access to instrument observation of a molten zone. In this case, about 16 kW are required for the heat source to process a 5 cm diameter sample of silicon (1410 C melting point temperature) using an incandescent source with focusing reflective optics. The power required to process samples having different sizes and melting points are proportional to the square of the sample diameter and approximately proportional to their absolute melting point temperature.

An example of an intermediate power requirement for the processing of electronic materials would involve the use of an insulated high gradient (250 C/cm) furnace. In this case, the insulating enclosure of the furnace reduces the required power considerably. To process a 5 cm diameter sample of an electronic material with a melting point of 1400 C in such a furnace would require a power source of approximately lkW. This power requirement is nearly proportional to the square of the sample diameter and the design temperature gradient of the furnace and only weakly dependent on the melting point temperature of the sample.

All experiments have as a minimum power requirement needed for experiment manipulators, data handling and display, controls, and instruments. A reasonable estimate of these requirements, based on Spacelab experiment requirements, is approximately 0.5 kW per experiment system. Most experiments at room temperature do not appreciably exceed this minimum power requirement. The use of 1.0 kW per room temperature experiment can reasonably be assumed.

Within these technical guidelines one can estimate the power requirements for an early version of a MPS facility for a space station based on the capabilities identified in Table 1.

TABLE 1

Estimated Power Requirements for Early Versions of MPS Facility

Experimental Multi-Purpose Experiment Facilities	Processing Temperature (C)	Sample Diameter (cm)	Power Heating Source (kW)	Other
• one (1) high-power electronic materials processing	1500	5	16	0.5
• four (4) intermediate power electronics materials processing	1500	5	4	2.0
• five (5) room temperature (pharmaceutical and other)	25	-	-	5.0
Subtotal: 10 multipurpose experiment systems			20	7.5
		Approximate Total	30	

The power required for the early versions of a MPS facility will be dominated by the processing needs of electronic materials. These needs are dependent on and adjustable to, the size of the sample to be processed and, to a lesser degree, on the processing temperature.

Larger size samples for experiments may be required to demonstrate the validity of the process on a pilot plant scale. This increase in scale will require one or two orders of magnitude greater power as success of experimentation beyond the ED phase dictates.

4. Thermal Control

The thermal power to be rejected from the MPS facility is the sum of its power inputs for experiment operation and climate control. The power required for experiment operations will dominate and be nearly equal to the power input required. For the early versions of the MPS facility this power is estimated to be 30kW. The heat rejection temperature for most of this power is near room temperature. A thermal utility to accept this heat and reject it to a space radiator will be required. Recent concepts for this utility which make use of working fluids in pumped, two-phase flow have advantages in near-isothermal operation, flexible piping arrangements and small pumping power compared with the pumped, liquid fluid systems currently used with the shuttle/ Spacelab systems. The mass and power requirements for such a thermal utility system, exclusive of the space radiator, for 30kW heat rejection are relatively small: approximately 400 kg. and 20 W. These figures are included in the estimates of the weight previously given.

5. Microgravity, Vacuum, and Radiation

The major scientific and technical argument for MPS is to exploit the low-gravity environment obtainable in space. A zero-gravity environment is the ideal for scientific investigation, but this ideal can only be approached on a manned space station which has multi-purpose missions. It is expected that a dedicated shuttle/Spacelab can maintain a 10^{-5}g background level with acceleration spikes up to 10^{-2}g due to crew activity. These levels are presently accepted as tolerable for a wide range of useful MPS experiments, although lowering of these accelerations is desired. As the dedication of a Manned Space Station to MPS activity may be in question, the means to achieve low-gravity levels in the MPS laboratory needs further attention. Systems for isolating the laboratory from the main frame or the experiment systems from the laboratory may be required.

Although an extensive region of ultra-high vacuum can be made available in the wake region of a specially-designed shield, there has been no impetus to use the vacuum availability of space as a prime factor in MPS. The reason is that a vacuum level down to the 10^{-13} torr can be obtained in laboratory research chambers on Earth. Also, chamber volumes measured in 10^4 cubic meters can be maintained at 10^{-6} torr by practically available means. Accordingly, early use of the vacuum of space is likely to be confined to its application as a pump to provide the vacuum environment useful to some equipment systems. Such is the case for the current Spacelab module in which the only access that the experiment systems have to the space vacuum is through a single tube about 3.5cm in diameter and 4m long. This access is only suitable as a fore pump for high-vacuum pumps to be included in the experiments which require it. It may seem ironic that, with the apparent availability of the space vacuum, high-vacuum pumps would be needed to service certain experiments on Spacelab. This apparent contradiction resulted from past trade-off studies. The use of the space vacuum as a fore pump only may require that future design tradeoffs be applied to the space station.

6. Automation, Data Handling

As described in the next section, a human operator is essential to MPS research and development through the engineering stage. At the same time the maintenance of humans is expensive in terms of materials life support and power supply requirements. These requirements may become the determinants of the time limits set for experimentation. Accordingly the payload specialists should be used to perform only those tasks that humans are best able to perform: experiment set-up and disassembly, delicate manipulation, critical overall observation, assessment and "trouble shooting" of observed experiment abnormalities, and repair and maintenance, where practical. The execution of experiment protocol, with the exceptions noted, should be automated to a very high degree. Each experiment would have its own best balance between human and machine operations. This balance would have the experimental operations controlled by microprocessors and the measurement and data logging completely automated. The sequencing of one experiment from one control mode to another could involve human judgment and intervention. For example, the payload specialists may be called upon to review the comparison between the experimental data and the expected results before switching over to the next test sequence.

Details of the data handling system will be specific to each experiment; however, one can anticipate their common architecture. The number of variables measured in each experiment would be conditioned to electric form, adjusted to a standard level, and converted, as necessary, to digital form. The digital representation would be sent to a microcomputer for storage and further processing control as required. Status signals of the yes/no variety, such as switch closures or logic level signals, also enter the computer through the digital interface. Data display on a CRT would be controlled by the payload specialist using a keyboard entry. A video and cine camera might be used for a real time and a permanent vital reference for critical experiment observations. In addition, selected experiment data will be telometered down-link to the payload operations control center for analysis.

7. Operations and Maintenance

Except for the housekeeping activities, the operation of the MPS laboratory will be mission-specific within the constraints of service power, heat rejection, data handling, and crew resources. These resources will be time-lined to best accommodate the requirements and goals of the experimental activities.

The maintenance of the laboratory facility and its experiment systems will be of the "remove-and-replace" type. A high level of quality assurance and reliability must be built into these systems not only to assure crew safety but because of the high value of the results of MPS experiments. The costs and risks involved with the reliability of the experiment systems are amplified in Section C.

8. Summary

A summary of the major technical requirements for a national MPS laboratory facility on the Manned Space Station is given in Table 2.

TABLE 2

Estimated Requirements for MPS Laboratory on Space Station
(Initial Version)

ITEM	VALUE	COMMENTS
Envelope Dimensions	Cylinder, 4m dia X 10m long	Extended version of Spacelab long modules
Box Volume	130 m^3	
Mission Independent Mass	12000 kg	
Payload Capability	7000 kg	
Total Take-Off Mass	19000 kg	
Electric Power	30 kW	An order of magnitude more power than available on shuttle/Spacelab
Number of Multi-Purpose Experiment Systems	10	Accomodated by 10 double rack installations
Heat Rejection	30 kW	
Crew Complement	4	
Consumables	TBD	Dominated by crew support needs Therefore are approximately proportion to mission duration
Data Handling	TBD	Experiment specific, highly automated
Operations and Maintenance	TBD	Remove and replace type. Procedures will be outgrowth of shuttle/Spacelab experience-proven procedures.

C. PERSONNEL REQUIREMENT

1. Role of Man

The human involvement in process and product development is absolutely essential in R & D phases. His ability to reason and interpret and his manipulative abilities have no successful substitute in automation. It is only after sufficient knowledge has been obtained to reduce a process to repeatability and a production routine that automation becomes an economic alternative. The use of automation deserves particular emphasis in connection with space processing because of the extraordinary cost and uncertainties of maintaining a human in space for extended periods. These high costs and uncertainties will persist for some time until sufficient experience has been obtained. Nevertheless, these high costs will not fundamentally change the human role in R & D. In space activities these costs will serve to advance the economic point of transfer to automation in the production cycle.

2. Safety

As in all similar endeavors, there is a need to establish levels of quality assurance, equipment reliability, and management review procedures for MPS experiments consistent with acceptable risk/management standards. These standards reflect the social or political perceptions of society. The standards developed for the STS are likely to serve in a somewhat modified form for the space station. At this time, although the shuttle/Spacelab is designed as a scientific laboratory in space, the substantial cost of the experimental apparatus and preceeding research have created pressures to obtain "successful" results. Therefore, the proceedures which apply to the flight experiments are much like those of an Appollo mission.

The effect of this approach is that the cost of the experimental facilities on shuttle/ Spacelab are about fifty times their equivalent in a ground-based laboratory. Standards for design and operating procedures to insure a reasonable level of crew safety must be maintained, but the transient influence of being in the public eye must gradually recede. Although there are no easy solutions to the cost/risk dilemna which will confront the individuals and organizations involved in MPS experiments aboard a space station, detailed assessments to reduce the cost impact on these experiments are warranted. It may well be that a lower cost/risk ratio is more appropriate to the early phases of MPS so as not to reduce the opportunities for trial and error so characteristic of preliminary experiments in Earth-based laboratories.

3. Training

Trained payload specialists are needed to conduct the in-flight experiments. The shuttle/Spacelab experience will serve to identify the professional backgrounds and special training required of these specialists. At this time, it is anticipated that a normally healthy person can conduct space experiments, with no special physical attributes required.

The ideal payload specialist would be one who has been intimately associated with the ground-based research leading to the flight experiment. Failing such a candidate, one with a similar, experience background, interest, and motivation would serve the purpose.

As a training facility, it is appropriate that the engineering models of the flight hardware systems be set up at a designated NASA center to enable the payload specialists to rehearse the flight experiments in as much detail as possible. While the space processing conditions of near-zero gravity cannot be duplicated in their entirety on Earth, the operational features of the experiment can be rehearsed. Through this rehearsal, possible problems of experimentation will come to light and hands-on familiarity with the experiment systems will be gained by the payload specialists. A two-to-four-month period of intensive training should suffice for training of a qualified payload specialist.

The current plan calls for three persons (one mission specialist and two payload specialists) to carry out the experiments on a fully loaded Spacelab involving approximately 10 experiment systems. Because of the greater complexity and duration of the experiments on the space station, a crew of 4 can be adopted to estimate the personnel needs for the MPS facility on the space station. In its early stages, we have estimated that this facility will have approximately 10 experimental systems if it operates as a national space laboratory. These systems will be programmed to accept two separate experimental protocols per year. To service these experiments, two crews of 4 persons each with one 4 person crew as backup appears to be a reasonable complement for the first activity year. Crew needs will likely expand with the success of the early mission. In addition, making the facility available to international use would double the activity and need for personnel.

D. TRANSPORTATION

1. Resupply

STS will provide the transportation needs of MPS on the space station. The resupply for the MPS facility will be totally dominated be the crew consumables in all stages of MPS development up to the pilot demonstration phase. A few kilograms of base materials and a few tens of kilograms of consumables (such as gas bottles) for each experiment would be a normal requirement. Moreover, materials which look sufficiently promising to pass into the pilot demonstration phase must have very high specific value, of the order of $5000-$10000/kg. The materials base of a 1000kg product would therefore be valued at $5 to $10 million. From this perspective the requirements for product supply for MPS activity in the foreseeable future will be modest.

Crew consumables can be estimated on the basis of man-days, per mission (reflecting 4 persons per experiment mission) times the mission duration, which may typically range from 30 to 180 days.

2. Product Return

The product resulting from MPS for ground evaluations would be off- loaded from the space station and returned to Earth via the STS with each rotation of the payload specialist crew. Many of these products must receive special handling (packing for temperature and contamination control etc.) in accordance with the experiment design requirements specification. The payload specialist will be responsible for overseeing satisfactory adherence to these specifications.

FEDERAL SPACE POLICY

Introduction

There are currently two major challenges facing the U.S. space program:

1. Federal space policy provides an incomplete framework for the civilian, applications-oriented space program within which the space station will be operational, and

2. Institutional barriers to commercialization require resolution.

Because large-scale, national programs such as the space program, must now be economically justified, the Material Processing in Space (MPS) program is receiving a great deal of attention as a new area for commercialization. NASA points with pride to the success of satellite communications and projects that MPS has a considerable potential for a profitable future. Previous assessments of MPS have focussed on the technical validity of near-term MPS experiments. This section focuses on the impact of current government policies and the institutional barriers which must be overcome if the potential of MPS commercialization is to be realized.

Summary of Current Policies and Effects

On July 4, 1982, President Reagan made a "National Space Policy Statement" in his speech at Edwards Air Force Base to commemorate the successful STS-4 landing. His stated goals are:

- Continue space activity for economic and scientific benefits,
- Expand private sector investment and involvement in space-related activities,
- Promote international uses of space,
- Cooperate with other nations to maintain the freedom of space for all activities that affect the security and welfare of mankind,
- Strengthen our own security by exploring new methods of using space as a means of maintaining the peace.(1)

While the last two items have implications for the military's space program, the first three are directed at the civilian space program. Since this speech, there has been no further administrative space policy effort. Without outlining the steps to meet these policy "goals," President Reagan's statement takes its place alongside President Carter's and President Ford's space statements, as guidelines rather than policy. For all intents and purposes, the space policy which guides the U.S. civilian space effort was established in the National Aeronautics and Space (NAS) Act of 1958. While there have been amendments and several presidential directives to supplement it, the policy adopted in the NAS Act has remained unchanged over the past 25 years. In the meantime, however, the space program has been evolving steadily from an era when the primary emphasis was on space exploration, towards an era of applications and operations opened up by the shuttle.

The six policy principles embodied in the NAS Act are that:

- U.S. preeminence in space science and applications be maintained
- NASA, the civilian agency, be limited largely to R&D;
- Scientific knowledge be increased;
- Civilian and military activities be separated (though they are to be coordinated and are not to duplicate one another unnecessarily);
- Economic and social benefits be derived; and
- International cooperation be fostered.

As the space program has evolved, it has become apparent that the NAS Act should be adapted and a new set of policies created to establish the goals and institutional framework for the civilian space applications program and to broadly define its implementation.(2) Because

Congressional and Executive policy direction has not been consistent in the past 25 years, "policy" has been made on a "de facto" basis by NASA and the Office of Management and Budget. The result has been that at present, the United States lacks the means to bring about a consensus among the scientific, technical, and political communities as to the goals of civilian space activities. Although NASA Administrator James Beggs has repeatedly stated that "NASA is not an operational agency," there are few arrangements (the Joint Endeavors Agreements being a notable exception) whereby the private sector can be brought into partnership in the development and operations of space systems.(3)

As President Reagan recognizes, it is vital that any new space policy has as one of its goals an increasing involvement of the private sector. To realize such a goal, however, the space policy will have to be sufficiently flexible to accommodate various space applications programs which are at different levels of development and offer an increasing economic attractiveness for private sector involvement. For example, satellite communications lie primarily in the province of the private sector, satisfying a growing market, with market needs acting as the driver for privately funded R&D.

In contrast, the benefits of an industrial MPS program are not clearly demonstrated. NASA's limited funds (0.5% of the NASA budget) do not provide a strong incentive for industry to expend MPS R&D efforts in directions which do not yet show commercial feasibility.

As MPS is currently at an early R&D stage, the R&D efforts should continue during the next 5 to 10 years in order for useful data to be obtained. The shuttle is an adequate transportation system to meet projected experiment requirements. The shuttle's capabilities will be augmented by Spacelab and backed up by the various terrestrial microgravity simulations offered by KC-35 airplanes and sounding rockets.

An MPS program that could create the solid scientific foundations on which commercialization could be built would require assured annual budgets over an extended period. Planning for MPS must take into account that MPS R&D depends on future Federal funding commitments to NASA; the level of that commitment, because it is annually reviewed by Congress, is uncertain. While MPS funding within NASA has been constant, NASA itself, to meet other program commitments has reduced the MPS budget periodically and efforts once started have been discontinued or stretched out in time. One notable example is the two year hiatus in the SPAR program.

Furthermore, the development of commercially interesting MPS products or processes may require space facilities dedicated to long-term use so as to assure the supply of the products to the marketplace. At this stage of MPS R&D, where microgravity advantages over terrestrial process have yet to be fully demonstrated, industrial commitment can be expected to be minimal. However, as the R&D produces promising results, NASA must have in place the space facilities and organizational infrastructure to make industrial participation effective. More extensive industrial commitments to devote R&D efforts and to perform space shuttle experiments as precursors to operations in a space station will be compromised without a credible assurance that a space station will be provided by a certain date with specified performance characteristics.

Although NASA has initiated several programs to enlist industry support in moving MPS towards an operational status and to encourage the production of commercially viable materials, industry's commitment to an extended MPS R&D program will be difficult to enlist unless the federal government's financial commitments are firm and meaningful for industrial planning and decision making.

Table 1 outlines the questions raised by the policy principles in the NAS Act. These issues will need to be addressed in any new space policy inititatives.

As new space policy initiatives are being considered, several stimuli could be provided to encourage the transfer of MPS to the private sector, including:

- commitment to a space station;
- commitment to a meaningful federal R&D program in MPS;

Table 1

Issues Raised by

Policy Principles in NAS Act

Policy Principle	General Issues	Materials Processing (MPS) Issues
1. Leadership in science and technology and application thereof	1. Given that portions of U.S. policy are sound, how can policy implementation be improved?	1. How should the United States respond to potential foreign competition?
2. NASA focus on R&D	1. What different role should Government and Industry play? 2. Who should perform oversight? 3. What is NASA's role in continuing R&D after commercialization if a system?	1. Who should pay for basic ground-based research? 2. Who decides what space-based research to do? Who pays?
3. Expansion of scientific knowledge (basic science research)	1. What is NASA's role?	
4. Civilian/military split	1. Is there adequate transfer of technology from military to civilian? 2. How should systems be shared?	1. Is there adequate coordination of efforts between military and civilian sectors? 2. On what basis can a potential space-based materials lab be shared?
5. Promote commercialization of civlian applications	1. Who decides when a technology is ready for the operational mode? 2. What criteria should be used to determine the operational readiness of a technology? 3. What role should NASA have in operating proven space systems? 4. How are commercial property interest to be protected?	1. How should costs of space-based materials lab be allocated? a) How is the lab shared between Government, industry, and academia?
6. International Cooperation	1. What should our policies be regarding international competition? 2. What institutions may be needed to address international competition? 3. Is the United States a reliable partner for cooperative programs? 4. Is it possible or desirable for the United States to institute Government-industry cooperative ventures similar to those of other nations? 5. How should the United States protect technology developed by Government R&D?	1. To what extent is the prospect of commercial activities detrimental to scientific cooperation?

- tax incentives for private companies doing MPS work
- guarantee of intellectual property rights
- government insurance of private credit for space processing innovations;
- using federal regulatory policies to encourage MPS investments;
- changing accounting standards to allow more rapid depreciation of MPS hardware;
- declaring space as a preferred zone for industrial expansion.

Once a modified space policy and associated incentives are in place, the institutional barriers to commercialization of MPS can be overcome.

Institutional Barriers

Innovations which have as their objective the development of commercial activities in space, compound the level of uncertainty by facing institutional barriers with which industry outside the aerospace industry sector is not familiar. These institutional barriers arise from the bureaucratic character of the federal agencies involved in the space program, from the absence of a publicized national space policy, from the blurred definition of responsibility and involvement of federal agencies in regulating space activities, and from the nature of the incentives and subsidies provided by the federal government to industry to advance commercial activities in space.

NASA has the primary responsibility for the civilian space program, and it represents an impressive national resource for space R&D. However, NASA was not set up to conduct routine operations of space systems or to provide services to public and private users.

In a sense NASA should endeavor to become "user friendly." Its bureaucratic, multi-level, multi-facility structure is daunting to any but aerospace industry organizations with whom it has synergistically evolved. The paperwork requirements; the ever-increasing list of acronyms; and most of all, the time required to accomplish what appear to be straightforward contractual agreements, discourage any but the most committed, persistent and entrepreneurial organizations. Several operational responsibilities for space systems have been assigned on an adhoc basis to other federal agencies, e.g., The National Oceanic and Atmospheric Administration to operate meteorological satellites, and COMSAT to operate communication satellites. NASA has been singularly successful as an institution in performing mandated missions, such as the Apollo Program. Its institutional and organization structure is capable of performing major technology development programs, such as the space shuttle and will be adequate to plan and build the space station. In an environment of level budgets in an inflationary period, the internal needs and objectives of the institution for survival, maintenance, and future growth represent barriers and may lead to R&D activities which are less responsive to externally determined needs or goals.

Reaching the goal of MPS commercialization depends on several key factors:

- A resolution of the conflicting goals in the MPS program: e.g. the need to perform basic R&D to establish the scientific framework vs. the need to successfully promote commercial ventures to justify the program's existence.
- Repeated and easy access to technical, management and contracting personnel who are responsible for MPS activities.
- Availability of scheduled allocations of STS payload space for pilot experiments. Internal political positioning is important in this allocation process in that MPS must compete with other programs for that space and must constantly justify use of that space in terms of congruence with overall agency goals.
- Enhancing credibility in negotiation with outside parties by ensuring that MPS commercialization is the responsibility of a group located in Washington where policy issues, legal questions, and resource allocations, are decided.

Successful transition from MPS R&D to applications where product opportunities can be demonstrated but where there are no appropriate private sector institutions, identified markets or established users, may necessitate the creation of new institutional structures such as:

1. Government-owned and operated facilities from which commercial users purchase services or products at costs determined by federal policy rather than market forces.

2. Government-owned and contractor-operated organizations in which the government uses a large portion of the products but where the contractor is also free within some specified restrictions to offer services and products to commercial users and to make a profit on those services and products.

3. Privately owned and operated organization which during the start-up period may require guaranteed government purchases, and specified protection from competition with the responsibility for developing and servicing commercial markets.

4. Privately owned and operated organization which engage in competitive sales and pricing determined by market forces.

The most desirable institutional structure and organization alternative will be determined by government policies, economic incentives, or political considerations and perceived benefits to participants.

Currently, NASA is assessing the most effective way to involve industry in the operation of the shuttle orbiter. The difficulties in establishing industry involvement underscore that innovations in institutional structures will also be required for the commercialization of MPS activities. Such structures will be needed to reduce the negative impacts of a bureaucracy, the uncertainties of Congressional authorizations and appropriations, and the rigidity of a civil service system, concerned about possible reductions in the Federal payroll. Commercial MPS organizations should be able to provide services and products, to meet both government and commercial requirements. The goal, of course, is to create an industry infrastructure as dynamic and effective as already exists in the aerospace and telecommunications fields.

Conclusions

MPS has a long-term future only as a commercial activity. Any federally funded R&D of MPS has to consider the steps to achieve the transition to commercial activities to serve both domestic and international markets rather than exploring exciting technical possibilities and neglecting their commercial potential. The success of MPS activities will be strongly influenced by costs, and therefore, the transition to routine space transportation will be essential. This transition will require policies to create a competitive cost structure, launch assurance, and liability protection and insurance of products required by

MPS commercial organizations during transportation to and return from orbit.

Therefore, the development of commercial MPS activities will be closely linked to space transportation services, within the framework of space station requirements. Although proposals have been advanced to establish a space industrialization corporation as source of investments and policy guidance, it would be premature at this stage of MPS development to establish an institutional structure and specific forms of subsidies prior to further demonstration of the commercial viability of MPS.

Finally, commercial MPS activities will be strongly influenced by the evolution of space policies and legislative actions in support of these policies. Industry will require clearly stated policies prior to commitments to long-term MPS programs. Increased high-level attention in the executive and legislative branches to decide on national space policies and to select from a range of possible policy options those which would be conducive to maintaining the U.S. competitive position in MPS programs will assure industry that they are in a position to develop strategies and plan commercial activities in MPS.

References

1. "President Reagan's 'State of Space' Speech." Space World, August-September, 1982, p. 5.

2. Office of Technology Assessment, <u>Civilian Space Policy and Applications</u>, June, 1982.

3. David, L. "Washington Orbit," <u>Space World</u>, January 1983, p. 3.

MPS PROGRAM DEVELOPMENT STRATEGIES AND PLANS

A. Program Goals

A clear statement of goals is mandatory in any program before an appropriate strategy and organizational response can be devised to achieve them. It has taken several years for the U.S. MPS program goals to be defined. The overall goal is to focus on the potential commercial applications of information obtained about materials in the space environment. This goal has five elements:

1. To perform research to improve industrial technology or to develop new products;
2. To prepare research quantities of a material and compare its properties with Earth-based materials;
3. To manufacture limited quantities of a unique high value product of MPS to test its market potential or to meet specific requirements;
4. To produce materials in space of sufficient quantity and value to stand on their own economically;
5. To establish the legal and managerial framework for commercial ventures.

There are at present no long-term strategies or plans which would allow the MPS program to achieve its goal of commercialization. The commercial potential of MPS has not been sufficiently demonstrated to use it as a sole justification for space station. However, few technologies stand to benefit more from a space station than MPS, but only if space station is taken into account in devising strategies and plans for MPS commercialization. As it stands today, without such plans, when a space station becomes a reality, MPS will not be in a position to take full advantage of the opportunities it can provide for achieving the program's goal.

B. Present Status

The current status of the MPS program does not prompt optimism as to its future. While its budget has been relatively steady, there have been no new program starts since 1977 when experiments were chosen for Spacelab 3. These experiments have been reduced to 12 compared to the 34 experiments the Europeans are planning for Spacelab 1. Since it takes 2 to 5 years to develop, test and integrate hardware into Spacelab, U.S. experimentation has been deferred beyond 1984. NASA hopes that industry will deveop sufficient interest to commit to basic research. However, the high risk, high cost, and lengthy payback periods make MPS, at present, commercially unattractive to industry. The few Joint Endeavor Agreements (JEA) NASA has signed while encouraging, are each so singular that they cannot be used as reliable indicators of future trends. Johnson & Johnson's and McDonnell Douglas' electrophoresis experiments are promising, but even when successful will require a large capital outlay. GTI, while not performing an experiment offers services through its JEA, however, it had to withdraw from the JEA. It is difficult to ascertain when or how Microgravity Research Associates will proceed with its MPS JEA.

The two major activities on which MPS commercialization depends, education and information, are currently, due to funding restrictions, at a very low level. The MPS program visibility is also very low. Since the resignation of Dr. Louis Testardi as head of the MPS Program there has been no successor announced. The MPS budget is about 0.5% of the NASA budget, hardly a level which would stimulate industry to take positive actions.

C. Strategy

To achieve continuing progress toward commercialization, the organization and management of the MPS program and the institutional entities within which the program is to be carried out have to recognize the needs of industrial organizations and to involve industry at various decision points in the program.

The MPS program must address a broad range of scientific and technical issues relating to technologies that in some cases may take a decade or more to develop fully. The program, therefore, must include both long-range research as well as engineering component development. Furthermore, it must obtain continuing, coordinated, support from the scientific and industrial community to meet its objectives. The program must also have a strong planning component to establish the scope and schedule of the program elements.

The strategy for MPS commercialization must take into account the budgetary constraints facing the space program as a whole. While trying to increase its share of the budget within the space program, the strategy should be to use whatever budget it has to maximum effect. The key to success in MPS are and will be creative ideas. The source of these ideas can be NASA, industry, or academia. But seed funds will have to be allocated to encourage research. Beyond coming up with novel approaches for experimentation, such funds would benefit the program further by creating the MPS industry-university infrastructure which is a necessary foundation for future work. As in other areas of research, the MPS participants can be depended on to act as a voice for MPS, bringing to the attention of Congress and the administration the budgetary needs of the program. Furthermore, once commercially promising MPS activities are identified, MPS program participants will be in a position to urge the government to create a positive investment environment for MPS commercialization, including tax incentives, equipment depreciation allowances, and so forth.

The strategy for MPS commercialization should also take into account the availability of STS and possibly free-flying carriers. It should endeavor to influence pricing policies and schedules to make experimentation in space almost as routine as ground based experimentation and SPAR flights.

Finally the strategy should adopt a space station planning approach. This approach should lead to informed decisions about whether or not to commit to a MPS development program, for joint planning with industry toward increasing involvement in MPS activities in an evolutionary program starting with STS experiments and culminating in a space station operational system.

In order for industrial organizations to be able to develop their plans for MPS activities in a space station, there has to be a reasonable assurance that the space station program plans are based on realistic possibilities to continue the program for at least a decade. Joint planning efforts with industrial organizations interested in MPS possibly in conjunction with a "space station MPS advancement industry planning committee" will provide the opportunity for both NASA and industry to develop realistic plans which are technically feasible, economically justifiable, and politically supportable. Plans for commercial MPS activities in a space station can benefit considerably from a better understanding of the objectives of NASA and industry and assure that the efforts of government and industry are in consonance with the National Space Policy of July 4, 1982; "to expand United States private sector investment and involvement in civil space and space related activities."

D. Plan for Strategy Implementation

The U.S. program plan for MPS should include at least 30 experiments per year for the next 10 years. Of these 30, 10 will probably be accepted for space demonstration. The scientific knowledge gained in the course of this experimentation will help to identify the most commercially promising applications of MPS. This experimentation should be conducted in an atmosphere of international cooperation to foster the exchange of ideas which, at this early stage of MPS development, is to everyone's benefit. A commitment to such a level of experimentation will create the sustained academic interest vital to MPS and demonstrate to industry the willingness of the government to participate in achieving long-term commercialization.

Three primary elements, using the history of MPS in the U.S. as reference, are necessary to elicit the interest, support, and involvement of industry in MPS. These elements are:

1. A central office whose sole function is to interface the MPS program with industry;

2. Information exchange; and

3. An institutional structure to maintain working relationships with industry.

1. Interface with Industry

Within the organizational structure of the MPS program, an office is needed whose sole function is to interface with the relevant industry in MPS. This office should be located in Washington where policy issues, legal questions, and budget allocation decisions are made. It is the responsibility of this office to administer programs of education and promotion to familiarize industry with MPS and to foster and administer government/industry working relationships. The functions of this office are to:

1. Provide a focal point for industry/government contacts.

2. Form a bridge between the government and industry for the exchange of information and views.

3. Facilitate synergistic relationships between the aerospace and the traditional materials processing industries.

4. Deal with issues of patent protection rights, proprietary rights, liabilities, leasing policy and pricing.

5. Offer working relationships having different levels of commitment and risk by the parties involved.

2. Information Exchange

Industry and university support is necessary to the implementation of an effective MPS program. Although these communities will be the primary beneficiaries of the program (universities by their involvement in the research and development phases; industries by receiving economic benefits from successful results), MPS must compete with alternative activities for human and material resources. As MPS will be in research and development phases prior to a space station mission, success will be linked to the human resources, particularly scientists and engineers, that it can enlist.

University-based scientists are natually attracted to work on the solution of the technical problems involved in MPS and will do so if worthwhile goals and a continuty of funding is provided. Industry may desire to be involved because MPS represents an opportunity to develop and use high technology products. To enhance industrial involvement, management of the relevant industrial organizations must be educated to the opportunities, goals and plans of the MPS program. In seeking best ways for obtaining this involvement, NASA's past experience will be useful.

Other forms of communication can assist in easing the interfaces with industry. In addition to disseminating technical knowledge, national and international technical conferences are appropriate forums for promoting a greater understanding of the purposes of MPS and for forming the interpersonal ties which are necessary for effective government/industry cooperation. News media and professional trade magazines are useful vehicles for explaining the MPS programs to a larger readership, providing factual information and presenting realistic projections of future accomplishments.

3. Government/Industry Working Relationship

The mechanisms that NASA has evolved to foster government/industry working relationships have been successful in enlisting the involvement of the industry in STS opportunities for MPS experiments. The mechanisms, offered by NASA are: Technical Exchange, Industrial Guest Investigator and Joint Endeavour agreements. Important and necessary features of these agreements are that they offer the flexibility needed to embrace the interests of different types and sizes of industrial organizations and provide for incremental increases in commitment and risk based on demonstrated positive results.

The experience obtained by NASA with industry contacts could be extended to future working relationships with industry in the framework of a space station program. Among the policy objectives of this program are: Providing continuity to the civilian space program and stimulating commercial activity in space. The "boundary conditions" imposed on the space station are that it be: STS compatible, "user friendly," evolutionary in nature, an amalgamation of manned and unmanned elements, and semi autonomous. The policy objectives and the space station boundary conditions can be part of the foundation for an effective government/industry working relationship.

7.2.2 Commercial Missions

7.2.2.1 Commercial Missions Data

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                         SSSS   P      A   A   CCCC  EEEEE


VAX/VMS  SPACE        BACX1000 11-MAY-1983 11:58   LVA0: 11-MAY-1983 11:58   DISK$VAXVMSRL2:[SPACE]BACX1000.SSP;2            VAX/VMS
VAX/VMS  SPACE        BACX1000 11-MAY-1983 11:58   LVA0: 11-MAY-1983 11:58   DISK$VAXVMSRL2:[SPACE]BACX1000.SSP;2            VAX/VMS
VAX/VMS  SPACE        BACX1000 11-MAY-1983 11:58   LVA0: 11-MAY-1983 11:58   DISK$VAXVMSRL2:[SPACE]BACX1000.SSP;2            VAX/VMS
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OF POOR QUALITY

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-----------------------------------------------------------------------------------------------------------
PAYLOAD ELEMENT NAME                       CODE                                TYPE
MULTIBEAM COMM SATELLITE                   BACX1000                            ( ) SCIENCE AND APPLICATIONS (NON-COMM.)
---------------------------------------------------------------------------    (X) COMMERCIAL
CONTACT                                                                        ( ) TECHNOLOGY DEVELOPMENT
NAME       DR. HERBERT H. GURK                                                 ( ) OPERATIONS
ADDRESS    RCA ASTRO-ELECTRONICS                                               ( ) OTHER
           PO BOX 800                                                          ( ) NATIONAL SECURITY
           PRINCETON, NJ  08540                                                TYPE NUMBER (SEE TABLE A)   7
                                                                               ----------------------------------------
                                                                               IMPORTANCE OF THE SPACE STATION TO
TELEPHONE  (609) 426-3225                                                      THIS ELEMENT
---------------------------------------------------------------------------    1  = LOW VALUE, BUT COULD USE
STATUS                                                                         10 = VITAL
 ( ) OPERATIONAL   ( ) APPROVED   ( ) PLANNED    ( ) CANDIDATE  (X) OPPORTUNITY   SCALE = 10
-----------------------------------------------------------------------------------------------------------
DESIRED FIRST FLIGHT, YEAR: 1995          NUMBER OF FLIGHTS      4          DURATION OF FLIGHT, DAYS    5
-----------------------------------------------------------------------------------------------------------
OBJECTIVE
PROVIDE HIGH CAPACITY C-BAND TRUNKING AND DIRECT COMMUNICATIONS SERVICES



-----------------------------------------------------------------------------------------------------------
DESCRIPTION
SATELLITE USES LARGE (25-40M) DEPLOYABLE ANTENNAS AND LARGE FEED CLUSTER TO PROVIDE HIGH LEVEL OF
FREQUENCY REUSE BASED ON SATELLITE GENERATION OF LARGE NUMBER OF NARROW BEAMS. EXTENSIVE USE OF ONBOARD
PROCESSING, INTERBEAM SWITCHING AND RECONFIGURABLE BEAM FORMING NETWORKS PROVIDE MAXIMUM FLEXIBILITY
TO MATCH CHANGING DEMAND PATTERNS.



-----------------------------------------------------------------------------------------------------------
ORBIT CHARACTERISTICS
   GEOSYNCHRONOUS ORBIT        (X) YES      ( ) NO
   APOGEE, KM                  35786    PERIGEE, KM   35786     TOLERANCE     +        -
   INCLINATION, DEG             0.0                             TOLERANCE     +        -
   NODAL ANGLE, DEG                                             EPHEMERIS ACCURACY, M
   ESCAPE DV REQUIRED, M/S      N/A
-----------------------------------------------------------------------------------------------------------
POINTING/ORIENTATION
   VIEW DIRECTION                      ( ) INERTIAL   ( ) SOLAR       (X) EARTH      ( ) ANY
   TRUTH SITES (IF KNOWN)
   POINTING ACCURACY, ARC-SEC 72.00                                   FIELD OF VIEW (DEG)
   POINTING STABILITY (JITTER), ARC-SEC/SEC
   SPECIAL RESTRICTIONS (AVOIDANCE)
-----------------------------------------------------------------------------------------------------------
POWER
   ( ) AC          (X) DC
                   POWER, W             DURATION, HRS/DAY
                   -------------------------------------
   OPERATING         4000                   24.00
   STANDBY              0                    0.00            (X) CONTINUOUS
   PEAK              4000                    0.00
   VOLTAGE, V          35               FREQUENCY, HZ           0
-----------------------------------------------------------------------------------------------------------
```

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DATA/COMMU   ATIONS
   MONITORING REQUIREMENTS:
   ( ) NONE          ( ) REALTIME     ( ) OFFLINE      ( ) OTHER:
   ( ) ENCRIPTION/DECRIPTION REQUIRED
   ( ) UPLINK REQUIRED:  COMMAND RATE (KBS):                     FREQUENCY (MHZ):
   ( ) ON-BOARD DATA PROCESSING REQUIRED
       DESCRIPTION:
       DATA TYPES:   ( ) ANALOG      ( ) DIGITAL                 HOURS/DAY
       FILM (AMOUNT):                                            VOICE (HOURS/DAY):
       LIVE TV (HOURS/DAY):                                      OTHER:
       ON-BOARD STORAGE (MBIT):
       DATA DUMP FREQUENCY (PER ORBIT)                           DOWNLINK COMMAND RATE:
       RECORDING RATE (KBPS)                                     DOWNLINK FREQUENCY (MHZ): 4000.00
------------------------------------------------------------------------------------------------------------------------------
THERMAL
   ( ) ACTIVE     (X) PASSIVE
       TEMPERATURE, DEG C   OPERATIONAL MINIMUM          0          MAXIMUM      50
                            NON-OPERATIONAL MINIMUM                 MAXIMUM
       HEAT REJECTION, W    OPERATIONAL MINIMUM          0          MAXIMUM    2000
                            NON-OPERATIONAL MINIMUM                 MAXIMUM
------------------------------------------------------------------------------------------------------------------------------
EQUIPMENT PHYSICAL CHARACTERISTICS
   LOCATION         ( ) INTERNAL        (X) EXTERNAL        ( ) REMOTE
   EQUIPMENT ID/FUNCTION                ( ) PRESSURIZED     (X) UNPRESSURIZED
                    L, M:     10.00     W, M:       4.40    H, M:       4.40    STOWED
                    L, M:     75.00     W, M:      40.00    H, M:      40.00    DEPLOYED
                    LAUNCH MASS, KG:    5000                RETURN MASS, KG:       0
                    CONSUMABLE TYPES
                    ACCELERATION SENSITIVITY, (G)      MIN:       E+00      MAX:       E+00
------------------------------------------------------------------------------------------------------------------------------
CREW REQUIREMENTS
   CREW SIZE          4            TASK ASSIGNMENTS
                                   -------------------------------------------------------------
   SKILLS (SEE TABLE B)            | SKILL       |       |       |       |       |       |       |
                                   -------------------------------------------------------------
                                   | LEVEL       |       |       |       |       |       |       |
                                   -------------------------------------------------------------
                                   | HOURS/DAY   |       |       |       |       |       |       |
                                   -------------------------------------------------------------
   EVA   (X) YES    ( ) NO         REASON                              HOURS/EVA   40.00
------------------------------------------------------------------------------------------------------------------------------
SERVICING/MAINTENANCE
   SERVICE:                            INTERVAL,  DAYS                       CONSUMABLES, KG
                                       RETURNABLES, KG                       MAN HOURS
   CONFIGURATION CHANGES:              INTERVAL, DAY                         MAN/HOURS REQUIRED
                                       DELIVERABLES, KG                      RETURNABLES, KG
------------------------------------------------------------------------------------------------------------------------------
SPECIAL CONSIDERATIONS/SEE INSTRUCTIONS
DEPLOYMENT OF ANTENNAS, FEEDS EFFECTED ON MANNED PLATFORM. DEPLOYED S/C TRANSPORTED TO GEOSYNCHRONOUS
ORBIT USING OTV. FINAL CHECKOUT AND ADJUSTMENT OF ANTENNA/FEED ASSEMBLY CARRIED OUT AT MANNED PLATFORM.
PRELIMINARY PROOF-OF-CONCEPT MECHANICAL DEPLOYMENT AND MEASUREMENT OF ANTENNA PATTERNS CARRIED OUT
USING MANNED PLATFORM.


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                                          BOEING-SPECIFIC INPUT DATA
------------------------------------------------------------------------------------------------------------
MISSION TYPE                                 OPS CODE
   FREE FLYER
   ( ) NOT SERVICED                             F
   ( ) REMOTE TMS                               FT
   ( ) REMOTE MANNED                            FM
   ( ) SERVICED AT STATION (TMS RETRIEVED)      FST
   ( ) SERVICED AT STATION (SELF-PROPELLED)     FS

   PLATFORM BASED
   ( ) NOT SERVICED                             P
   ( ) REMOTE TMS                               PT
   ( ) REMOTE MANNED                            PM
   ( ) SERVICED AT STATION (TMS RETRIEVED)      PST
   ( ) SERVICED AT STATION (SELF-PROPELLED)     PS

   OTHER
   ( ) SPACE STATION BASED                      SS
   ( ) SORTIE                                   SOR

CONSTRUCTION/SERVICING COMPLEXITY
   ( ) LOW
   ( ) MEDIUM
   ( ) HIGH

OPERATIONS TIMES
   OTV UP/DOWN                         DAYS
   OTV OR TMS ON ORBIT                 DAYS
   MISSION USE                         DAYS/YEAR
   IVA SERVICE                         MAN-DAYS/YEAR
   EVA SERVICE                         MAN-DAYS/YEAR
   EXPERIMENT OPS                      MAN-DAYS/YEAR
   SERVICE FREQUENCY                   TIMES/YEAR

DELTA VELOCITIES
   UP                        0.00
   DOWN                      0.00
   AERO RETURN               0.00

SUPPORT EQUIPMENT
             LENGTH:         0.00 METERS       WIDTH:      0.00 METERS        HEIGHT:      0.00 METERS      (STOWED)
             LENGTH:         0.00 METERS       WIDTH:      0.00 METERS        HEIGHT:      0.00 METERS      (DEPLOYED)

             MASS:              0 KG

MANIFEST RESTRICTIONS
   (X) NO RESTRICTIONS
   ( ) ONLY WITH COMPATIBLE PAYLOADS
   ( ) FLY-ALONE
   ( ) MUST HAVE DOCKING MODULE

LENGTH OF BEAM FAB                                         0.00
NUMBER OF APPENDAGES                                          0
NUMBER OF MODULES REQUIRED TO ASSEMBLE THE PAYLOAD?           0
------------------------------------------------------------------------------------------------------------
```

PAYLOAD ELEMENT NAME
RECONFIGURATION COMM SATELLITE

CODE
BACX1001

TYPE
( ) SCIENCE AND APPLICATIONS (NON-COMM.)
(X) COMMERCIAL
( ) TECHNOLOGY DEVELOPMENT
( ) OPERATIONS
( ) OTHER
( ) NATIONAL SECURITY
TYPE NUMBER (SEE TABLE A) 7

CONTACT
NAME DR. HERBERT M. GURK
ADDRESS RCA ASTRO-ELECTRONICS
PO BOX 800
PRINCETON, NJ 00540

TELEPHONE (609) 426-3225

IMPORTANCE OF THE SPACE STATION TO THIS ELEMENT
1 = LOW VALUE, BUT COULD USE
10 = VITAL
SCALE = 9

STATUS
( ) OPERATIONAL ( ) APPROVED ( ) PLANNED (X) CANDIDATE ( ) OPPORTUNITY

DESIRED FIRST FLIGHT, YEAR: 1990 NUMBER OF FLIGHTS 30 DURATION OF FLIGHT, DAYS 5

OBJECTIVE
PROVIDE SATELLITE CAPABLE OF RECONFIGURATION OF BEAM PATTERN IN ORDER TO RESPOND TO CHANGING TRAFFIC PATTERNS AND TO PROVIDE RAPID REPLACEMENT OF SATELLITES IN DIFFERENT ORBITAL POSITIONS.

DESCRIPTION
SATELLITE IS PROVIDED WITH MANUALLY ADJUSTABLE FEED HORN ARRAY AND MANUALLY RECONFIGURABLE BEAM FORMING NETWORKS. WHEN USED AS A SPARE, SATELLITE IS STORED ABOARD OR NEAR MANNED PLATFORM. WHEN ONE OF SEVERAL SATELLITES FAILS, THE SPARE SATELLITE IS CONFIGURED MANUALLY TO REPLACE THE FAILED SATELLITE AND IS THEN LAUNCHED GEOSYNCHRONOUS ORBIT TO THE DESIRED POSITION. DURING THE LIFETIME OF A SATELLITE, RECONFIGURATION MAY BE EFFECTIVE BY BRINGING THE SATELLITE DOWN FROM GEOSYNC ORBIT, CARRYING OUT THE RECONFIGURATION ON THE PLATFORM AND THEN RETURNING IT TO ITS GEOSYNC POSITION. TYPICALLY A MULTI-ZONE DIRECT BROADCAST SYSTEM WOULD USE SUCH A SATELLITE.

ORBIT CHARACTERISTICS
GEOSYNCHRONOUS ORBIT (X) YES ( ) NO
APOGEE, KM 35786 PERIGEE, KM 35786
INCLINATION, DEG 0.0 TOLERANCE + -
NODAL ANGLE, DEG TOLERANCE + -
ESCAPE DV REQUIRED, M/S N/A EPHEMERIS ACCURACY, M

POINTING/ORIENTATION
VIEW DIRECTION ( ) INERTIAL ( ) SOLAR (X) EARTH ( ) ANY
TRUTH SITES (IF KNOWN)
POINTING ACCURACY, ARC-SEC360.00
POINTING STABILITY (JITTER), ARC-SEC/SE(FIELD OF VIEW (DEG)
SPECIAL RESTRICTIONS (AVOIDANCE)

POWER
( ) AC (X) DC

	POWER, W	DURATION, HRS/DAY	
OPERATING	3500	22.00	
STANDBY	500	1.20	
PEAK	3500		(X) CONTINUOUS
VOLTAGE, V	100	FREQUENCY, HZ	0

DATA/COMMUNICATIONS

MONITORING REQUIREMENTS:

( ) NONE (X) REALTIME ( ) OFFLINE ( ) OTHER:

( ) ENCRIPTION/DECRIPTION REQUIRED

(X) UPLINK REQUIRED: COMMAND RATE (KBS): 1 FREQUENCY (MHZ): 6000.00

( ) ON-BOARD DATA PROCESSING REQUIRED

DESCRIPTION:

DATA TYPES: ( ) ANALOG ( ) DIGITAL HOURS/DAY

FILM (AMOUNT): VOICE (HOURS/DAY):

LIVE TV (HOURS/DAY): 8.00 OTHER:

ON-BOARD STORAGE (MBIT):

DATA DUMP FREQUENCY (PER ORBIT) DOWNLINK COMMAND RATE:

RECORDING RATE (KBPS) DOWNLINK FREQUENCY (MHZ): 4000.00

THERMAL

( ) ACTIVE (X) PASSIVE

TEMPERATURE, DEG C	OPERATIONAL MINIMUM	10	MAXIMUM	50
	NON-OPERATIONAL MINIMUM	0	MAXIMUM	
HEAT REJECTION, W	OPERATIONAL MINIMUM	0	MAXIMUM	3300
	NON-OPERATIONAL MINIMUM	0	MAXIMUM	

EQUIPMENT PHYSICAL CHARACTERISTICS

LOCATION ( ) INTERNAL (X) EXTERNAL ( ) REMOTE

EQUIPMENT ID/FUNCTION ( ) PRESSURIZED (X) UNPRESSURIZED

L, M: 4.40 W, M: 4.00 H, M: 4.00 STOWED

L, M: 7.50 W, M: 4.00 H, M: 4.00 DEPLOYED

LAUNCH MASS, KG: 1800 RETURN MASS, KG: 0

CONSUMABLE TYPES

ACCELERATION SENSITIVITY, (G) MIN: E+00 MAX: E+00

CREW REQUIREMENTS

CREW SIZE 2 TASK ASSIGNMENTS

SKILLS (SEE TABLE B)

SKILL						
LEVEL						
HOURS/DAY						

EVA (X) YES ( ) NO REASON HOURS/EVA 40.00

SERVICING/MAINTENANCE

SERVICE: INTERVAL, DAYS 650 CONSUMABLES, KG

RETURNABLES, KG 0 MAN HOURS

CONFIGURATION CHANGES: INTERVAL, DAY 650 MAN/HOURS REQUIRED

DELIVERABLES, KG RETURNABLES, KG

SPECIAL CONSIDERATIONS/SEE INSTRUCTIONS

RECONFIGURABILITY OF THE SPARE SATELLITE IS WORTHWHILE ONLY IF IT WOULD REPLACE ANY ONE OF A NUMBER OF SATELLITES ALREADY IN ORBIT. THE ADVANTAGE IN STORING THE RECONFIGURABLE SATELLITE AT THE PLATFORM IS THAT IT CAN REPLACE A FAILED SATELLITE IN A SHORT TIME, RATHER THAN WAITING FOR THE NEXT GROUND LAUNCH THAT COULD BE SCHEDULED.

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                                                  BOEING-SPECIFIC INPUT DATA
-----------------------------------------------------------------------------------------------------------------------------
MISSION TYPE                                  OPS CODE
   FREE FLYER
   ( ) NOT SERVICED                              F
   ( ) REMOTE TMS                                FT
   ( ) REMOTE MANNED                             FM
   ( ) SERVICED AT STATION (TMS RETRIEVED)       FST
   ( ) SERVICED AT STATION (SELF-PROPELLED)      FS

   PLATFORM BASED
   ( ) NOT SERVICED                              P
   ( ) REMOTE TMS                                PT
   ( ) REMOTE MANNED                             PM
   ( ) SERVICED AT STATION (TMS RETRIEVED)       PST
   ( ) SERVICED AT STATION (SELF-PROPELLED)      PS

   OTHER
   ( ) SPACE STATION BASED                       SS
   ( ) SORTIE                                    SOR

CONSTRUCTION/SERVICING COMPLEXITY
   ( ) LOW
   ( ) MEDIUM
   ( ) HIGH

OPERATIONS TIMES
   OTV UP/DOWN                          DAYS
   OTV OR TMS ON ORBIT                  DAYS
   MISSION USE                          DAYS/YEAR
   IVA SERVICE                          MAN-DAYS/YEAR
   EVA SERVICE                          MAN-DAYS/YEAR
   EXPERIMENT OPS                       MAN-DAYS/YEAR
   SERVICE FREQUENCY                    TIMES/YEAR

DELTA VELOCITIES
   UP                        0.00
   DOWN                      0.00
   AERO RETURN               0.00

SUPPORT EQUIPMENT
             LENGTH:         0.00 METERS      WIDTH:      0.00 METERS       HEIGHT:      0.00 METERS     (STOWED)
             LENGTH:         0.00 METERS      WIDTH:      0.00 METERS       HEIGHT:      0.00 METERS     (DEPLOYED)

             MASS:              0 KG

MANIFEST RESTRICTIONS
   (X) NO RESTRICTIONS
   ( ) ONLY WITH COMPATIBLE PAYLOADS
   ( ) FLY-ALONE
   ( ) MUST HAVE DOCKING MODULE

LENGTH OF BEAM FAB                                        0.00
NUMBER OF APPENDAGES                                         0
NUMBER OF MODULES REQUIRED TO ASSEMBLE THE PAYLOAD           0
-----------------------------------------------------------------------------------------------------------------------------
```

PAYLOAD ELEMENT NAME
FLOAT ZONE CRYSTAL PROCESSING

CODE
BACX1002

TYPE
( ) SCIENCE AND APPLICATIONS (NON-COMM.)
(X) COMMERCIAL
( ) TECHNOLOGY DEVELOPMENT
( ) OPERATIONS
( ) OTHER
( ) NATIONAL SECURITY
TYPE NUMBER (SEE TABLE A) 8

CONTACT
NAME JERRY GILL
ADDRESS WESTEC
3502 EAST ATLANTA AVE
PHOENIX, AZ 85040

TELEPHONE (602) 276-4261

IMPORTANCE OF THE SPACE STATION TO THIS ELEMENT
1 = LOW VALUE, BUT COULD USE
10 = VITAL
SCALE = 8

STATUS
( ) OPERATIONAL ( ) APPROVED ( ) PLANNED ( ) CANDIDATE (X) OPPORTUNITY

DESIRED FIRST FLIGHT, YEAR: 1990 NUMBER OF FLIGHTS 4 DURATION OF FLIGHT, DAYS 90

OBJECTIVE
GROW LARGE SILICON CRYSTALS BY A FLOAT ZONE PROCESS.

DESCRIPTION
MOVE A 4 INCH DIAMETER ROD THROUGH A RADIANT FURNACE WHICH MELTS THE SILICON AND RECRYSTALLIZES IT INTO A SINGLE CRYSTAL. MELT ZONE SPEED AT 1-10 MIL/MIN.

ORBIT CHARACTERISTICS
GEOSYNCHRONOUS ORBIT ( ) YES (X) NO
APOGEE, KM PERIGEE, KM TOLERANCE + -
INCLINATION, DEG . TOLERANCE + -
NODAL ANGLE, DEG EPHEMERIS ACCURACY, M
ESCAPE DV REQUIRED, M/S .

POINTING/ORIENTATION
VIEW DIRECTION ( ) INERTIAL ( ) SOLAR ( ) EARTH (X) ANY
TRUTH SITES (IF KNOWN)
POINTING ACCURACY, ARC-SEC FIELD OF VIEW (DEG)
POINTING STABILITY (JITTER), ARC-SEC/SEC
SPECIAL RESTRICTIONS (AVOIDANCE)

POWER
(X) AC ( ) DC

	POWER, W	DURATION, HRS/DAY
OPERATING	20000	24.00
STANDBY	0	0.00
PEAK	20000	24.00
VOLTAGE, V	10000	FREQUENCY, HZ

(X) CONTINUOUS

```
DATA/COMMUNICATIONS
   MONITORING REQUIREMENTS:
    ( ) NONE        ( ) REALTIME    (X) OFFLINE     ( ) OTHER:
    ( ) ENCRIPTION/DECRIPTION REQUIRED
    ( ) UPLINK REQUIRED:  COMMAND RATE (KBS):       0           FREQUENCY (MHZ):
    ( ) ON-BOARD DATA PROCESSING REQUIRED
        DESCRIPTION:
        DATA TYPES:   ( ) ANALOG     ( ) DIGITAL                HOURS/DAY
        FILM (AMOUNT):                  *****                   VOICE (HOURS/DAY):   0.50
        LIVE TV (HOURS/DAY):            24.00                   OTHER:
        ON-BOARD STORAGE (MBIT):   60000.00
        DATA DUMP FREQUENCY (PER ORBIT)                         DOWNLINK COMMAND RATE:
        RECORDING RATE (KBPS)     100000.00                     DOWNLINK FREQUENCY (MHZ):
---------------------------------------------------------------------------------------------------------
THERMAL
   (X) ACTIVE      ( ) PASSIVE
        TEMPERATURE, DEG C   OPERATIONAL MINIMUM       2000          MAXIMUM    2000
                             NON-OPERATIONAL MINIMUM                 MAXIMUM
        HEAT REJECTION, W    OPERATIONAL MINIMUM      20000          MAXIMUM
                             NON-OPERATIONAL MINIMUM                MAXIMUM
---------------------------------------------------------------------------------------------------------
EQUIPMENT PHYSICAL CHARACTERISTICS
   LOCATION          (X) INTERNAL        ( ) EXTERNAL        ( ) REMOTE
   EQUIPMENT ID/FUNCTION                 (X) PRESSURIZED     ( ) UNPRESSURIZED
                 L, M:      3.00         W, M:      3.00     H, M:      3.00    STOWED
                 L, M:      3.00         W, M:      3.00     H, M:      3.00    DEPLOYED
                 LAUNCH MASS, KG:        1000                RETURN MASS, KG:    1000
                 CONSUMABLE TYPES
                 ACCELERATION SENSITIVITY, (G)       MIN:        E+00       MAX:       E+00
---------------------------------------------------------------------------------------------------------
CREW REQUIREMENTS
   CREW SIZE            1            TASK ASSIGNMENTS
                                     ------------------------------------------------------------
   SKILLS (SEE TABLE B)              ! SKILL     !       !       !       !       !       !       !
                                     ------------------------------------------------------------
                                     ! LEVEL     !       !       !       !       !       !       !
                                     ------------------------------------------------------------
                                     ! HOURS/DAY !       !       !       !       !       !       !
                                     ------------------------------------------------------------
   EVA  ( ) YES    (X) NO            REASON                            HOURS/EVA   40.00
---------------------------------------------------------------------------------------------------------
SERVICING/MAINTENANCE
   SERVICE:                              INTERVAL,  DAYS                     CONSUMABLES, KG
                                         RETURNABLES, KG                     MAN HOURS
   CONFIGURATION CHANGES:                INTERVAL, DAY                       MAN/HOURS REQUIRED
                                         DELIVERABLES, KG                    RETURNABLES, KG
---------------------------------------------------------------------------------------------------------
SPECIAL CONSIDERATIONS/SEE INSTRUCTIONS



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-----------------------------------------------------------------------------------------------------------
                                          BOEING-SPECIFIC INPUT DATA
-----------------------------------------------------------------------------------------------------------
MISSION TYPE                                   OPS CODE
  FREE FLYER
   ( ) NOT SERVICED                              F
   ( ) REMOTE TMS                                FT
   ( ) REMOTE MANNED                             FM
   ( ) SERVICED AT STATION (TMS RETRIEVED)       FST
   ( ) SERVICED AT STATION (SELF-PROPELLED)      FS

  PLATFORM BASED
   ( ) NOT SERVICED                              P
   ( ) REMOTE TMS                                PT
   ( ) REMOTE MANNED                             PM
   ( ) SERVICED AT STATION (TMS RETRIEVED)       PST
   ( ) SERVICED AT STATION (SELF-PROPELLED)      PS

  OTHER
   ( ) SPACE STATION BASED                       SS
   ( ) SORTIE                                    SOR

CONSTRUCTION/SERVICING COMPLEXITY
   ( ) LOW
   ( ) MEDIUM
   ( ) HIGH

OPERATIONS TIMES
   OTV UP/DOWN                           DAYS
   OTV OR TMS ON ORBIT                   DAYS
   MISSION USE                           DAYS/YEAR
   IVA SERVICE                           MAN-DAYS/YEAR
   EVA SERVICE                           MAN-DAYS/YEAR
   EXPERIMENT OPS                        MAN-DAYS/YEAR
   SERVICE FREQUENCY                     TIMES/YEAR

DELTA VELOCITIES
   UP                        0.00
   DOWN                      0.00
   AERO RETURN               0.00

SUPPORT EQUIPMENT
            LENGTH:          0.00 METERS      WIDTH:      0.00 METERS       HEIGHT:      0.00 METERS      (STOWED)
            LENGTH:          0.00 METERS      WIDTH:      0.00 METERS       HEIGHT:      0.00 METERS      (DEPLOYED)

            MASS:               0 KG

MANIFEST RESTRICTIONS
   (X) NO RESTRICTIONS
   ( ) ONLY WITH COMPATIBLE PAYLOADS
   ( ) FLY-ALONE
   ( ) MUST HAVE DOCKING MODULE

LENGTH OF BEAM FAB                                       0.00
NUMBER OF APPENDAGES                                        0
NUMBER OF MODULES REQUIRED TO ASSEMBLE THE PAYLOAD          0
-----------------------------------------------------------------------------------------------------------
```

PAYLOAD ELEMENT NAME
VAPOR EPITAXIAL CRYSTAL GROWTH

CODE
BACX1003

TYPE
( ) SCIENCE AND APPLICATIONS (NON-COMM.)
(X) COMMERCIAL
( ) TECHNOLOGY DEVELOPMENT
( ) OPERATIONS
( ) OTHER
( ) NATIONAL SECURITY
TYPE NUMBER (SEE TABLE A) 8

CONTACT
NAME DR. HERIBERT WIEDEMEIER
ADDRESS RENSSELAER POLYTECHNIC I
TROY, NY 12181

TELEPHONE (518) 270-6456

IMPORTANCE OF THE SPACE STATION TO THIS ELEMENT
1 = LOW VALUE, BUT COULD USE
10 = VITAL
SCALE = 6

STATUS
( ) OPERATIONAL ( ) APPROVED ( ) PLANNED ( ) CANDIDATE (X) OPPORTUNITY

DESIRED FIRST FLIGHT, YEAR: 1991
NUMBER OF FLIGHTS 6
DURATION OF FLIGHT, DAYS 60

OBJECTIVE
THE PAYLOAD OBJECTIVE IS TO PRODUCE LARGE MERCURY CADMIUM TELLURIDE CRYSTALS BY A CHEMICAL VAPOR TRANSPORT PROCESS. MANNED INTERACTION IS NECESSARY TO EXAMINE IN SITU EACH BATCH OF CRYSTALS PRODUCED AND VARY THE PROCESS PARAMETERS ACCORDINGLY.

DESCRIPTION
THE CHEMICAL VAPOR TRANSPORT PROCESS IS LIMITED TO PRODUCING SMALL CRYSTALS IN A GRAVITY ENVIRONMENT BECAUSE OF THE INFLUENCE OF CONVECTION IN THE GAS PHASE. MICROGRAVITY PRODUCTON WOULD ELIMINATE THESE CONVECTION EFFECTS AND PRODUCE LARGER, INDUSTRIAL GRADE CRYSTALS FOR INFRARED DETECTORS.
THE LARGE CRYSTALS WILL BE PRODUCED IN QUARTZ AMPOULES 5 TO 8 CM IN DIAMETER AND 30 TO 45 CM IN LENGTH.
THE TWO ZONE, TUBULAR RESISTANCE FURNACE WILL BE LESS THAN 1.5 METERS IN LENGTH AND .25 METERS IN DIAMETER.
THE MANUFACTURING PROCESS WILL REQUIRE A DEDICATED MICROPROCESSOR FOR TEMPERATURE GRADIENT CONTROL.
AS THE PROCESS IS COMPLETED, A CREW MEMBER MUST REMOVE THE CRYSTALS AND EXAMIN THEM USING THE ONBOARD LABORATORY FACILITIES. A METALLOGRAPHY MICROSCOPE IS NECESSARY EQUIPMENT, WITH X-RAY DIFFRACTION EQUIPMENT AND A HALL PROBE DESIRABLE. THE REQD MICROGRAVITY ENVIR IS ON THE ORDER OF 10-4G'S.

ORBIT CHARACTERISTICS
GEOSYNCHRONOUS ORBIT ( ) YES (X) NO
APOGEE, KM
PERIGEE, KM
TOLERANCE + -
INCLINATION, DEG .
TOLERANCE + -
NODAL ANGLE, DEG
EPHEMERIS ACCURACY, M
ESCAPE DV REQUIRED, M/S .

POINTING/ORIENTATION
VIEW DIRECTION ( ) INERTIAL ( ) SOLAR ( ) EARTH (X) ANY
TRUTH SITES (IF KNOWN)
POINTING ACCURACY, ARC-SEC
FIELD OF VIEW (DEG)
POINTING STABILITY (JITTER), ARC-SEC/SEC
SPECIAL RESTRICTIONS (AVOIDANCE) MICROGRAVITY PURITY MINIMIZE ACCELERATIONS

POWER
( ) AC (X) DC

	POWER, W	DURATION, HRS/DAY
OPERATING	10000	24.00
STANDBY		
PEAK	15000	3.00

(X) CONTINUOUS

VOLTAGE, V
FREQUENCY, HZ

DATA/COMMUNICATIONS
MONITORING REQUIREMENTS:
( ) NONE (X) REALTIME ( ) OFFLINE ( ) OTHER:
( ) ENCRIPTION/DECRIPTION REQUIRED
( ) UPLINK REQUIRED: COMMAND RATE (KBS): FREQUENCY (MHZ):
( ) ON-BOARD DATA PROCESSING REQUIRED
DESCRIPTION:
DATA TYPES: ( ) ANALOG ( ) DIGITAL
FILM (AMOUNT): HOURS/DAY
LIVE TV (HOURS/DAY): VOICE (HOURS/DAY):
ON-BOARD STORAGE (MBIT): OTHER:
DATA DUMP FREQUENCY (PER ORBIT)
RECORDING RATE (KBPS) DOWNLINK COMMAND RATE:
DOWNLINK FREQUENCY (MHZ):

THERMAL
(X) ACTIVE ( ) PASSIVE

TEMPERATURE, DEG C	OPERATIONAL MINIMUM	500	MAXIMUM	600
	NON-OPERATIONAL MINIMUM	0	MAXIMUM	700
HEAT REJECTION, W	OPERATIONAL MINIMUM	5000	MAXIMUM	15000
	NON-OPERATIONAL MINIMUM	0	MAXIMUM	

EQUIPMENT PHYSICAL CHARACTERISTICS
LOCATION (X) INTERNAL ( ) EXTERNAL ( ) REMOTE
EQUIPMENT ID/FUNCTION (X) PRESSURIZED ( ) UNPRESSURIZED
L, M: 1.50 W, M: 0.25 H, M: 0.25 STOWED
L, M: 1.50 W, M: 0.25 H, M: 0.25 DEPLOYED
LAUNCH MASS, KG: 3000 RETURN MASS, KG: 3000
CONSUMABLE TYPES
ACCELERATION SENSITIVITY, (G) MIN: 0.00E+00 MAX: 1.00E-05

CREW REQUIREMENTS
CREW SIZE 1

TASK ASSIGNMENTS

SKILLS (SEE TABLE B)

SKILL	3					
LEVEL	2					
HOURS/DAY	4.00					

EVA (X) YES ( ) NO REASON HOURS/EVA

SERVICING/MAINTENANCE
SERVICE: INTERVAL, DAYS 60 CONSUMABLES, KG
RETURNABLES, KG 200 MAN HOURS
CONFIGURATION CHANGES: INTERVAL, DAY MAN/HOURS REQUIRED
DELIVERABLES, KG RETURNABLES, KG

SPECIAL CONSIDERATIONS/SEE INSTRUCTIONS
LABORATORY FACILITIES REQUIRED: CLEAN ROOM, WORKSPACE, SOME COMPUTING CAPABILITY
CRYSTAL CHARACTERIZATION EQUIP REQUIRED: CUTTING SAW, MICROSCOPE, HALL APPARATUS, X-RAY DIFF (IF POSSIBLE)

ORIGINAL PAGE IS
OF POOR QUALITY

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                                                 BOEING-SPECIFIC INPUT DATA
----------------------------------------------------------------------------------------------------------------------------
MISSION TYPE                                  OPS CODE
   FREE FLYER
   ( ) NOT SERVICED                              F
   ( ) REMOTE TMS                                FT
   ( ) REMOTE MANNED                             FM
   ( ) SERVICED AT STATION (TMS RETRIEVED)       FST
   ( ) SERVICED AT STATION (SELF-PROPELLED)      FS

   PLATFORM BASED
   ( ) NOT SERVICED                              P
   ( ) REMOTE TMS                                PT
   ( ) REMOTE MANNED                             PM
   ( ) SERVICED AT STATION (TMS RETRIEVED)       PST
   ( ) SERVICED AT STATION (SELF-PROPELLED)      PS

   OTHER
   ( ) SPACE STATION BASED                       SS
   ( ) SORTIE                                    SOR

CONSTRUCTION/SERVICING COMPLEXITY
   ( ) LOW
   ( ) MEDIUM
   ( ) HIGH

OPERATIONS TIMES
   OTV UP/DOWN                          DAYS
   OTV OR TMS ON ORBIT                  DAYS
   MISSION USE                          DAYS/YEAR
   IVA SERVICE                          MAN-DAYS/YEAR
   EVA SERVICE                          MAN-DAYS/YEAR
   EXPERIMENT OPS                       MAN-DAYS/YEAR
   SERVICE FREQUENCY                    TIMES/YEAR

DELTA VELOCITIES
   UP                        0.00
   DOWN                      0.00
   AERO RETURN               0.00

SUPPORT EQUIPMENT
            LENGTH:          0.00 METERS      WIDTH:      0.00 METERS        HEIGHT:      0.00 METERS     (STOWED)
            LENGTH:          0.00 METERS      WIDTH:      0.00 METERS        HEIGHT:      0.00 METERS     (DEPLOYED)

            MASS:              0 KG

MANIFEST RESTRICTIONS
   (X) NO RESTRICTIONS
   ( ) ONLY WITH COMPATIBLE PAYLOADS
   ( ) FLY-ALONE
   ( ) MUST HAVE DOCKING MODULE

LENGTH OF BEAM FAB                                          0.00
NUMBER OF APPENDAGES                                           0
NUMBER OF MODULES REQUIRED TO ASSEMBLE THE PAYLOAD             0
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ORIGINAL PAGE IS
OF POOR QUALITY

PAYLOAD ELEMENT NAME — CODE
ELECTROEPITAXIAL CRYSTAL GROWTH — BACX1004

CONTACT
NAME ROBERT E. PACE, JR.
ADDRESS MICROGRAVITY RESEARCH AS
PO BOX 12426
HUNTSVILLE, AL 35802

TELEPHONE (205) 881-6670

TYPE
( ) SCIENCE AND APPLICATIONS (NON-COMM.)
(X) COMMERCIAL
( ) TECHNOLOGY DEVELOPMENT
( ) OPERATIONS
( ) OTHER
( ) NATIONAL SECURITY
TYPE NUMBER (SEE TABLE A) 8

IMPORTANCE OF THE SPACE STATION TO THIS ELEMENT
1 = LOW VALUE, BUT COULD USE
10 = VITAL
SCALE = 7

STATUS
( ) OPERATIONAL ( ) APPROVED (X) PLANNED ( ) CANDIDATE ( ) OPPORTUNITY

DESIRED FIRST FLIGHT, YEAR: 1990 NUMBER OF FLIGHTS 40 DURATION OF FLIGHT, DAYS 90

OBJECTIVE
DEVELOP AND COMMERCIALIZE A PROCESS FOR PRODUCING LARGE SINGLE CRYSTALS OF COMPOUND SEMICONDUCTOR MATERIALS.

DESCRIPTION
CRYSTALS ARE GROWN IN SPACE BY AN ELECTROEPITAXIAL GROWTH PROCESS. COMMERCIAL MANUFACTURING UNITS ARE PLACED IN MODULES ATTACHED TO THE SPACE STATION, AND GROWTH CELLS ARE REPLACED PERIODICALLY AND CRYSTALS RETURNED TO EARTH. A PROCESS DEVELOPMENT LABORATORY ON THE SPACE STATION IS USED TO CHARACTERIZE THE CRYSTALS AND DEVELOP THE PROCESS.

ORBIT CHARACTERISTICS
GEOSYNCHRONOUS ORBIT ( ) YES (X) NO
APOGEE, KM PERIGEE, KM TOLERANCE + -
INCLINATION, DEG . TOLERANCE + -
NODAL ANGLE, DEG EPHEMERIS ACCURACY, M
ESCAPE DV REQUIRED, M/S .

POINTING/ORIENTATION
VIEW DIRECTION ( ) INERTIAL ( ) SOLAR ( ) EARTH (X) ANY
TRUTH SITES (IF KNOWN)
POINTING ACCURACY, ARC-SEC FIELD OF VIEW (DEG)
POINTING STABILITY (JITTER), ARC-SEC/SEC
SPECIAL RESTRICTIONS (AVOIDANCE)

POWER
( ) AC (X) DC

	POWER, W	DURATION, HRS/DAY	
OPERATING	20000	24.00	
STANDBY			(X) CONTINUOUS
PEAK	20000	24.00	

VOLTAGE, V 50 FREQUENCY, HZ 0

DATA/COMMUN IONS

MONITORING REQUIREMENTS:

( ) NONE ( ) REALTIME (X) OFFLINE ( ) OTHER:

( ) ENCRIPTION/DECRIPTION REQUIRED

( ) UPLINK REQUIRED: COMMAND RATE (KBS): 0 FREQUENCY (MHZ):

( ) ON-BOARD DATA PROCESSING REQUIRED

DESCRIPTION:

DATA TYPES: ( ) ANALOG ( ) DIGITAL

FILM (AMOUNT):

HOURS/DAY

LIVE TV (HOURS/DAY):

VOICE (HOURS/DAY):

OTHER:

ON-BOARD STORAGE (MBIT):

DATA DUMP FREQUENCY (PER ORBIT)

RECORDING RATE (KBPS) 0.10

DOWNLINK COMMAND RATE:

DOWNLINK FREQUENCY (MHZ):

THERMAL

(X) ACTIVE ( ) PASSIVE

TEMPERATURE, DEG C	OPERATIONAL MINIMUM	850	MAXIMUM	950
	NON-OPERATIONAL MINIMUM	0	MAXIMUM	100
HEAT REJECTION, W	OPERATIONAL MINIMUM	10000	MAXIMUM	20000
	NON-OPERATIONAL MINIMUM	0	MAXIMUM	

EQUIPMENT PHYSICAL CHARACTERISTICS

LOCATION (X) INTERNAL ( ) EXTERNAL ( ) REMOTE

EQUIPMENT ID/FUNCTION (X) PRESSURIZED ( ) UNPRESSURIZED

L, M: 5.00 W, M: 1.00 H, M: 4.00 STOWED

L, M: 5.00 W, M: 1.00 H, M: 4.00 DEPLOYED

LAUNCH MASS, KG: 3000 RETURN MASS, KG: 3000

CONSUMABLE TYPES

ACCELERATION SENSITIVITY, (G) MIN: 1.00E-06 MAX: 1.00E-04

CREW REQUIREMENTS

CREW SIZE 2

TASK ASSIGNMENTS

SKILLS (SEE TABLE B)

SKILL						
LEVEL						
HOURS/DAY	4.00					

EVA ( ) YES (X) NO REASON HOURS/EVA

SERVICING/MAINTENANCE

SERVICE: INTERVAL, DAYS 90 CONSUMABLES, KG

RETURNABLES, KG 3000 MAN HOURS

CONFIGURATION CHANGES: INTERVAL, DAY MAN/HOURS REQUIRED

DELIVERABLES, KG RETURNABLES, KG

SPECIAL CONSIDERATIONS/SEE INSTRUCTIONS

LABORATORY FACILITIES REQUIRED: CLEAN ROOM, WORKSPACE, MINICOMUTER, DOWNLINK TERMINAL

CRYSTAL CHARACTERIZATION EQUIPMENT REQUIRED: CUTTING SAW, POLISHER, ETCHER, COMPACT EVAPORATOR, HALL APPARATUS LIGHT SOURCE AND SPECTROMETER.

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                                                      BOEING-SPECIFIC INPUT DATA
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MISSION TYPE                                 OPS CODE
   FREE FLYER
   ( ) NOT SERVICED                             F
   ( ) REMOTE TMS                               FT
   ( ) REMOTE MANNED                            FM
   ( ) SERVICED AT STATION (TMS RETRIEVED)      FST
   ( ) SERVICED AT STATION (SELF-PROPELLED)     FS

   PLATFORM BASED
   ( ) NOT SERVICED                             P
   ( ) REMOTE TMS                               PT
   ( ) REMOTE MANNED                            PM
   ( ) SERVICED AT STATION (TMS RETRIEVED)      PST
   ( ) SERVICED AT STATION (SELF-PROPELLED)     PS

   OTHER
   ( ) SPACE STATION BASED                      SS
   ( ) SORTIE                                   SOR

CONSTRUCTION/SERVICING COMPLEXITY
   ( ) LOW
   ( ) MEDIUM
   ( ) HIGH

OPERATIONS TIMES
   OTV UP/DOWN                      DAYS
   OTV OR TMS ON ORBIT              DAYS
   MISSION USE                      DAYS/YEAR
   IVA SERVICE                      MAN-DAYS/YEAR
   EVA SERVICE                      MAN-DAYS/YEAR
   EXPERIMENT OPS                   MAN-DAYS/YEAR
   SERVICE FREQUENCY                TIMES/YEAR

DELTA VELOCITIES
   UP                      0.00
   DOWN                    0.00
   AERO RETURN             0.00

SUPPORT EQUIPMENT
             LENGTH:       0.00 METERS      WIDTH:      0.00 METERS        HEIGHT:     0.00 METERS      (STOWED)
             LENGTH:       0.00 METERS      WIDTH:      0.00 METERS        HEIGHT:     0.00 METERS      (DEPLOYED)

             MASS:            0 KG

MANIFEST RESTRICTIONS
   (X) NO RESTRICTIONS
   ( ) ONLY WITH COMPATIBLE PAYLOADS
   ( ) FLY-ALONE
   ( ) MUST HAVE DOCKING MODULE

LENGTH OF BEAM FAB                                     0.00
NUMBER OF APPENDAGES                                      0
NUMBER OF MODULES REQUIRED TO ASSEMBLE THE PAYLOAD        0
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PAYLOAD ELEMENT NAME
CONTINUOUS FLOW ELECTROPHORESIS

CODE
BACX1005

TYPE
( ) SCIENCE AND APPLICATIONS (NON-COMM.)
(X) COMMERCIAL
( ) TECHNOLOGY DEVELOPMENT
( ) OPERATIONS
( ) OTHER
( ) NATIONAL SECURITY
TYPE NUMBER (SEE TABLE A) 8

CONTACT
NAME DR. HARVEY J. WILLENBERG
ADDRESS BOEING AEROSPACE COMPANY
PO BOX 3999, MS 84-86
SEATTLE, WA 98124

TELEPHONE (206) 773-2020

IMPORTANCE OF THE SPACE STATION TO THIS ELEMENT
1 = LOW VALUE, BUT COULD USE
10 = VITAL
SCALE = 6

STATUS
( ) OPERATIONAL ( ) APPROVED (X) PLANNED ( ) CANDIDATE ( ) OPPORTUNITY

DESIRED FIRST FLIGHT, YEAR: 1991 NUMBER OF FLIGHTS 170 DURATION OF FLIGHT, DAYS 21

OBJECTIVE
PROVIDE BIOCHEMICAL LABORATORY FOR DEVELOPING NEW ELECTROPHORESIS PRODUCTS, TESTING NEW EQUIPMENT AND PROCEDURES, AND PRODUCING RESEARCH QUANTITIES OF BIOLOGICAL MATERIALS.

DESCRIPTION
A BIOCHEMICAL LABORATORY IS NEEDED TO DEVELOP ELECTROPHORESIS TECHNOLOGY BEYOND PROTOTYPE COMMERCIAL PRODUCTION FREE-FLYER. THE LABORATORY WOULD INCLUDE 5-10 ELECTROPHORESIS UNITS FOR SEVERAL RESEARCH AND COMMERCIAL USERS. A CONTROL LABORATORY STORAGE RACKS, AND CREW ACCOMMODATIONS. THESE UNITS WOULD PROVIDE SEPARATIONS FOR A NUMBER OF DIFFERENT PHARMACEUTICALS AND DIFFERENT COMMERCIAL USERS. THE CONTROL LABORATORY WOULD BE FOR PROCESS CONTROL OF THE ELECTROPHORESIS UNITS, QUALITY CONTROL OF THE PRODUCT, AND REPAIR OF THE PROCESS UNITS. IT IS BELIEVED THAT THIS CAN BE A SHARED MULTI-USER FACILITY, OF ROUGHLY 50 M3, WITH FLUID, THERMAL, AND ELECTRICAL CONTROL SYSTEMS AND BIOLOGICAL LABORATORY EQUIPMENT. ABOUT 5 M3 O STORAGE RACKS WOULD BE REQUIRED.

ORBIT CHARACTERISTICS
GEOSYNCHRONOUS ORBIT ( ) YES (X) NO
APOGEE, KM 300 PERIGEE, KM 300 TOLERANCE + 200 - 100
INCLINATION, DEG TOLERANCE + -
NODAL ANGLE, DEG EPHEMERIS ACCURACY, M
ESCAPE DV REQUIRED, M/S .

POINTING/ORIENTATION
VIEW DIRECTION ( ) INERTIAL ( ) SOLAR ( ) EARTH (X) ANY
TRUTH SITES (IF KNOWN)
POINTING ACCURACY, ARC-SEC FIELD OF VIEW (DEG)
POINTING STABILITY (JITTER), ARC-SEC/SEC
SPECIAL RESTRICTIONS (AVOIDANCE)

POWER
( ) AC (X) DC

	POWER, W	DURATION, HRS/DAY	
OPERATING	10000	24.00	
STANDBY	3000	0.00	(X) CONTINUOUS
PEAK	10000	0.00	
VOLTAGE, V	2000	FREQUENCY, HZ	0

DATA/COMMUN. IONS

MONITORING REQUIREMENTS:

( ) NONE ( ) REALTIME (X) OFFLINE ( ) OTHER:

( ) ENCRIPTION/DECRIPTION REQUIRED

( ) UPLINK REQUIRED: COMMAND RATE (KBS): FREQUENCY (MHZ):

( ) ON-BOARD DATA PROCESSING REQUIRED

DESCRIPTION:

DATA TYPES: ( ) ANALOG ( ) DIGITAL HOURS/DAY

FILM (AMOUNT):

VOICE (HOURS/DAY):

LIVE TV (HOURS/DAY):

OTHER:

ON-BOARD STORAGE (MBIT):

DATA DUMP FREQUENCY (PER ORBIT)

DOWNLINK COMMAND RATE:

RECORDING RATE (KBPS)

DOWNLINK FREQUENCY (MHZ):

THERMAL

( ) ACTIVE (X) PASSIVE

TEMPERATURE, DEG C	OPERATIONAL MINIMUM	20	MAXIMUM	40
	NON-OPERATIONAL MINIMUM	4	MAXIMUM	40
HEAT REJECTION, W	OPERATIONAL MINIMUM	9000	MAXIMUM	11000
	NON-OPERATIONAL MINIMUM	0	MAXIMUM	

EQUIPMENT PHYSICAL CHARACTERISTICS

LOCATION (X) INTERNAL ( ) EXTERNAL ( ) REMOTE

EQUIPMENT ID/FUNCTION (X) PRESSURIZED ( ) UNPRESSURIZED

L, M: 12.00 W, M: 5.00 H, M: 5.00 STOWED

L, M: 35.00 W, M: 2.00 H, M: 5.00 DEPLOYED

LAUNCH MASS, KG: 30000 RETURN MASS, KG: 15000

CONSUMABLE TYPES

ACCELERATION SENSITIVITY, (G) MIN: E+00 MAX: E+00

CREW REQUIREMENTS

CREW SIZE 18

TASK ASSIGNMENTS

SKILLS (SEE TABLE B)

SKILL						
LEVEL						
HOURS/DAY						

EVA ( ) YES (X) NO REASON HOURS/EVA

SERVICING/MAINTENANCE

SERVICE: INTERVAL, DAYS CONSUMABLES, KG

RETURNABLES, KG MAN HOURS

CONFIGURATION CHANGES: INTERVAL, DAY MAN/HOURS REQUIRED

DELIVERABLES, KG RETURNABLES, KG

SPECIAL CONSIDERATIONS/SEE INSTRUCTIONS

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                                                 BOEING-SPECIFIC INPUT DATA
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MISSION TYPE                                 OPS CODE
  FREE FLYER
   ( ) NOT SERVICED                             F
   ( ) REMOTE TMS                               FT
   ( ) REMOTE MANNED                            FM
   ( ) SERVICED AT STATION (TMS RETRIEVED)      FST
   ( ) SERVICED AT STATION (SELF-PROPELLED)     FS

  PLATFORM BASED
   ( ) NOT SERVICED                             P
   ( ) REMOTE TMS                               PT
   ( ) REMOTE MANNED                            PM
   ( ) SERVICED AT STATION (TMS RETRIEVED)      PST
   ( ) SERVICED AT STATION (SELF-PROPELLED)     PS

  OTHER
   ( ) SPACE STATION BASED                      SS
   ( ) SORTIE                                   SOR

CONSTRUCTION/SERVICING COMPLEXITY
   ( ) LOW
   ( ) MEDIUM
   ( ) HIGH

OPERATIONS TIMES
  OTV UP/DOWN                        DAYS
  OTV OR TMS ON ORBIT                DAYS
  MISSION USE                        DAYS/YEAR
  IVA SERVICE                        MAN-DAYS/YEAR
  EVA SERVICE                        MAN-DAYS/YEAR
  EXPERIMENT OPS                     MAN-DAYS/YEAR
  SERVICE FREQUENCY                  TIMES/YEAR

DELTA VELOCITIES
  UP                      0.00
  DOWN                    0.00
  AERO RETURN             0.00

SUPPORT EQUIPMENT
             LENGTH:      0.00 METERS      WIDTH:     0.00 METERS        HEIGHT:     0.00 METERS       (STOWED)
             LENGTH:      0.00 METERS      WIDTH:     0.00 METERS        HEIGHT:     0.00 METERS       (DEPLOYED)

             MASS:           0 KG

MANIFEST RESTRICTIONS
  (X) NO RESTRICTIONS
  ( ) ONLY WITH COMPATIBLE PAYLOADS
  ( ) FLY-ALONE
  ( ) MUST HAVE DOCKING MODULE

LENGTH OF BEAM FAB                                    0.00
NUMBER OF APPENDAGES                                     0
NUMBER OF MODULES REQUIRED TO ASSEMBLE THE PAYLOAD       0
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PAYLOAD ELEMENT NAME
COLLAGEN PROCESSING

CODE
BACX1006

TYPE
( ) SCIENCE AND APPLICATIONS (NON-COMM.)
(X) COMMERCIAL
( ) TECHNOLOGY DEVELOPMENT
( ) OPERATIONS
( ) OTHER
( ) NATIONAL SECURITY
TYPE NUMBER (SEE TABLE A) 8

CONTACT
NAME DR. KENNETH E. HUGHES
ADDRESS BATTELLE COLUMBUS LAB
505 KING AVENUE
COLUMBUS, OHIO 43201

TELEPHONE (614) 424-7627

IMPORTANCE OF THE SPACE STATION TO THIS ELEMENT
1 = LOW VALUE, BUT COULD USE
10 = VITAL
SCALE = 3

STATUS
( ) OPERATIONAL ( ) APPROVED ( ) PLANNED (X) CANDIDATE ( ) OPPORTUNITY

DESIRED FIRST FLIGHT, YEAR: 1995 NUMBER OF FLIGHTS 4 DURATION OF FLIGHT, DAYS 10

OBJECTIVE
1. DETERMINE THE EFFECTS OF GRAVITATIONAL FORCE ON COLLAGEN FIBRIL GROWTH IN VITRO.
2. EVENTUAL GOAL TO FABRICATE COLLAGEN BIOMEDICAL MATERIALS HAVING CONTROLLED MORPHOLOGY.

DESCRIPTION
POLYMERIZE COLLAGEN MATRICES BY THE THERMAL GELATION PROCESS; DETERMINE REACTION KINETICS, GEL MATRIX STRUCTURE, AND PHYSICAL PROPERTIES OF MATERIALS. DEVELOP A PHENOMENOLOGICAL MODEL OF COLLAGEN FIBRIL GROWTH.

ORBIT CHARACTERISTICS
GEOSYNCHRONOUS ORBIT ( ) YES (X) NO
APOGEE, KM PERIGEE, KM TOLERANCE + -
INCLINATION, DEG . TOLERANCE + -
NODAL ANGLE, DEG EPHEMERIS ACCURACY, M
ESCAPE DV REQUIRED, M/S .

POINTING/ORIENTATION
VIEW DIRECTION ( ) INERTIAL ( ) SOLAR ( ) EARTH (X) ANY
TRUTH SITES (IF KNOWN)
POINTING ACCURACY, ARC-SEC FIELD OF VIEW (DEG)
POINTING STABILITY (JITTER), ARC-SEC/SEC
SPECIAL RESTRICTIONS (AVOIDANCE)

POWER
(X) AC ( ) DC

	POWER, W	DURATION, HRS/DAY
OPERATING	200	1.00
STANDBY	50	0.00
PEAK	500	0.00
VOLTAGE, V	28	FREQUENCY, HZ

( ) CONTINUOUS

```
DATA/COMMUNICATIONS
    MONITORING REQUIREMENTS:
    ( ) NONE          ( ) REALTIME    (X) OFFLINE      ( ) OTHER:
    ( ) ENCRIPTION/DECRIPTION REQUIRED
    ( ) UPLINK REQUIRED:  COMMAND RATE (KBS):                    FREQUENCY (MHZ):
    ( ) ON-BOARD DATA PROCESSING REQUIRED
        DESCRIPTION:
        DATA TYPES:   ( ) ANALOG      ( ) DIGITAL                HOURS/DAY
        FILM (AMOUNT):                    1000                   VOICE (HOURS/DAY):
        LIVE TV (HOURS/DAY):                                     OTHER:
        ON-BOARD STORAGE (MBIT):
        DATA DUMP FREQUENCY (PER ORBIT)                          DOWNLINK COMMAND RATE:
        RECORDING RATE (KBPS)                                    DOWNLINK FREQUENCY (MHZ):
--------------------------------------------------------------------------------------------------
THERMAL
    ( ) ACTIVE      (X) PASSIVE
        TEMPERATURE, DEG C   OPERATIONAL MINIMUM          4        MAXIMUM      40
                             NON-OPERATIONAL MINIMUM     25        MAXIMUM      40
        HEAT REJECTION, W    OPERATIONAL MINIMUM        200        MAXIMUM       0
                             NON-OPERATIONAL MINIMUM      0        MAXIMUM
--------------------------------------------------------------------------------------------------
EQUIPMENT PHYSICAL CHARACTERISTICS
    LOCATION          (X) INTERNAL         ( ) EXTERNAL          ( ) REMOTE
    EQUIPMENT ID/FUNCTION                  (X) PRESSURIZED       ( ) UNPRESSURIZED
                  L, M:      2.00      W, M:      1.00      H, M:      2.00      STOWED
                  L, M:      2.00      W, M:      1.00      H, M:      2.00      DEPLOYED
                  LAUNCH MASS, KG:     500                  RETURN MASS, KG:     100
                  CONSUMABLE TYPES
                  ACCELERATION SENSITIVITY, (G)       MIN:      E+00      MAX:      E+00
--------------------------------------------------------------------------------------------------
CREW REQUIREMENTS
    CREW SIZE          1            TASK ASSIGNMENTS
                                    -------------------------------------------------------
    SKILLS (SEE TABLE B)            ! SKILL    !        !        !        !        !        !
                                    -------------------------------------------------------
                                    ! LEVEL    !        !        !        !        !        !
                                    -------------------------------------------------------
                                    ! HOURS/DAY !       !        !        !        !        !
                                    -------------------------------------------------------
    EVA   ( ) YES    (X) NO         REASON                        HOURS/EVA
--------------------------------------------------------------------------------------------------
SERVICING/MAINTENANCE
    SERVICE:                            INTERVAL,  DAYS                  CONSUMABLES, KG
                                        RETURNABLES, KG                  MAN HOURS
    CONFIGURATION CHANGES:              INTERVAL, DAY                    MAN/HOURS REQUIRED
                                        DELIVERABLES, KG                 RETURNABLES, KG
--------------------------------------------------------------------------------------------------
SPECIAL CONSIDERATIONS/SEE INSTRUCTIONS
SPECIAL EQUIPMENT REQUIRED FOR COLLAGEN PROCESSING: UNIFORM-TEMPERATURE INCUBATOR; COLD STORAGE UNIT; FLUID
HANDLING PUMP; MICRO-FILTRATION; COLLAGEN FIXATION BY CHEMICAL CROSS-LINKING OR UV RADIATION; EPOXY
EMBEDMENT; DRYING.



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                                                        BOEING-SPECIFIC INPUT DATA
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MISSION TYPE                                    OPS CODE
   FREE FLYER
   ( ) NOT SERVICED                                F
   ( ) REMOTE TMS                                  FT
   ( ) REMOTE MANNED                               FM
   ( ) SERVICED AT STATION (TMS RETRIEVED)         FST
   ( ) SERVICED AT STATION (SELF-PROPELLED)        FS

   PLATFORM BASED
   ( ) NOT SERVICED                                P
   ( ) REMOTE TMS                                  PT
   ( ) REMOTE MANNED                               PM
   ( ) SERVICED AT STATION (TMS RETRIEVED)         PST
   ( ) SERVICED AT STATION (SELF-PROPELLED)        PS

   OTHER
   ( ) SPACE STATION BASED                         SS
   ( ) SORTIE                                      SOR

CONSTRUCTION/SERVICING COMPLEXITY
   ( ) LOW
   ( ) MEDIUM
   ( ) HIGH

OPERATIONS TIMES
   OTV UP/DOWN                           DAYS
   OTV OR TMS ON ORBIT                   DAYS
   MISSION USE                           DAYS/YEAR
   IVA SERVICE                           MAN-DAYS/YEAR
   EVA SERVICE                           MAN-DAYS/YEAR
   EXPERIMENT OPS                        MAN-DAYS/YEAR
   SERVICE FREQUENCY                     TIMES/YEAR

DELTA VELOCITIES
   UP                         0.00
   DOWN                       0.00
   AERO RETURN                0.00

SUPPORT EQUIPMENT
                LENGTH:       0.00 METERS      WIDTH:      0.00 METERS        HEIGHT:      0.00 METERS      (STOWED)
                LENGTH:       0.00 METERS      WIDTH:      0.00 METERS        HEIGHT:      0.00 METERS      (DEPLOYED)

                MASS:            0 KG

MANIFEST RESTRICTIONS
   (X) NO RESTRICTIONS
   ( ) ONLY WITH COMPATIBLE PAYLOADS
   ( ) FLY-ALONE
   ( ) MUST HAVE DOCKING MODULE

LENGTH OF BEAM FAB                                          0.00
NUMBER OF APPENDAGES                                           0
NUMBER OF MODULES REQUIRED TO ASSEMBLE THE PAYLOAD             0
------------------------------------------------------------------------------------------------------------------------------------
```

PAYLOAD ELEMENT NAME
INFRARED DETECTOR PRODUCTION

CODE
BACX1007

TYPE
( ) SCIENCE AND APPLICATIONS (NON-COMM.)
(X) COMMERCIAL
( ) TECHNOLOGY DEVELOPMENT
( ) OPERATIONS
( ) OTHER
( ) NATIONAL SECURITY
TYPE NUMBER (SEE TABLE A) 8

CONTACT
NAME DR. R.K. CROUCH
ADDRESS NASA-LANGLEY RESEARCH CE
HAMPTON, VA 23665

TELEPHONE

IMPORTANCE OF THE SPACE STATION TO THIS ELEMENT
1 = LOW VALUE, BUT COULD USE
10 = VITAL
SCALE = 4

STATUS
( ) OPERATIONAL ( ) APPROVED ( ) PLANNED (X) CANDIDATE ( ) OPPORTUNITY

DESIRED FIRST FLIGHT, YEAR: 1995
NUMBER OF FLIGHTS 5
DURATION OF FLIGHT, DAYS 30

OBJECTIVE
TO PROVIDE LARGE SCALE FACILITIES FOR THE GROWTH OF COMPOUND SEMICONDUCTOR CRYSTALS. FOR MANUFACTURE OF CRYSTALS OF THE PSEUDOBINARY LEAD-TIN-TELLURIDE SYSTEM WITH APPLICATIONS AS INFRARED DETECTORS AND TUNABLE LASERS FOR REMOTE SENSING.

DESCRIPTION
CRYSTALS ARE GROWN USING BOTH VAPOR TRANSPORT AND SOLIDIFICATION FROM MELT TECHNIQUES. COMMERCIAL MANUFACTURING UNITS ARE PLACED EITHER IN AN ATTACHED LABORATORY MODULE OR ON FREE-FLYERS (TO MINIMIZE ACCELERATION GRADIENT), PROBABLY TETHERED TO THE SPACE STATION. THE CRYSTAL AMPOULES ARE REPLACED PERIODICALLY, AND THE CRYSTALS ARE EXAMINED IN THE SPACE STATION. A LABORATORY ON THE SPACE STATION IS USED TO CHARACTERIZE THE CRYSTALS AND DEVELOP THE PROCESS.

ORBIT CHARACTERISTICS
GEOSYNCHRONOUS ORBIT ( ) YES (X) NO
APOGEE, KM
PERIGEE, KM
TOLERANCE + -
INCLINATION, DEG .
TOLERANCE + -
NODAL ANGLE, DEG
EPHEMERIS ACCURACY, M
ESCAPE DV REQUIRED, M/S .

POINTING/ORIENTATION
VIEW DIRECTION ( ) INERTIAL ( ) SOLAR ( ) EARTH (X) ANY
TRUTH SITES (IF KNOWN)
POINTING ACCURACY, ARC-SEC
FIELD OF VIEW (DEG)
POINTING STABILITY (JITTER), ARC-SEC/SEC
SPECIAL RESTRICTIONS (AVOIDANCE) AVOID LARGE ACCELERATION

POWER
( ) AC (X) DC

	POWER, W	DURATION, HRS/DAY
OPERATING	8000	24.00
STANDBY	0	0.00
PEAK	12000	5.00

( ) CONTINUOUS
VOLTAGE, V
FREQUENCY, HZ 0

```
DATA/COMMUNICATIONS
    MONITORING REQUIREMENTS:
    ( ) NONE        ( ) REALTIME    ( ) OFFLINE     ( ) OTHER:
    ( ) ENCRIPTION/DECRIPTION REQUIRED
    ( ) UPLINK REQUIRED:  COMMAND RATE (KBS):                FREQUENCY (MHZ):
    ( ) ON-BOARD DATA PROCESSING REQUIRED
        DESCRIPTION:
        DATA TYPES:   ( ) ANALOG      ( ) DIGITAL            HOURS/DAY
        FILM (AMOUNT):                                       VOICE (HOURS/DAY):
        LIVE TV (HOURS/DAY):                                 OTHER:
        ON-BOARD STORAGE (MBIT):
        DATA DUMP FREQUENCY (PER ORBIT)                      DOWNLINK COMMAND RATE:
        RECORDING RATE (KBPS)                                DOWNLINK FREQUENCY (MHZ):
-----------------------------------------------------------------------------------------------
THERMAL
    (X) ACTIVE      ( ) PASSIVE
        TEMPERATURE, DEG C   OPERATIONAL MINIMUM          890       MAXIMUM    950
                             NON-OPERATIONAL MINIMUM        0       MAXIMUM   1000
        HEAT REJECTION, W    OPERATIONAL MINIMUM         5000       MAXIMUM  15000
                             NON-OPERATIONAL MINIMUM        0       MAXIMUM
-----------------------------------------------------------------------------------------------
EQUIPMENT PHYSICAL CHARACTERISTICS
    LOCATION           (X) INTERNAL        ( ) EXTERNAL         ( ) REMOTE
    EQUIPMENT ID/FUNCTION                  (X) PRESSURIZED      ( ) UNPRESSURIZED
                   L, M:       2.00        W, M:      0.50      H, M:      0.50     STOWED
                   L, M:       2.00        W, M:      0.50      H, M:      0.50     DEPLOYED
                   LAUNCH MASS, KG:       400                   RETURN MASS, KG:       50
                   CONSUMABLE TYPES
                   ACCELERATION SENSITIVITY, (G)       MIN:  1.00E-04      MAX:  1.00E-02
-----------------------------------------------------------------------------------------------
CREW REQUIREMENTS
    CREW SIZE               1               TASK ASSIGNMENTS
                                            ------------------------------------------------
    SKILLS (SEE TABLE B)                    | SKILL     |  3   |     |     |     |     |     |
                                            ------------------------------------------------
                                            | LEVEL     |  2   |     |     |     |     |     |
                                            ------------------------------------------------
                                            | HOURS/DAY | 6.00 |     |     |     |     |     |
                                            ------------------------------------------------
    EVA   ( ) YES    (X) NO                 REASON                      HOURS/EVA
-----------------------------------------------------------------------------------------------
SERVICING/MAINTENANCE
    SERVICE:                                   INTERVAL,  DAYS                 CONSUMABLES, KG
                                               RETURNABLES, KG                 MAN HOURS
    CONFIGURATION CHANGES:                     INTERVAL, DAY                   MAN/HOURS REQUIRED
                                               DELIVERABLES, KG                RETURNABLES, KG
-----------------------------------------------------------------------------------------------
SPECIAL CONSIDERATIONS/SEE INSTRUCTIONS
LABORATORY FACILITIES REQUIRED: CLEAN ROOM, WORKSPACE, SOME COMPUTING CAPABILITY
CRYSTAL CHARACTERIZATION EQUIPMENT REQUIRED: MICROSCOPE, SMALL WET CHEMISTRY LAB, CUTTING SAW, HALL
APPARATUS



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ORIGINAL PAGE IS
OF POOR QUALITY

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                                                  BOEING-SPECIFIC INPUT DATA
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MISSION TYPE                                  OPS CODE
   FREE FLYER
   ( ) NOT SERVICED                              F
   ( ) REMOTE TMS                                FT
   ( ) REMOTE MANNED                             FM
   ( ) SERVICED AT STATION (TMS RETRIEVED)       FST
   ( ) SERVICED AT STATION (SELF-PROPELLED)      FS

   PLATFORM BASED
   ( ) NOT SERVICED                              P
   ( ) REMOTE TMS                                PT
   ( ) REMOTE MANNED                             PM
   ( ) SERVICED AT STATION (TMS RETRIEVED)       PST
   ( ) SERVICED AT STATION (SELF-PROPELLED)      PS

   OTHER
   ( ) SPACE STATION BASED                       SS
   ( ) SORTIE                                    SOR

CONSTRUCTION/SERVICING COMPLEXITY
   ( ) LOW
   ( ) MEDIUM
   ( ) HIGH

OPERATIONS TIMES
   OTV UP/DOWN                        DAYS
   OTV OR TMS ON ORBIT                DAYS
   MISSION USE                        DAYS/YEAR
   IVA SERVICE                        MAN-DAYS/YEAR
   EVA SERVICE                        MAN-DAYS/YEAR
   EXPERIMENT OPS                     MAN-DAYS/YEAR
   SERVICE FREQUENCY                  TIMES/YEAR

DELTA VELOCITIES
   UP                      0.00
   DOWN                    0.00
   AERO RETURN             0.00

SUPPORT EQUIPMENT
             LENGTH:       0.00 METERS      WIDTH:      0.00 METERS        HEIGHT:      0.00 METERS      (STOWED)
             LENGTH:       0.00 METERS      WIDTH:      0.00 METERS        HEIGHT:      0.00 METERS      (DEPLOYED)

             MASS:           0 KG

MANIFEST RESTRICTIONS
   (X) NO RESTRICTIONS
   ( ) ONLY WITH COMPATIBLE PAYLOADS
   ( ) FLY-ALONE
   ( ) MUST HAVE DOCKING MODULE

LENGTH OF BEAM FAB                                        0.00
NUMBER OF APPENDAGES                                        0
NUMBER OF MODULES REQUIRED TO ASSEMBLE THE PAYLOAD          0
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```

PAYLOAD ELEMENT NAME
ELECTROEPITAXIAL CRYSTAL GROWTH

CODE
BACX1008

TYPE
( ) SCIENCE AND APPLICATIONS (NON-COMM.)
(X) COMMERCIAL
( ) TECHNOLOGY DEVELOPMENT
( ) OPERATIONS
( ) OTHER
( ) NATIONAL SECURITY
TYPE NUMBER (SEE TABLE A) 8

CONTACT
NAME ROBERT E. PACE, JR.
ADDRESS MICROGRAVITY RESEARCH AS
PO BOX 12426
HUNTSVILLE, AL 35802

TELEPHONE (205) 881-6670

IMPORTANCE OF THE SPACE STATION TO THIS ELEMENT
1 = LOW VALUE, BUT COULD USE
10 = VITAL
SCALE = 7

STATUS
( ) OPERATIONAL ( ) APPROVED (X) PLANNED ( ) CANDIDATE ( ) OPPORTUNITY

DESIRED FIRST FLIGHT, YEAR: 1992 NUMBER OF FLIGHTS 1 DURATION OF FLIGHT, DAYS 35

OBJECTIVE
DEVELOP AND COMMERCIALIZE A PROCESS FOR PRODUCING LARGE SINGLE CRYSTALS OF COMPOUND SEMICONDUCTOR MATERIALS.

DESCRIPTION
CRYSTALS ARE GROWN IN SPACE BY AN ELECTROEPITAXIAL GROWTH PROCESS. COMMERCIAL MANUFACTURING UNITS ARE PLACED IN MODULES ATTACHED TO THE SPACE STATION, AND GROWTH CELLS ARE REPLACED PERIODICALLY AND CRYSTALS RETURNED TO EARTH. A PROCESS DEVELOPMENT LABORATORY ON THE SPACE STATION IS USED TO CHARACTERIZE THE CRYSTALS AND DEVELOP THE PROCESS.

ORBIT CHARACTERISTICS
GEOSYNCHRONOUS ORBIT ( ) YES (X) NO
APOGEE, KM PERIGEE, KM TOLERANCE + -
INCLINATION, DEG . TOLERANCE + -
NODAL ANGLE, DEG EPHEMERIS ACCURACY, M
ESCAPE DV REQUIRED, M/S .

POINTING/ORIENTATION
VIEW DIRECTION ( ) INERTIAL ( ) SOLAR ( ) EARTH (X) ANY
TRUTH SITES (IF KNOWN)
POINTING ACCURACY, ARC-SEC FIELD OF VIEW (DEG)
POINTING STABILITY (JITTER), ARC-SEC/SEC
SPECIAL RESTRICTIONS (AVOIDANCE)

POWER
( ) AC (X) DC

	POWER, W	DURATION, HRS/DAY
OPERATING	20000	24.00
STANDBY		
PEAK	20000	24.00

(X) CONTINUOUS

VOLTAGE, V 50 FREQUENCY, HZ 0

```
DATA/COMMUNICATIONS
   MONITORING REQUIREMENTS:
   ( ) NONE        ( ) REALTIME    (X) OFFLINE     ( ) OTHER:
   ( ) ENCRIPTION/DECRIPTION REQUIRED
   ( ) UPLINK REQUIRED:  COMMAND RATE (KBS):        0          FREQUENCY (MHZ):
   ( ) ON-BOARD DATA PROCESSING REQUIRED
       DESCRIPTION:
       DATA TYPES:   ( ) ANALOG      ( ) DIGITAL               HOURS/DAY
       FILM (AMOUNT):                                          VOICE (HOURS/DAY):
       LIVE TV (HOURS/DAY):                                    OTHER:
       ON-BOARD STORAGE (MBIT):
       DATA DUMP FREQUENCY (PER ORBIT)                         DOWNLINK COMMAND RATE:
       RECORDING RATE (KBPS)          0.10                     DOWNLINK FREQUENCY (MHZ):
--------------------------------------------------------------------------------------------------------
THERMAL
   (X) ACTIVE      ( ) PASSIVE
       TEMPERATURE, DEG C   OPERATIONAL MINIMUM          850        MAXIMUM     950
                            NON-OPERATIONAL MINIMUM        0        MAXIMUM     100
       HEAT REJECTION, W    OPERATIONAL MINIMUM        10000        MAXIMUM   20000
                            NON-OPERATIONAL MINIMUM        0        MAXIMUM
--------------------------------------------------------------------------------------------------------
EQUIPMENT PHYSICAL CHARACTERISTICS
   LOCATION          (X) INTERNAL          ( ) EXTERNAL          ( ) REMOTE
   EQUIPMENT ID/FUNCTION                   (X) PRESSURIZED       ( ) UNPRESSURIZED
                     L, M:      5.00       W, M:       1.00      H, M:       4.00    STOWED
                     L, M:      5.00       W, M:       1.00      H, M:       4.00    DEPLOYED
                     LAUNCH MASS, KG:      1950                  RETURN MASS, KG:    0
                     CONSUMABLE TYPES
                     ACCELERATION SENSITIVITY, (G)       MIN:  1.00E-06      MAX:  1.00E-04
--------------------------------------------------------------------------------------------------------
CREW REQUIREMENTS
   CREW SIZE            2           TASK ASSIGNMENTS
                                    ------------------------------------------------------------
   SKILLS (SEE TABLE B)             | SKILL     |        |        |        |        |        |        |
                                    ------------------------------------------------------------
                                    | LEVEL     |        |        |        |        |        |        |
                                    ------------------------------------------------------------
                                    | HOURS/DAY |  4.00  |        |        |        |        |        |
                                    ------------------------------------------------------------
   EVA   ( ) YES    (X) NO          REASON                            HOURS/EVA
--------------------------------------------------------------------------------------------------------
SERVICING/MAINTENANCE
   SERVICE:                             INTERVAL,  DAYS        90          CONSUMABLES, KG
                                        RETURNABLES, KG      1950          MAN HOURS
   CONFIGURATION CHANGES:               INTERVAL, DAY                      MAN/HOURS REQUIRED
                                        DELIVERABLES, KG                   RETURNABLES, KG
--------------------------------------------------------------------------------------------------------
SPECIAL CONSIDERATIONS/SEE INSTRUCTIONS
LABORATORY FACILITIES REQUIRED: CLEAN ROOM, WORKSPACE, MINICOMUTER, DOWNLINK TERMINAL
CRYSTAL CHARACTERIZATION EQUIPMENT REQUIRED: CUTTING SAW, POLISHER, ETCHER, COMPACT EVAPORATOR, HALL
APPARATUS LIGHT SOURCE AND SPECTROMETER.

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                                                    BOEING-SPECIFIC INPUT DATA
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MISSION TYPE                                 OPS CODE
   FREE FLYER
   ( ) NOT SERVICED                             F
   ( ) REMOTE TMS                               FT
   ( ) REMOTE MANNED                            FM
   ( ) SERVICED AT STATION (TMS RETRIEVED)      FST
   ( ) SERVICED AT STATION (SELF-PROPELLED)     FS

   PLATFORM BASED
   ( ) NOT SERVICED                             P
   ( ) REMOTE TMS                               PT
   ( ) REMOTE MANNED                            PM
   ( ) SERVICED AT STATION (TMS RETRIEVED)      PST
   ( ) SERVICED AT STATION (SELF-PROPELLED)     PS

   OTHER
   ( ) SPACE STATION BASED                      SS
   ( ) SORTIE                                   SOR

CONSTRUCTION/SERVICING COMPLEXITY
   ( ) LOW
   ( ) MEDIUM
   ( ) HIGH

OPERATIONS TIMES
   OTV UP/DOWN                      DAYS
   OTV OR TMS ON ORBIT              DAYS
   MISSION USE                      DAYS/YEAR
   IVA SERVICE                      MAN-DAYS/YEAR
   EVA SERVICE                      MAN-DAYS/YEAR
   EXPERIMENT OPS                   MAN-DAYS/YEAR
   SERVICE FREQUENCY                TIMES/YEAR

DELTA VELOCITIES
   UP                       0.00
   DOWN                     0.00
   AERO RETURN              0.00

SUPPORT EQUIPMENT
             LENGTH:        0.00 METERS      WIDTH:     0.00 METERS        HEIGHT:     0.00 METERS      (STOWED)
             LENGTH:        0.00 METERS      WIDTH:     0.00 METERS        HEIGHT:     0.00 METERS      (DEPLOYED)

             MASS:             0 KG

MANIFEST RESTRICTIONS
   (X) NO RESTRICTIONS
   ( ) ONLY WITH COMPATIBLE PAYLOADS
   ( ) FLY-ALONE
   ( ) MUST HAVE DOCKING MODULE

LENGTH OF BEAM FAB                                        0.00
NUMBER OF APPENDAGES                                         0
NUMBER OF MODULES REQUIRED TO ASSEMBLE THE PAYLOAD           0
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PAYLOAD ELEMENT NAME
ELECTROEPITAXIAL CRYSTAL GROWTH

CODE
BACX1009

TYPE
( ) SCIENCE AND APPLICATIONS (NON-COMM.)
(X) COMMERCIAL
( ) TECHNOLOGY DEVELOPMENT
( ) OPERATIONS
( ) OTHER
( ) NATIONAL SECURITY
TYPE NUMBER (SEE TABLE A) 8

CONTACT
NAME ROBERT E. PACE, JR.
ADDRESS MICROGRAVITY RESEARCH AS
PO BOX 12426
HUNTSVILLE, AL 35802

TELEPHONE (205) 881-6670

IMPORTANCE OF THE SPACE STATION TO THIS ELEMENT
1 = LOW VALUE, BUT COULD USE
10 = VITAL
SCALE = 7

STATUS
( ) OPERATIONAL ( ) APPROVED (X) PLANNED ( ) CANDIDATE ( ) OPPORTUNITY

DESIRED FIRST FLIGHT, YEAR: 1992
NUMBER OF FLIGHTS 1
DURATION OF FLIGHT, DAYS 35

OBJECTIVE
DEVELOP AND COMMERCIALIZE A PROCESS FOR PRODUCING LARGE SINGLE CRYSTALS OF COMPOUND SEMICONDUCTOR MATERIALS.

DESCRIPTION
CRYSTALS ARE GROWN IN SPACE BY AN ELECTROEPITAXIAL GROWTH PROCESS. COMMERCIAL MANUFACTURING UNITS ARE PLACED IN MODULES ATTACHED TO THE SPACE STATION, AND GROWTH CELLS ARE REPLACED PERIODICALLY AND CRYSTALS RETURNED TO EARTH. A PROCESS DEVELOPMENT LABORATORY ON THE SPACE STATION IS USED TO CHARACTERIZE THE CRYSTALS AND DEVELOP
THE PROCESS.

ORBIT CHARACTERISTICS
GEOSYNCHRONOUS ORBIT ( ) YES (X) NO
APOGEE, KM
PERIGEE, KM
INCLINATION, DEG .
TOLERANCE + -
NODAL ANGLE, DEG
TOLERANCE + -
ESCAPE DV REQUIRED, M/S .
EPHEMERIS ACCURACY, M

POINTING/ORIENTATION
VIEW DIRECTION ( ) INERTIAL ( ) SOLAR ( ) EARTH (X) ANY
TRUTH SITES (IF KNOWN)
POINTING ACCURACY, ARC-SEC
FIELD OF VIEW (DEG)
POINTING STABILITY (JITTER), ARC-SEC/SEC
SPECIAL RESTRICTIONS (AVOIDANCE)

POWER
( ) AC (X) DC

	POWER, W	DURATION, HRS/DAY
OPERATING	20000	24.00
STANDBY		
PEAK	20000	24.00

(X) CONTINUOUS

VOLTAGE, V 50
FREQUENCY, HZ 0

```
DATA/COMMUNICATIONS
   MONITORING REQUIREMENTS:
   ( ) NONE        ( ) REALTIME   (X) OFFLINE    ( ) OTHER:
   ( ) ENCRIPTION/DECRIPTION REQUIRED
   ( ) UPLINK REQUIRED:  COMMAND RATE (KBS):       0         FREQUENCY (MHZ):
   ( ) ON-BOARD DATA PROCESSING REQUIRED
       DESCRIPTION:
       DATA TYPES:   ( ) ANALOG      ( ) DIGITAL                 HOURS/DAY
       FILM (AMOUNT):                                            VOICE (HOURS/DAY):
       LIVE TV (HOURS/DAY):                                      OTHER:
       ON-BOARD STORAGE (MBIT):
       DATA DUMP FREQUENCY (PER ORBIT)                           DOWNLINK COMMAND RATE:
       RECORDING RATE (KBPS)          0.10                       DOWNLINK FREQUENCY (MHZ):
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THERMAL
   (X) ACTIVE      ( ) PASSIVE
       TEMPERATURE, DEG C  OPERATIONAL MINIMUM          850         MAXIMUM     950
                           NON-OPERATIONAL MINIMUM        0         MAXIMUM     100
       HEAT REJECTION, W   OPERATIONAL MINIMUM        10000         MAXIMUM   20000
                           NON-OPERATIONAL MINIMUM        0         MAXIMUM
--------------------------------------------------------------------------------------------------------
EQUIPMENT PHYSICAL CHARACTERISTICS
   LOCATION        (X) INTERNAL           ( ) EXTERNAL        ( ) REMOTE
   EQUIPMENT ID/FUNCTION                  (X) PRESSURIZED     ( ) UNPRESSURIZED
                L, M:      5.00        W, M:       1.00     H, M:       4.00     STOWED
                L, M:      5.00        W, M:       1.00     H, M:       4.00     DEPLOYED
                LAUNCH MASS, KG:       1000                 RETURN MASS, KG:      1000
                CONSUMABLE TYPES
                ACCELERATION SENSITIVITY, (G)        MIN:  1.00E-06      MAX:  1.00E-04
--------------------------------------------------------------------------------------------------------
CREW REQUIREMENTS
   CREW SIZE             2              TASK ASSIGNMENTS
                                        -------------------------------------------------------------
   SKILLS (SEE TABLE B)                 ! SKILL     !        !        !        !        !        !        !
                                        -------------------------------------------------------------
                                        ! LEVEL     !        !        !        !        !        !        !
                                        -------------------------------------------------------------
                                        ! HOURS/DAY !  4.00  !        !        !        !        !        !
                                        -------------------------------------------------------------
   EVA   ( ) YES    (X) NO              REASON                          HOURS/EVA
--------------------------------------------------------------------------------------------------------
SERVICING/MAINTENANCE
   SERVICE:                     INTERVAL,  DAYS         90          CONSUMABLES, KG
                                RETURNABLES, KG       1000          MAN HOURS
   CONFIGURATION CHANGES:       INTERVAL, DAY                       MAN/HOURS REQUIRED
                                DELIVERABLES, KG                    RETURNABLES, KG
--------------------------------------------------------------------------------------------------------
SPECIAL CONSIDERATIONS/SEE INSTRUCTIONS
LABORATORY FACILITIES REQUIRED: CLEAN ROOM, WORKSPACE, MINICOMUTER, DOWNLINK TERMINAL
CRYSTAL CHARACTERIZATION EQUIPMENT REQUIRED: CUTTING SAW, POLISHER, ETCHER, COMPACT EVAPORATOR, HALL
APPARATUS LIGHT SOURCE AND SPECTROMETER.


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ORIGINAL PAGE IS
OF POOR QUALITY

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                                          BOEING-SPECIFIC INPUT DATA
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MISSION TYPE                                    OPS CODE
   FREE FLYER
   ( ) NOT SERVICED                                F
   ( ) REMOTE TMS                                  FT
   ( ) REMOTE MANNED                               FM
   ( ) SERVICED AT STATION (TMS RETRIEVED)         FST
   ( ) SERVICED AT STATION (SELF-PROPELLED)        FS

   PLATFORM BASED
   ( ) NOT SERVICED                                P
   ( ) REMOTE TMS                                  PT
   ( ) REMOTE MANNED                               PM
   ( ) SERVICED AT STATION (TMS RETRIEVED)         PST
   ( ) SERVICED AT STATION (SELF-PROPELLED)        PS

   OTHER
   ( ) SPACE STATION BASED                         SS
   ( ) SORTIE                                      SOR

CONSTRUCTION/SERVICING COMPLEXITY
   ( ) LOW
   ( ) MEDIUM
   ( ) HIGH

OPERATIONS TIMES
   OTV UP/DOWN                           DAYS
   OTV OR TMS ON ORBIT                   DAYS
   MISSION USE                           DAYS/YEAR
   IVA SERVICE                           MAN-DAYS/YEAR
   EVA SERVICE                           MAN-DAYS/YEAR
   EXPERIMENT OPS                        MAN-DAYS/YEAR
   SERVICE FREQUENCY                     TIMES/YEAR

DELTA VELOCITIES
   UP                     0.00
   DOWN                   0.00
   AERO RETURN            0.00

SUPPORT EQUIPMENT
             LENGTH:      0.00 METERS      WIDTH:     0.00 METERS      HEIGHT:     0.00 METERS     (STOWED)
             LENGTH:      0.00 METERS      WIDTH:     0.00 METERS      HEIGHT:     0.00 METERS     (DEPLOYED)

             MASS:          0 KG

MANIFEST RESTRICTIONS
   (X) NO RESTRICTIONS
   ( ) ONLY WITH COMPATIBLE PAYLOADS
   ( ) FLY-ALONE
   ( ) MUST HAVE DOCKING MODULE

LENGTH OF BEAM FAB                                          0.00
NUMBER OF APPENDAGES                                           0
NUMBER OF MODULES REQUIRED TO ASSEMBLE THE PAYLOAD             0
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PAYLOAD ELEMENT NAME
ELECTROEPITAXIAL CRYSTAL GROWTH

CODE
BACX1010

TYPE
( ) SCIENCE AND APPLICATIONS (NON-COMM.)
(X) COMMERCIAL
( ) TECHNOLOGY DEVELOPMENT
( ) OPERATIONS
( ) OTHER
( ) NATIONAL SECURITY
TYPE NUMBER (SEE TABLE A) 8

CONTACT
NAME ROBERT E. PACE, JR.
ADDRESS MICROGRAVITY RESEARCH AS
PO BOX 12426
HUNTSVILLE, AL 35802

TELEPHONE (205) 881-6670

IMPORTANCE OF THE SPACE STATION TO THIS ELEMENT
1 = LOW VALUE, BUT COULD USE
10 = VITAL
SCALE = 7

STATUS
( ) OPERATIONAL ( ) APPROVED (X) PLANNED ( ) CANDIDATE ( ) OPPORTUNITY

DESIRED FIRST FLIGHT, YEAR: 1993 NUMBER OF FLIGHTS 1 DURATION OF FLIGHT, DAYS 35

OBJECTIVE
DEVELOP AND COMMERCIALIZE A PROCESS FOR PRODUCING LARGE SINGLE CRYSTALS OF COMPOUND SEMICONDUCTOR MATERIALS.

DESCRIPTION
CRYSTALS ARE GROWN IN SPACE BY AN ELECTROEPITAXIAL GROWTH PROCESS. COMMERCIAL MANUFACTURING UNITS ARE PLACED IN MODULES ATTACHED TO THE SPACE STATION, AND GROWTH CELLS ARE REPLACED PERIODICALLY AND CRYSTALS RETURNED TO EARTH. A PROCESS DEVELOPMENT LABORATORY ON THE SPACE STATION IS USED TO CHARACTERIZE THE CRYSTALS AND DEVELOP THE PROCESS.

ORBIT CHARACTERISTICS
GEOSYNCHRONOUS ORBIT ( ) YES (X) NO
APOGEE, KM PERIGEE, KM
INCLINATION, DEG . TOLERANCE + -
NODAL ANGLE, DEG TOLERANCE + -
ESCAPE DV REQUIRED, M/S . EPHEMERIS ACCURACY, M

POINTING/ORIENTATION
VIEW DIRECTION ( ) INERTIAL ( ) SOLAR ( ) EARTH (X) ANY
TRUTH SITES (IF KNOWN)
POINTING ACCURACY, ARC-SEC
POINTING STABILITY (JITTER), ARC-SEC/SEC FIELD OF VIEW (DEG)
SPECIAL RESTRICTIONS (AVOIDANCE)

POWER
( ) AC (X) DC

	POWER, W	DURATION, HRS/DAY	
OPERATING	20000	24.00	
STANDBY			
PEAK	20000	24.00	(X) CONTINUOUS
VOLTAGE, V	50	FREQUENCY, HZ	0

.A/COMMU TIONS
MONITORING REQUIREMENTS:
( ) NONE ( ) REALTIME (X) OFFLINE ( ) OTHER:
( ) ENCRIPTION/DECRIPTION REQUIRED
( ) UPLINK REQUIRED: COMMAND RATE (KBS): 0 FREQUENCY (MHZ):
( ) ON-BOARD DATA PROCESSING REQUIRED
DESCRIPTION:
DATA TYPES: ( ) ANALOG ( ) DIGITAL
HOURS/DAY
FILM (AMOUNT):
VOICE (HOURS/DAY):
LIVE TV (HOURS/DAY):
OTHER:
ON-BOARD STORAGE (MBIT):
DATA DUMP FREQUENCY (PER ORBIT)
DOWNLINK COMMAND RATE:
RECORDING RATE (KBPS) 0.10
DOWNLINK FREQUENCY (MHZ):

THERMAL
(X) ACTIVE ( ) PASSIVE

TEMPERATURE, DEG C	OPERATIONAL MINIMUM	850	MAXIMUM	950
	NON-OPERATIONAL MINIMUM	0	MAXIMUM	100
HEAT REJECTION, W	OPERATIONAL MINIMUM	10000	MAXIMUM	20000
	NON-OPERATIONAL MINIMUM	0	MAXIMUM	

EQUIPMENT PHYSICAL CHARACTERISTICS
LOCATION (X) INTERNAL ( ) EXTERNAL ( ) REMOTE
EQUIPMENT ID/FUNCTION (X) PRESSURIZED ( ) UNPRESSURIZED

L, M: 5.00	W, M:	1.00	H, M:	4.00	STOWED
L, M: 5.00	W, M:	1.00	H, M:	4.00	DEPLOYED

LAUNCH MASS, KG: 1460 RETURN MASS, KG: 1000
CONSUMABLE TYPES
ACCELERATION SENSITIVITY, (G) MIN: 1.00E-06 MAX: 1.00E-04

CREW REQUIREMENTS
CREW SIZE 2
TASK ASSIGNMENTS
SKILLS (SEE TABLE B)

SKILL						
LEVEL						
HOURS/DAY	4.00					

EVA ( ) YES (X) NO REASON HOURS/EVA

SERVICING/MAINTENANCE
SERVICE: INTERVAL, DAYS 90 CONSUMABLES, KG
RETURNABLES, KG 1450 MAN HOURS
CONFIGURATION CHANGES: INTERVAL, DAY MAN/HOURS REQUIRED
DELIVERABLES, KG RETURNABLES, KG

SPECIAL CONSIDERATIONS/SEE INSTRUCTIONS
LABORATORY FACILITIES REQUIRED: CLEAN ROOM, WORKSPACE, MINICOMUTER, DOWNLINK TERMINAL
CRYSTAL CHARACTERIZATION EQUIPMENT REQUIRED: CUTTING SAW, POLISHER, ETCHER, COMPACT EVAPORATOR, HALL APPARATUS LIGHT SOURCE AND SPECTROMETER.

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                                          BOEING-SPECIFIC INPUT DATA
---------------------------------------------------------------------------------------------------------------
MISSION TYPE                                  OPS CODE
   FREE FLYER
   ( ) NOT SERVICED                              F
   ( ) REMOTE TMS                                FT
   ( ) REMOTE MANNED                             FM
   ( ) SERVICED AT STATION (TMS RETRIEVED)       FST
   ( ) SERVICED AT STATION (SELF-PROPELLED)      FS

   PLATFORM BASED
   ( ) NOT SERVICED                              P
   ( ) REMOTE TMS                                PT
   ( ) REMOTE MANNED                             PM
   ( ) SERVICED AT STATION (TMS RETRIEVED)       PST
   ( ) SERVICED AT STATION (SELF-PROPELLED)      PS

   OTHER
   ( ) SPACE STATION BASED                       SS
   ( ) SORTIE                                    SOR

CONSTRUCTION/SERVICING COMPLEXITY
   ( ) LOW
   ( ) MEDIUM
   ( ) HIGH

OPERATIONS TIMES
   OTV UP/DOWN                        DAYS
   OTV OR TMS ON ORBIT                DAYS
   MISSION USE                        DAYS/YEAR
   IVA SERVICE                        MAN-DAYS/YEAR
   EVA SERVICE                        MAN-DAYS/YEAR
   EXPERIMENT OPS                     MAN-DAYS/YEAR
   SERVICE FREQUENCY                  TIMES/YEAR

DELTA VELOCITIES
   UP                        0.00
   DOWN                      0.00
   AERO RETURN               0.00

SUPPORT EQUIPMENT
            LENGTH:          0.00 METERS       WIDTH:       0.00 METERS        HEIGHT:       0.00 METERS     (STOWED)
            LENGTH:          0.00 METERS       WIDTH:       0.00 METERS        HEIGHT:       0.00 METERS     (DEPLOYED)

            MASS:               0 KG

MANIFEST RESTRICTIONS
   (X) NO RESTRICTIONS
   ( ) ONLY WITH COMPATIBLE PAYLOADS
   ( ) FLY-ALONE
   ( ) MUST HAVE DOCKING MODULE

LENGTH OF BEAM FAB                                        0.00
NUMBER OF APPENDAGES                                         0
NUMBER OF MODULES REQUIRED TO ASSEMBLE THE PAYLOAD:          0
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```

D ELEMENT NAME
TROEPITAXIAL CRYSTAL GROWTH

CODE
BACX1011

TYPE
( ) SCIENCE AND APPLICATIONS (NON-COMM.)
(X) COMMERCIAL
( ) TECHNOLOGY DEVELOPMENT
( ) OPERATIONS
( ) OTHER
( ) NATIONAL SECURITY
TYPE NUMBER (SEE TABLE A) 8

CONTACT
NAME ROBERT E. PACE, JR.
ADDRESS MICROGRAVITY RESEARCH AS
PO BOX 12426
HUNTSVILLE, AL 35802

TELEPHONE (205) 881-6670

IMPORTANCE OF THE SPACE STATION TO THIS ELEMENT
1 = LOW VALUE, BUT COULD USE
10 = VITAL
SCALE = 7

STATUS
( ) OPERATIONAL ( ) APPROVED ( ) PLANNED (X) PLANNED ( ) CANDIDATE ( ) OPPORTUNITY

DESIRED FIRST FLIGHT, YEAR: 1993 NUMBER OF FLIGHTS 1 DURATION OF FLIGHT, DAYS 52

OBJECTIVE
DEVELOP AND COMMERCIALIZE A PROCESS FOR PRODUCING LARGE SINGLE CRYSTALS OF COMPOUND SEMICONDUCTOR MATERIALS.

ORIGINAL PAGE IS
OF POOR QUALITY

DESCRIPTION
CRYSTALS ARE GROWN IN SPACE BY AN ELECTROEPITAXIAL GROWTH PROCESS. COMMERCIAL MANUFACTURING UNITS ARE PLACED IN MODULES ATTACHED TO THE SPACE STATION, AND GROWTH CELLS ARE REPLACED PERIODICALLY AND CRYSTALS RETURNED TO EARTH. A PROCESS DEVELOPMENT LABORATORY ON THE SPACE STATION IS USED TO CHARACTERIZE THE CRYSTALS AND DEVELOP
THE PROCESS.

ORBIT CHARACTERISTICS
GEOSYNCHRONOUS ORBIT ( ) YES (X) NO
APOGEE, KM PERIGEE, KM TOLERANCE + -
INCLINATION, DEG . TOLERANCE + -
NODAL ANGLE, DEG EPHEMERIS ACCURACY, M
ESCAPE DV REQUIRED, M/S .

POINTING/ORIENTATION
VIEW DIRECTION ( ) INERTIAL ( ) SOLAR ( ) EARTH (X) ANY
TRUTH SITES (IF KNOWN)
POINTING ACCURACY, ARC-SEC FIELD OF VIEW (DEG)
POINTING STABILITY (JITTER), ARC-SEC/SEC
SPECIAL RESTRICTIONS (AVOIDANCE)

POWER
( ) AC (X) DC

	POWER, W	DURATION, HRS/DAY
OPERATING	20000	24.00
STANDBY		
PEAK	20000	24.00
VOLTAGE, V	50	FREQUENCY, HZ 0

(X) CONTINUOUS

```
   MU  ATIONS
  ITORING REQUIREMENTS:
   ) NONE          ( ) REALTIME    (X) OFFLINE     ( ) OTHER:
  ( ) ENCRIPTION/DECRIPTION REQUIRED
  ( ) UPLINK REQUIRED:  COMMAND RATE (KBS):       0          FREQUENCY (MHZ):
  ( ) ON-BOARD DATA PROCESSING REQUIRED
      DESCRIPTION:
      DATA TYPES:   ( ) ANALOG     ( ) DIGITAL               HOURS/DAY
      FILM (AMOUNT):                                         VOICE (HOURS/DAY):
      LIVE TV (HOURS/DAY):                                   OTHER:
      ON-BOARD STORAGE (MBIT):
      DATA DUMP FREQUENCY (PER ORBIT)                        DOWNLINK COMMAND RATE:
      RECORDING RATE (KBPS)          0.10                    DOWNLINK FREQUENCY (MHZ):
-----------------------------------------------------------------------------------------
THERMAL
   (X) ACTIVE      ( ) PASSIVE
      TEMPERATURE, DEG C    OPERATIONAL MINIMUM          850         MAXIMUM    950
                            NON-OPERATIONAL MINIMUM        0         MAXIMUM    100
      HEAT REJECTION, W     OPERATIONAL MINIMUM        10000         MAXIMUM  20000
                            NON-OPERATIONAL MINIMUM        0         MAXIMUM
-----------------------------------------------------------------------------------------
EQUIPMENT PHYSICAL CHARACTERISTICS
   LOCATION       (X) INTERNAL         ( ) EXTERNAL         ( ) REMOTE
   EQUIPMENT ID/FUNCTION               (X) PRESSURIZED      ( ) UNPRESSURIZED
                  L, M:     5.00       W, M:     1.00       H, M:     4.00     STOWED
                  L, M:     5.00       W, M:     1.00       H, M:     4.00     DEPLOYED
                  LAUNCH MASS, KG:     1460                 RETURN MASS, KG:     1460
                  CONSUMABLE TYPES
                  ACCELERATION SENSITIVITY, (G)      MIN:  1.00E-06     MAX:  1.00E-04
-----------------------------------------------------------------------------------------
CREW REQUIREMENTS
   CREW SIZE           2              TASK ASSIGNMENTS
                                      -----------------------------------------------------
   SKILLS (SEE TABLE B)               ! SKILL     !        !        !      !      !      !
                                      -----------------------------------------------------
                                      ! LEVEL     !        !        !      !      !      !
                                      -----------------------------------------------------
                                      ! HOURS/DAY !  4.00  !        !      !      !      !
                                      -----------------------------------------------------
   EVA   ( ) YES    (X) NO            REASON                       HOURS/EVA
-----------------------------------------------------------------------------------------
SERVICING/MAINTENANCE
   SERVICE:
                                INTERVAL,  DAYS        90            CONSUMABLES, KG
                                RETURNABLES, KG      1460            MAN HOURS
   CONFIGURATION CHANGES:       INTERVAL, DAY                        MAN/HOURS REQUIRED
                                DELIVERABLES, KG                     RETURNABLES, KG
-----------------------------------------------------------------------------------------
SPECIAL CONSIDERATIONS/SEE INSTRUCTIONS
LABORATORY FACILITIES REQUIRED: CLEAN ROOM, WORKSPACE, MINICOMUTER, DOWNLINK TERMINAL
CRYSTAL CHARACTERIZATION EQUIPMENT REQUIRED: CUTTING SAW, POLISHER, ETCHER, COMPACT EVAPORATOR, HALL
APPARATUS LIGHT SOURCE AND SPECTROMETER.

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                                        BOEING-SPECIFIC INPUT DATA
--------------------------------------------------------------------------------------------------
MISSION TYPE                              OPS CODE
  FREE FLYER
  ( ) NOT SERVICED                          F
  ( ) REMOTE TMS                            FT
  ( ) REMOTE MANNED                         FM
  ( ) SERVICED AT STATION (TMS RETRIEVED)   FST
  ( ) SERVICED AT STATION (SELF-PROPELLED)  FS

  PLATFORM BASED
  ( ) NOT SERVICED                          P
  ( ) REMOTE TMS                            PT
  ( ) REMOTE MANNED                         PM
  ( ) SERVICED AT STATION (TMS RETRIEVED)   PST
  ( ) SERVICED AT STATION (SELF-PROPELLED)  PS

  OTHER
  ( ) SPACE STATION BASED                   SS
  ( ) SORTIE                                SOR

CONSTRUCTION/SERVICING COMPLEXITY
  ( ) LOW
  ( ) MEDIUM
  ( ) HIGH

OPERATIONS TIMES
  OTV UP/DOWN                          DAYS
  OTV OR TMS ON ORBIT                  DAYS
  MISSION USE                          DAYS/YEAR
  IVA SERVICE                          MAN-DAYS/YEAR
  EVA SERVICE                          MAN-DAYS/YEAR
  EXPERIMENT OPS                       MAN-DAYS/YEAR
  SERVICE FREQUENCY                    TIMES/YEAR

DELTA VELOCITIES
  UP                      0.00
  DOWN                    0.00
  AERO RETURN             0.00

SUPPORT EQUIPMENT
          LENGTH:         0.00 METERS      WIDTH:      0.00 METERS      HEIGHT:     0.00 METERS     (STOWED)
          LENGTH:         0.00 METERS      WIDTH:      0.00 METERS      HEIGHT:     0.00 METERS     (DEPLOYED)

          MASS:              0 KG

MANIFEST RESTRICTIONS
  (X) NO RESTRICTIONS
  ( ) ONLY WITH COMPATIBLE PAYLOADS
  ( ) FLY-ALONE
  ( ) MUST HAVE DOCKING MODULE

LENGTH OF BEAM FAB                                   0.00
NUMBER OF APPENDAGES                                    0
NUMBER OF MODULES REQUIRED TO ASSEMBLE THE PAYLOAD:     0
--------------------------------------------------------------------------------------------------
```

PAYLOAD ELEMENT NAME
ELECTROEPITAXIAL CRYSTAL GROWTH

CODE
BACX1012

CONTACT
NAME ROBERT E. PACE, JR.
ADDRESS MICROGRAVITY RESEARCH AS
PO BOX 12426
HUNTSVILLE, AL 35802

TELEPHONE (205) 881-6670

TYPE
( ) SCIENCE AND APPLICATIONS (NON-COMM.)
(X) COMMERCIAL
( ) TECHNOLOGY DEVELOPMENT
( ) OPERATIONS
( ) OTHER
( ) NATIONAL SECURITY
TYPE NUMBER (SEE TABLE A) 8

IMPORTANCE OF THE SPACE STATION TO THIS ELEMENT
1 = LOW VALUE, BUT COULD USE
10 = VITAL
SCALE = 7

STATUS
( ) OPERATIONAL ( ) APPROVED (X) PLANNED ( ) CANDIDATE ( ) OPPORTUNITY

DESIRED FIRST FLIGHT, YEAR: 1993 NUMBER OF FLIGHTS 1 DURATION OF FLIGHT, DAYS 7

OBJECTIVE
DEVELOP AND COMMERCIALIZE A PROCESS FOR PRODUCING LARGE SINGLE CRYSTALS OF COMPOUND SEMICONDUCTOR MATERIALS.

DESCRIPTION
CRYSTALS ARE GROWN IN SPACE BY AN ELECTROEPITAXIAL GROWTH PROCESS. COMMERCIAL MANUFACTURING UNITS ARE PLACED IN MODULES ATTACHED TO THE SPACE STATION, AND GROWTH CELLS ARE REPLACED PERIODICALLY AND CRYSTALS RETURNED TO EARTH. A PROCESS DEVELOPMENT LABORATORY ON THE SPACE STATION IS USED TO CHARACTERIZE THE CRYSTALS AND DEVELOP THE PROCESS.

ORBIT CHARACTERISTICS
GEOSYNCHRONOUS ORBIT ( ) YES (X) NO
APOGEE, KM PERIGEE, KM TOLERANCE + -
INCLINATION, DEG . TOLERANCE + -
NODAL ANGLE, DEG EPHEMERIS ACCURACY, M
ESCAPE DV REQUIRED, M/S .

POINTING/ORIENTATION
VIEW DIRECTION ( ) INERTIAL ( ) SOLAR ( ) EARTH (X) ANY
TRUTH SITES (IF KNOWN)
POINTING ACCURACY, ARC-SEC FIELD OF VIEW (DEG)
POINTING STABILITY (JITTER), ARC-SEC/SEC
SPECIAL RESTRICTIONS (AVOIDANCE)

POWER
( ) AC (X) DC

	POWER, W	DURATION, HRS/DAY
OPERATING	20000	24.00
STANDBY		
PEAK	20000	24.00

(X) CONTINUOUS

VOLTAGE, V 50 FREQUENCY, HZ 0

```
DATA/COMMUNICATIONS
   MONITORING REQUIREMENTS:
   ( ) NONE        ( ) REALTIME    (X) OFFLINE     ( ) OTHER:
   ( ) ENCRIPTION/DECRIPTION REQUIRED
   ( ) UPLINK REQUIRED:  COMMAND RATE (KBS):        0          FREQUENCY (MHZ):
   ( ) ON-BOARD DATA PROCESSING REQUIRED
       DESCRIPTION:
       DATA TYPES:   ( ) ANALOG      ( ) DIGITAL               HOURS/DAY
       FILM (AMOUNT):                                          VOICE (HOURS/DAY):
       LIVE TV (HOURS/DAY):                                    OTHER:
       ON-BOARD STORAGE (MBIT):
       DATA DUMP FREQUENCY (PER ORBIT)                         DOWNLINK COMMAND RATE:
       RECORDING RATE (KBPS)          0.10                     DOWNLINK FREQUENCY (MHZ):
----------------------------------------------------------------------------------------------
THERMAL
   (X) ACTIVE      ( ) PASSIVE
       TEMPERATURE, DEG C   OPERATIONAL MINIMUM          850         MAXIMUM     950
                            NON-OPERATIONAL MINIMUM        0         MAXIMUM     100
       HEAT REJECTION, W    OPERATIONAL MINIMUM        10000         MAXIMUM   20000
                            NON-OPERATIONAL MINIMUM        0         MAXIMUM
----------------------------------------------------------------------------------------------
EQUIPMENT PHYSICAL CHARACTERISTICS
   LOCATION        (X) INTERNAL          ( ) EXTERNAL         ( ) REMOTE
   EQUIPMENT ID/FUNCTION                 (X) PRESSURIZED      ( ) UNPRESSURIZED
                 L, M:      5.00     W, M:      1.00     H, M:      4.00     STOWED
                 L, M:      5.00     W, M:      1.00     H, M:      4.00     DEPLOYED
                 LAUNCH MASS, KG:    2110                RETURN MASS, KG:    1460
                 CONSUMABLE TYPES
                 ACCELERATION SENSITIVITY, (G)      MIN:  1.00E-06     MAX:  1.00E-04
----------------------------------------------------------------------------------------------
CREW REQUIREMENTS
   CREW SIZE           2          TASK ASSIGNMENTS
                                  ------------------------------------------------------------
   SKILLS (SEE TABLE B)           | SKILL     |       |       |       |       |       |      |
                                  ------------------------------------------------------------
                                  | LEVEL     |       |       |       |       |       |      |
                                  ------------------------------------------------------------
                                  | HOURS/DAY |  4.00 |       |       |       |       |      |
                                  ------------------------------------------------------------
   EVA  ( ) YES   (X) NO          REASON                        HOURS/EVA
----------------------------------------------------------------------------------------------
SERVICING/MAINTENANCE
   SERVICE:                          INTERVAL,  DAYS       90          CONSUMABLES, KG
                                     RETURNABLES, KG     2110          MAN HOURS
   CONFIGURATION CHANGES:            INTERVAL, DAY                     MAN/HOURS REQUIRED
                                     DELIVERABLES, KG                  RETURNABLES, KG
----------------------------------------------------------------------------------------------
SPECIAL CONSIDERATIONS/SEE INSTRUCTIONS
LABORATORY FACILITIES REQUIRED: CLEAN ROOM, WORKSPACE, MINICOMUTER, DOWNLINK TERMINAL
CRYSTAL CHARACTERIZATION EQUIPMENT REQUIRED: CUTTING SAW, POLISHER, ETCHER, COMPACT EVAPORATOR, HALL
APPARATUS LIGHT SOURCE AND SPECTROMETER.

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                                                                  BOEING-SPECIFIC INPUT DATA
MISSION TYPE
   FREE FLYER                                           OPS CODE
   ( ) NOT SERVICED                                        F
   ( ) REMOTE TMS                                          FT
   ( ) REMOTE MANNED                                       FM
   ( ) SERVICED AT STATION (TMS RETRIEVED)                 FST
   ( ) SERVICED AT STATION (SELF-PROPELLED)                FS

   PLATFORM BASED
   ( ) NOT SERVICED                                        P
   ( ) REMOTE TMS                                          PT
   ( ) REMOTE MANNED                                       PM
   ( ) SERVICED AT STATION (TMS RETRIEVED)                 PST
   ( ) SERVICED AT STATION (SELF-PROPELLED)                PS

   OTHER
   ( ) SPACE STATION BASED                                 SS
   ( ) SORTIE                                              SOR

CONSTRUCTION/SERVICING COMPLEXITY
   ( ) LOW
   ( ) MEDIUM
   ( ) HIGH

OPERATIONS TIMES
   OTV UP/DOWN                             DAYS
   OTV OR TMS ON ORBIT                     DAYS
   MISSION USE                             DAYS/YEAR
   IVA SERVICE                             MAN-DAYS/YEAR
   EVA SERVICE                             MAN-DAYS/YEAR
   EXPERIMENT OPS                          MAN-DAYS/YEAR
   SERVICE FREQUENCY                       TIMES/YEAR

DELTA VELOCITIES
   UP                          0.00
   DOWN                        0.00
   AERO RETURN                 0.00

SUPPORT EQUIPMENT
            LENGTH:            0.00 METERS       WIDTH:      0.00 METERS       HEIGHT:      0.00 METERS      (STOWED)
            LENGTH:            0.00 METERS       WIDTH:      0.00 METERS       HEIGHT:      0.00 METERS      (DEPLOYED)

            MASS:                 0 KG

MANIFEST RESTRICTIONS
   (X) NO RESTRICTIONS
   ( ) ONLY WITH COMPATIBLE PAYLOADS
   ( ) FLY-ALONE
   ( ) MUST HAVE DOCKING MODULE

LENGTH OF BEAM FAB                                         0.00
NUMBER OF APPENDAGES                                          0
NUMBER OF MODULES REQUIRED TO ASSEMBLE THE PAYLOAD:           0
```

ORIGINAL PAGE IS
OF POOR QUALITY

PAYLOAD ELEMENT NAME
ELECTROEPITAXIAL CRYSTAL GROWTH

CODE
BACX1013

CONTACT
NAME ROBERT E. PACE, JR.
ADDRESS MICROGRAVITY RESEARCH AS
PO BOX 12426
HUNTSVILLE, AL 35802

TELEPHONE (205) 881-6670

TYPE
( ) SCIENCE AND APPLICATIONS (NON-COMM.)
(X) COMMERCIAL
( ) TECHNOLOGY DEVELOPMENT
( ) OPERATIONS
( ) OTHER
( ) NATIONAL SECURITY
TYPE NUMBER (SEE TABLE A) 8

IMPORTANCE OF THE SPACE STATION TO THIS ELEMENT
1 = LOW VALUE, BUT COULD USE
10 = VITAL
SCALE = 7

STATUS
( ) OPERATIONAL ( ) APPROVED (X) PLANNED ( ) CANDIDATE ( ) OPPORTUNITY

DESIRED FIRST FLIGHT, YEAR: 1994 NUMBER OF FLIGHTS 1 DURATION OF FLIGHT, DAYS 84

OBJECTIVE
DEVELOP AND COMMERCIALIZE A PROCESS FOR PRODUCING LARGE SINGLE CRYSTALS OF COMPOUND SEMICONDUCTOR MATERIALS.

DESCRIPTION
CRYSTALS ARE GROWN IN SPACE BY AN ELECTROEPITAXIAL GROWTH PROCESS. COMMERCIAL MANUFACTURING UNITS ARE PLACED IN MODULES ATTACHED TO THE SPACE STATION, AND GROWTH CELLS ARE REPLACED PERIODICALLY AND CRYSTALS RETURNED TO EARTH. A PROCESS DEVELOPMENT LABORATORY ON THE SPACE STATION IS USED TO CHARACTERIZE THE CRYSTALS AND DEVELOP THE PROCESS.

ORBIT CHARACTERISTICS
GEOSYNCHRONOUS ORBIT ( ) YES (X) NO
APOGEE, KM PERIGEE, KM TOLERANCE + -
INCLINATION, DEG . TOLERANCE + -
NODAL ANGLE, DEG EPHEMERIS ACCURACY, M
ESCAPE DV REQUIRED, M/S .

POINTING/ORIENTATION
VIEW DIRECTION ( ) INERTIAL ( ) SOLAR ( ) EARTH (X) ANY
TRUTH SITES (IF KNOWN)
POINTING ACCURACY, ARC-SEC FIELD OF VIEW (DEG)
POINTING STABILITY (JITTER), ARC-SEC/SEC
SPECIAL RESTRICTIONS (AVOIDANCE)

POWER
( ) AC (X) DC

	POWER, W	DURATION, HRS/DAY
OPERATING	20000	24.00
STANDBY		
PEAK	20000	24.00
VOLTAGE, V	50	FREQUENCY, HZ 0

(X) CONTINUOUS

```
DATA/COMMUNICATIONS
   MONITORING REQUIREMENTS:
    ( ) NONE         ( ) REALTIME    (X) OFFLINE     ( ) OTHER:
    ( ) ENCRIPTION/DECRIPTION REQUIRED
    ( ) UPLINK REQUIRED:  COMMAND RATE (KBS):      0         FREQUENCY (MHZ):
    ( ) ON-BOARD DATA PROCESSING REQUIRED
        DESCRIPTION:
        DATA TYPES:    ( ) ANALOG     ( ) DIGITAL            HOURS/DAY
        FILM (AMOUNT):                                       VOICE (HOURS/DAY):
        LIVE TV (HOURS/DAY):                                 OTHER:
        ON-BOARD STORAGE (MBIT):
        DATA DUMP FREQUENCY (PER ORBIT)                      DOWNLINK COMMAND RATE:
        RECORDING RATE (KBPS)          0.10                  DOWNLINK FREQUENCY (MHZ):
-------------------------------------------------------------------------------------------
THERMAL
   (X) ACTIVE      ( ) PASSIVE
        TEMPERATURE, DEG C   OPERATIONAL MINIMUM         850        MAXIMUM    950
                             NON-OPERATIONAL MINIMUM       0        MAXIMUM    100
        HEAT REJECTION, W    OPERATIONAL MINIMUM       10000        MAXIMUM  20000
                             NON-OPERATIONAL MINIMUM       0        MAXIMUM
-------------------------------------------------------------------------------------------
EQUIPMENT PHYSICAL CHARACTERISTICS
   LOCATION        (X) INTERNAL         ( ) EXTERNAL          ( ) REMOTE
   EQUIPMENT ID/FUNCTION                (X) PRESSURIZED       ( ) UNPRESSURIZED
                 L, M:      5.00      W, M:      1.00      H, M:      4.00     STOWED
                 L, M:      5.00      W, M:      1.00      H, M:      4.00     DEPLOYED
                 LAUNCH MASS, KG:     2880                 RETURN MASS, KG:     2450
                 CONSUMABLE TYPES
                 ACCELERATION SENSITIVITY, (G)      MIN:  1.00E-06     MAX:  1.00E-04
-------------------------------------------------------------------------------------------
CREW REQUIREMENTS
   CREW SIZE              2         TASK ASSIGNMENTS
                                    ---------------------------------------------------
   SKILLS (SEE TABLE B)             | SKILL      |        |     |     |     |     |     |
                                    ---------------------------------------------------
                                    | LEVEL      |        |     |     |     |     |     |
                                    ---------------------------------------------------
                                    | HOURS/DAY  |  4.00  |     |     |     |     |     |
                                    ---------------------------------------------------
   EVA   ( ) YES    (X) NO          REASON                      HOURS/EVA
-------------------------------------------------------------------------------------------
SERVICING/MAINTENANCE
   SERVICE:                         INTERVAL,  DAYS        90             CONSUMABLES, KG
                                    RETURNABLES, KG      2880             MAN HOURS
   CONFIGURATION CHANGES:           INTERVAL, DAY                         MAN/HOURS REQUIRED
                                    DELIVERABLES, KG                      RETURNABLES, KG
-------------------------------------------------------------------------------------------
SPECIAL CONSIDERATIONS/SEE INSTRUCTIONS
LABORATORY FACILITIES REQUIRED: CLEAN ROOM, WORKSPACE, MINICOMUTER, DOWNLINK TERMINAL
CRYSTAL CHARACTERIZATION EQUIPMENT REQUIRED: CUTTING SAW, POLISHER, ETCHER, COMPACT EVAPORATOR, HALL
APPARATUS LIGHT SOURCE AND SPECTROMETER.

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------------------------------------------------------------------------------------------------------------
                                            BOEING-SPECIFIC INPUT DATA
------------------------------------------------------------------------------------------------------------
MISSION TYPE                                     OPS CODE
   FREE FLYER
   ( ) NOT SERVICED                                 F
   ( ) REMOTE TMS                                   FT
   ( ) REMOTE MANNED                                FM
   ( ) SERVICED AT STATION (TMS RETRIEVED)          FST
   ( ) SERVICED AT STATION (SELF-PROPELLED)         FS

   PLATFORM BASED
   ( ) NOT SERVICED                                 P
   ( ) REMOTE TMS                                   PT
   ( ) REMOTE MANNED                                PM
   ( ) SERVICED AT STATION (TMS RETRIEVED)          PST
   ( ) SERVICED AT STATION (SELF-PROPELLED)         PS

   OTHER
   ( ) SPACE STATION BASED                          SS
   ( ) SORTIE                                       SOR

CONSTRUCTION/SERVICING COMPLEXITY
   ( ) LOW
   ( ) MEDIUM
   ( ) HIGH

OPERATIONS TIMES
   OTV UP/DOWN                           DAYS
   OTV OR TMS ON ORBIT                   DAYS
   MISSION USE                           DAYS/YEAR
   IVA SERVICE                           MAN-DAYS/YEAR
   EVA SERVICE                           MAN-DAYS/YEAR
   EXPERIMENT OPS                        MAN-DAYS/YEAR
   SERVICE FREQUENCY                     TIMES/YEAR

DELTA VELOCITIES
   UP                           0.00
   DOWN                         0.00
   AERO RETURN                  0.00

SUPPORT EQUIPMENT
             LENGTH:            0.00 METERS      WIDTH:      0.00 METERS       HEIGHT:      0.00 METERS     (STOWED)
             LENGTH:            0.00 METERS      WIDTH:      0.00 METERS       HEIGHT:      0.00 METERS     (DEPLOYED)

             MASS:                 0 KG

MANIFEST RESTRICTIONS
   (X) NO RESTRICTIONS
   ( ) ONLY WITH COMPATIBLE PAYLOADS
   ( ) FLY-ALONE
   ( ) MUST HAVE DOCKING MODULE

LENGTH OF BEAM FAB                                          0.00
NUMBER OF APPENDAGES                                           0
NUMBER OF MODULES REQUIRED TO ASSEMBLE THE PAYLOAD:            0
------------------------------------------------------------------------------------------------------------
```

PAYLOAD ELEMENT NAME
ELECTROEPITAXIAL CRYSTAL GROWTH

CODE
BACX1014

TYPE
( ) SCIENCE AND APPLICATIONS (NON-COMM.)
(X) COMMERCIAL
( ) TECHNOLOGY DEVELOPMENT
( ) OPERATIONS
( ) OTHER
( ) NATIONAL SECURITY
TYPE NUMBER (SEE TABLE A) 8

CONTACT
NAME ROBERT E. PACE, JR.
ADDRESS MICROGRAVITY RESEARCH AS
PO BOX 12426
HUNTSVILLE, AL 35802

TELEPHONE (205) 881-6670

IMPORTANCE OF THE SPACE STATION TO
THIS ELEMENT
1 = LOW VALUE, BUT COULD USE
10 = VITAL
SCALE = 7

STATUS
( ) OPERATIONAL ( ) APPROVED ! (X) PLANNED ( ) CANDIDATE ( ) OPPORTUNITY

DESIRED FIRST FLIGHT, YEAR: 1994 NUMBER OF FLIGHTS 2 DURATION OF FLIGHT, DAYS 84

OBJECTIVE
DEVELOP AND COMMERCIALIZE A PROCESS FOR PRODUCING LARGE SINGLE CRYSTALS OF COMPOUND SEMICONDUCTOR MATERIALS.

DESCRIPTION
CRYSTALS ARE GROWN IN SPACE BY AN ELECTROEPITAXIAL GROWTH PROCESS. COMMERCIAL MANUFACTURING UNITS ARE PLACED IN MODULES ATTACHED TO THE SPACE STATION, AND GROWTH CELLS ARE REPLACED PERIODICALLY AND CRYSTALS RETURNED TO EARTH. A PROCESS DEVELOPMENT LABORATORY ON THE SPACE STATION IS USED TO CHARACTERIZE THE CRYSTALS AND DEVELOP THE PROCESS.

ORBIT CHARACTERISTICS
GEOSYNCHRONOUS ORBIT ( ) YES (X) NO
APOGEE, KM PERIGEE, KM TOLERANCE + -
INCLINATION, DEG . TOLERANCE + -
NODAL ANGLE, DEG EPHEMERIS ACCURACY, M
ESCAPE DV REQUIRED, M/S .

POINTING/ORIENTATION
VIEW DIRECTION ( ) INERTIAL ( ) SOLAR ( ) EARTH (X) ANY
TRUTH SITES (IF KNOWN)
POINTING ACCURACY, ARC-SEC FIELD OF VIEW (DEG)
POINTING STABILITY (JITTER), ARC-SEC/SEC
SPECIAL RESTRICTIONS (AVOIDANCE)

POWER
( ) AC (X) DC

	POWER, W	DURATION, HRS/DAY
OPERATING	20000	24.00
STANDBY		
PEAK	20000	24.00
VOLTAGE, V	50	FREQUENCY, HZ 0

(X) CONTINUOUS

```
DATA/COMMUNICATIONS
  MONITORING REQUIREMENTS:
  ( ) NONE         ( ) REALTIME   (X) OFFLINE    ( ) OTHER:
  ( ) ENCRIPTION/DECRIPTION REQUIRED
  ( ) UPLINK REQUIRED:  COMMAND RATE (KBS):       0          FREQUENCY (MHZ):
  ( ) ON-BOARD DATA PROCESSING REQUIRED
      DESCRIPTION:
      DATA TYPES:   ( ) ANALOG     ( ) DIGITAL               HOURS/DAY
      FILM (AMOUNT):                                         VOICE (HOURS/DAY):
      LIVE TV (HOURS/DAY):                                   OTHER:
      ON-BOARD STORAGE (MBIT):
      DATA DUMP FREQUENCY (PER ORBIT)                        DOWNLINK COMMAND RATE:
      RECORDING RATE (KBPS)          0.10                    DOWNLINK FREQUENCY (MHZ):
--------------------------------------------------------------------------------
THERMAL
  (X) ACTIVE      ( ) PASSIVE
      TEMPERATURE, DEG C  OPERATIONAL MINIMUM        850        MAXIMUM     950
                          NON-OPERATIONAL MINIMUM      0        MAXIMUM     100
      HEAT REJECTION, W   OPERATIONAL MINIMUM      10000        MAXIMUM   20000
                          NON-OPERATIONAL MINIMUM      0        MAXIMUM
--------------------------------------------------------------------------------
EQUIPMENT PHYSICAL CHARACTERISTICS
  LOCATION        (X) INTERNAL         ( ) EXTERNAL      ( ) REMOTE
  EQUIPMENT ID/FUNCTION                (X) PRESSURIZED   ( ) UNPRESSURIZED
             L, M:      5.00     W, M:      1.00     H, M:      4.00     STOWED
             L, M:      5.00     W, M:      1.00     H, M:      4.00     DEPLOYED
             LAUNCH MASS, KG:    2380                RETURN MASS, KG:    2380
             CONSUMABLE TYPES
             ACCELERATION SENSITIVITY, (G)      MIN:  1.00E-06     MAX:  1.00E-04
--------------------------------------------------------------------------------
CREW REQUIREMENTS
  CREW SIZE          2       TASK ASSIGNMENTS
                             ------------------------------------------------
  SKILLS (SEE TABLE B)       | SKILL     |      |      |      |      |      |      |
                             ------------------------------------------------
                             | LEVEL     |      |      |      |      |      |      |
                             ------------------------------------------------
                             | HOURS/DAY |  4.00|      |      |      |      |      |
                             ------------------------------------------------
  EVA   ( ) YES   (X) NO     REASON                   HOURS/EVA
--------------------------------------------------------------------------------
SERVICING/MAINTENANCE
  SERVICE:                  INTERVAL,  DAYS       90          CONSUMABLES, KG
                            RETURNABLES, KG     2380          MAN HOURS
  CONFIGURATION CHANGES:    INTERVAL, DAY                     MAN/HOURS REQUIRED
                            DELIVERABLES, KG                  RETURNABLES, KG
--------------------------------------------------------------------------------
SPECIAL CONSIDERATIONS/SEE INSTRUCTIONS
LABORATORY FACILITIES REQUIRED: CLEAN ROOM, WORKSPACE, MINICOMUTER, DOWNLINK TERMINAL
CRYSTAL CHARACTERIZATION EQUIPMENT REQUIRED: CUTTING SAW, POLISHER, ETCHER, COMPACT EVAPORATOR, HALL
APPARATUS LIGHT SOURCE AND SPECTROMETER.


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                                                         BOEING-SPECIFIC INPUT DATA
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MISSION TYPE                                 OPS CODE
   FREE FLYER
   ( ) NOT SERVICED                             F
   ( ) REMOTE TMS                               FT
   ( ) REMOTE MANNED                            FM
   ( ) SERVICED AT STATION (TMS RETRIEVED)      FST
   ( ) SERVICED AT STATION (SELF-PROPELLED)     FS

   PLATFORM BASED
   ( ) NOT SERVICED                             P
   ( ) REMOTE TMS                               PT
   ( ) REMOTE MANNED                            PM
   ( ) SERVICED AT STATION (TMS RETRIEVED)      PST
   ( ) SERVICED AT STATION (SELF-PROPELLED)     PS

   OTHER
   ( ) SPACE STATION BASED                      SS
   ( ) SORTIE                                   SOR

CONSTRUCTION/SERVICING COMPLEXITY
   ( ) LOW
   ( ) MEDIUM
   ( ) HIGH

OPERATIONS TIMES
   OTV UP/DOWN                          DAYS
   OTV OR TMS ON ORBIT                  DAYS
   MISSION USE                          DAYS/YEAR
   IVA SERVICE                          MAN-DAYS/YEAR
   EVA SERVICE                          MAN-DAYS/YEAR
   EXPERIMENT OPS                       MAN-DAYS/YEAR
   SERVICE FREQUENCY                    TIMES/YEAR

DELTA VELOCITIES
   UP                       0.00
   DOWN                     0.00
   AERO RETURN              0.00

SUPPORT EQUIPMENT
             LENGTH:        0.00 METERS       WIDTH:     0.00 METERS        HEIGHT:     0.00 METERS     (STOWED)
             LENGTH:        0.00 METERS       WIDTH:     0.00 METERS        HEIGHT:     0.00 METERS     (DEPLOYED)

             MASS:             0 KG

MANIFEST RESTRICTIONS
   (X) NO RESTRICTIONS
   ( ) ONLY WITH COMPATIBLE PAYLOADS
   ( ) FLY-ALONE
   ( ) MUST HAVE DOCKING MODULE

LENGTH OF BEAM FAB                                     0.00
NUMBER OF APPENDAGES                                      0
NUMBER OF MODULES REQUIRED TO ASSEMBLE THE PAYLOAD        0
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OF POOR QUALITY

PAYLOAD ELEMENT NAME
ELECTROEPITAXIAL CRYSTAL GROWTH

CODE
BACX1015

TYPE
( ) SCIENCE AND APPLICATIONS (NON-COMM.)
(X) COMMERCIAL
( ) TECHNOLOGY DEVELOPMENT
( ) OPERATIONS
( ) OTHER
( ) NATIONAL SECURITY
TYPE NUMBER (SEE TABLE A) 8

CONTACT
NAME ROBERT E. PACE, JR.
ADDRESS MICROGRAVITY RESEARCH AS
PO BOX 12426
HUNTSVILLE, AL 35802

TELEPHONE (205) 881-6670

IMPORTANCE OF THE SPACE STATION TO THIS ELEMENT
1 = LOW VALUE, BUT COULD USE
10 = VITAL
SCALE = 7

STATUS
( ) OPERATIONAL ( ) APPROVED (X) PLANNED ( ) CANDIDATE ( ) OPPORTUNITY

DESIRED FIRST FLIGHT, YEAR: 1995 NUMBER OF FLIGHTS 1 DURATION OF FLIGHT, DAYS 70

OBJECTIVE
DEVELOP AND COMMERCIALIZE A PROCESS FOR PRODUCING LARGE SINGLE CRYSTALS OF COMPOUND SEMICONDUCTOR MATERIALS.

DESCRIPTION
CRYSTALS ARE GROWN IN SPACE BY AN ELECTROEPITAXIAL GROWTH PROCESS. COMMERCIAL MANUFACTURING UNITS ARE PLACED IN MODULES ATTACHED TO THE SPACE STATION, AND GROWTH CELLS ARE REPLACED PERIODICALLY AND CRYSTALS RETURNED TO EARTH. A PROCESS DEVELOPMENT LABORATORY ON THE SPACE STATION IS USED TO CHARACTERIZE THE CRYSTALS AND DEVELOP THE PROCESS.

ORBIT CHARACTERISTICS
GEOSYNCHRONOUS ORBIT ( ) YES (X) NO
APOGEE, KM PERIGEE, KM TOLERANCE + -
INCLINATION, DEG . TOLERANCE + -
NODAL ANGLE, DEG EPHEMERIS ACCURACY, M
ESCAPE DV REQUIRED, M/S .

POINTING/ORIENTATION
VIEW DIRECTION ( ) INERTIAL ( ) SOLAR ( ) EARTH (X) ANY
TRUTH SITES (IF KNOWN)
POINTING ACCURACY, ARC-SEC FIELD OF VIEW (DEG)
POINTING STABILITY (JITTER), ARC-SEC/SEC
SPECIAL RESTRICTIONS (AVOIDANCE)

POWER
( ) AC (X) DC

	POWER, W	DURATION, HRS/DAY
OPERATING	40000	24.00
STANDBY		
PEAK	40000	24.00

(X) CONTINUOUS
VOLTAGE, V 50 FREQUENCY, HZ 0

```
DATA/COMMUNICATIONS
   MONITORING REQUIREMENTS:
   ( ) NONE        ( ) REALTIME    (X) OFFLINE     ( ) OTHER:
   ( ) ENCRIPTION/DECRIPTION REQUIRED
   ( ) UPLINK REQUIRED:  COMMAND RATE (KBS):      0         FREQUENCY (MHZ):
   ( ) ON-BOARD DATA PROCESSING REQUIRED
       DESCRIPTION:
       DATA TYPES:   ( ) ANALOG      ( ) DIGITAL
       FILM (AMOUNT):                                        HOURS/DAY
       LIVE TV (HOURS/DAY):                                  VOICE (HOURS/DAY):
       ON-BOARD STORAGE (MBIT):                              OTHER:
       DATA DUMP FREQUENCY (PER ORBIT)
       RECORDING RATE (KBPS)          0.10                   DOWNLINK COMMAND RATE:
                                                             DOWNLINK FREQUENCY (MHZ):
------------------------------------------------------------------------------------------
THERMAL
   (X) ACTIVE     ( ) PASSIVE
       TEMPERATURE, DEG C   OPERATIONAL MINIMUM          850        MAXIMUM    950
                            NON-OPERATIONAL MINIMUM        0        MAXIMUM    100
       HEAT REJECTION, W    OPERATIONAL MINIMUM        10000        MAXIMUM  40000
                            NON-OPERATIONAL MINIMUM        0        MAXIMUM
------------------------------------------------------------------------------------------
EQUIPMENT PHYSICAL CHARACTERISTICS
   LOCATION        (X) INTERNAL             ( ) EXTERNAL        ( ) REMOTE
   EQUIPMENT ID/FUNCTION                    (X) PRESSURIZED     ( ) UNPRESSURIZED
                L, M:      5.00      W, M:     1.00      H, M:      4.00    STOWED
                L, M:      5.00      W, M:     1.00      H, M:      4.00    DEPLOYED
                LAUNCH MASS, KG:     4500                RETURN MASS, KG:   2400
                CONSUMABLE TYPES
                ACCELERATION SENSITIVITY, (G)      MIN:  1.00E-06     MAX:  1.00E-04
------------------------------------------------------------------------------------------
CREW REQUIREMENTS
   CREW SIZE           2              TASK ASSIGNMENTS
                                      -------------------------------------------------
   SKILLS (SEE TABLE B)               | SKILL     |       |     |     |     |     |     |
                                      -------------------------------------------------
                                      | LEVEL     |       |     |     |     |     |     |
                                      -------------------------------------------------
                                      | HOURS/DAY |  4.00 |     |     |     |     |     |
                                      -------------------------------------------------
   EVA  ( ) YES   (X) NO              REASON                      HOURS/EVA
------------------------------------------------------------------------------------------
SERVICING/MAINTENANCE
   SERVICE:                           INTERVAL,  DAYS        90        CONSUMABLES, KG
                                      RETURNABLES, KG      4500        MAN HOURS
   CONFIGURATION CHANGES:             INTERVAL, DAY                    MAN/HOURS REQUIRED
                                      DELIVERABLES, KG                 RETURNABLES, KG
------------------------------------------------------------------------------------------
SPECIAL CONSIDERATIONS/SEE INSTRUCTIONS
LABORATORY FACILITIES REQUIRED: CLEAN ROOM, WORKSPACE, MINICOMUTER, DOWNLINK TERMINAL
CRYSTAL CHARACTERIZATION EQUIPMENT REQUIRED: CUTTING SAW, POLISHER, ETCHER, COMPACT EVAPORATOR, HALL
APPARATUS LIGHT SOURCE AND SPECTROMETER.

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                                              BOEING-SPECIFIC INPUT DATA
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MISSION TYPE                                OPS CODE
   FREE FLYER
   ( ) NOT SERVICED                           F
   ( ) REMOTE TMS                             FT
   ( ) REMOTE MANNED                          FM
   ( ) SERVICED AT STATION (TMS RETRIEVED)    FST
   ( ) SERVICED AT STATION (SELF-PROPELLED)   FS

   PLATFORM BASED
   ( ) NOT SERVICED                           P
   ( ) REMOTE TMS                             PT
   ( ) REMOTE MANNED                          PM
   ( ) SERVICED AT STATION (TMS RETRIEVED)    PST
   ( ) SERVICED AT STATION (SELF-PROPELLED)   PS

   OTHER
   ( ) SPACE STATION BASED                    SS
   ( ) SORTIE                                 SOR

CONSTRUCTION/SERVICING COMPLEXITY
   ( ) LOW
   ( ) MEDIUM
   ( ) HIGH

OPERATIONS TIMES
   OTV UP/DOWN                         DAYS
   OTV OR TMS ON ORBIT                 DAYS
   MISSION USE                         DAYS/YEAR
   IVA SERVICE                         MAN-DAYS/YEAR
   EVA SERVICE                         MAN-DAYS/YEAR
   EXPERIMENT OPS                      MAN-DAYS/YEAR
   SERVICE FREQUENCY                   TIMES/YEAR

DELTA VELOCITIES
   UP                    0.00
   DOWN                  0.00
   AERO RETURN           0.00

SUPPORT EQUIPMENT
             LENGTH:     0.00 METERS      WIDTH:      0.00 METERS        HEIGHT:      0.00 METERS      (STOWED)
             LENGTH:     0.00 METERS      WIDTH:      0.00 METERS        HEIGHT:      0.00 METERS      (DEPLOYED)

             MASS:          0 KG

MANIFEST RESTRICTIONS
   (X) NO RESTRICTIONS
   ( ) ONLY WITH COMPATIBLE PAYLOADS
   ( ) FLY-ALONE
   ( ) MUST HAVE DOCKING MODULE

LENGTH OF BEAM FAB                                    0.00
NUMBER OF APPENDAGES                                     0
NUMBER OF MODULES REQUIRED TO ASSEMBLE THE PAYLOAD       0
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PAYLOAD ELEMENT NAME
ELECTROEPITAXIAL CRYSTAL GROWTH

CODE
BACX1016

TYPE
( ) SCIENCE AND APPLICATIONS (NON-COMM.)
(X) COMMERCIAL
( ) TECHNOLOGY DEVELOPMENT
( ) OPERATIONS
( ) OTHER
( ) NATIONAL SECURITY
TYPE NUMBER (SEE TABLE A) 8

CONTACT
NAME ROBERT E. PACE, JR.
ADDRESS MICROGRAVITY RESEARCH AS
PO BOX 12426
HUNTSVILLE, AL 35802

TELEPHONE (205) 881-6670

IMPORTANCE OF THE SPACE STATION TO THIS ELEMENT
1 = LOW VALUE, BUT COULD USE
10 = VITAL
SCALE = 7

STATUS
( ) OPERATIONAL ( ) APPROVED (X) PLANNED ( ) CANDIDATE ( ) OPPORTUNITY

DESIRED FIRST FLIGHT, YEAR: 1995
NUMBER OF FLIGHTS 2
DURATION OF FLIGHT, DAYS 70

OBJECTIVE
DEVELOP AND COMMERCIALIZE A PROCESS FOR PRODUCING LARGE SINGLE CRYSTALS OF COMPOUND SEMICONDUCTOR MATERIALS.

DESCRIPTION
CRYSTALS ARE GROWN IN SPACE BY AN ELECTROEPITAXIAL GROWTH PROCESS. COMMERCIAL MANUFACTURING UNITS ARE PLACED IN MODULES ATTACHED TO THE SPACE STATION, AND GROWTH CELLS ARE REPLACED PERIODICALLY AND CRYSTALS RETURNED TO EARTH. A PROCESS DEVELOPMENT LABORATORY ON THE SPACE STATION IS USED TO CHARACTERIZE THE CRYSTALS AND DEVELOP THE PROCESS.

ORBIT CHARACTERISTICS
GEOSYNCHRONOUS ORBIT ( ) YES (X) NO
APOGEE, KM
PERIGEE, KM
INCLINATION, DEG TOLERANCE + -
NODAL ANGLE, DEG TOLERANCE + -
ESCAPE DV REQUIRED, M/S
EPHEMERIS ACCURACY, M

POINTING/ORIENTATION
VIEW DIRECTION ( ) INERTIAL ( ) SOLAR ( ) EARTH (X) ANY
TRUTH SITES (IF KNOWN)
POINTING ACCURACY, ARC-SEC
FIELD OF VIEW (DEG)
POINTING STABILITY (JITTER), ARC-SEC/SEC
SPECIAL RESTRICTIONS (AVOIDANCE)

POWER
( ) AC (X) DC

	POWER, W	DURATION, HRS/DAY
OPERATING	40000	24.00
STANDBY		
PEAK	40000	24.00
VOLTAGE, V	50	

(X) CONTINUOUS
FREQUENCY, HZ 0

DATA/COMMUN.   IONS

MONITORING REQUIREMENTS:

( ) NONE   ( ) REALTIME   (X) OFFLINE   ( ) OTHER:

( ) ENCRIPTION/DECRIPTION REQUIRED

( ) UPLINK REQUIRED: COMMAND RATE (KBS): 0   FREQUENCY (MHZ):

( ) ON-BOARD DATA PROCESSING REQUIRED

DESCRIPTION:

DATA TYPES: ( ) ANALOG   ( ) DIGITAL   HOURS/DAY

FILM (AMOUNT):   VOICE (HOURS/DAY):

LIVE TV (HOURS/DAY):   OTHER:

ON-BOARD STORAGE (MBIT):

DATA DUMP FREQUENCY (PER ORBIT)   DOWNLINK COMMAND RATE:

RECORDING RATE (KBPS) 0.10   DOWNLINK FREQUENCY (MHZ):

THERMAL

(X) ACTIVE   ( ) PASSIVE

TEMPERATURE, DEG C	OPERATIONAL MINIMUM	850	MAXIMUM	950
	NON-OPERATIONAL MINIMUM	0	MAXIMUM	100
HEAT REJECTION, W	OPERATIONAL MINIMUM	10000	MAXIMUM	40000
	NON-OPERATIONAL MINIMUM	0	MAXIMUM	

EQUIPMENT PHYSICAL CHARACTERISTICS

LOCATION   (X) INTERNAL   ( ) EXTERNAL   ( ) REMOTE

EQUIPMENT ID/FUNCTION   (X) PRESSURIZED   ( ) UNPRESSURIZED

L, M: 5.00   W, M: 1.00   H, M: 4.00   STOWED

L, M: 5.00   W, M: 1.00   H, M: 4.00   DEPLOYED

LAUNCH MASS, KG: 4000   RETURN MASS, KG: 4000

CONSUMABLE TYPES

ACCELERATION SENSITIVITY, (G)   MIN: 1.00E-06   MAX: 1.00E-04

CREW REQUIREMENTS

CREW SIZE 2

SKILLS (SEE TABLE B)

TASK ASSIGNMENTS

SKILL						
LEVEL						
HOURS/DAY	4.00					

EVA ( ) YES (X) NO   REASON   HOURS/EVA

SERVICING/MAINTENANCE

SERVICE: INTERVAL, DAYS 90   CONSUMABLES, KG

RETURNABLES, KG 4000   MAN HOURS

CONFIGURATION CHANGES: INTERVAL, DAY   MAN/HOURS REQUIRED

DELIVERABLES, KG   RETURNABLES, KG

SPECIAL CONSIDERATIONS/SEE INSTRUCTIONS

LABORATORY FACILITIES REQUIRED: CLEAN ROOM, WORKSPACE, MINICOMUTER, DOWNLINK TERMINAL

CRYSTAL CHARACTERIZATION EQUIPMENT REQUIRED: CUTTING SAW, POLISHER, ETCHER, COMPACT EVAPORATOR, HALL APPARATUS LIGHT SOURCE AND SPECTROMETER.

ORIGINAL PAGE IS
OF POOR QUALITY

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                                                    BOEING-SPECIFIC INPUT DATA
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MISSION TYPE                                 OPS CODE
   FREE FLYER
   ( ) NOT SERVICED                             F
   ( ) REMOTE TMS                               FT
   ( ) REMOTE MANNED                            FM
   ( ) SERVICED AT STATION (TMS RETRIEVED)      FST
   ( ) SERVICED AT STATION (SELF-PROPELLED)     FS

   PLATFORM BASED
   ( ) NOT SERVICED                             P
   ( ) REMOTE TMS                               PT
   ( ) REMOTE MANNED                            PM
   ( ) SERVICED AT STATION (TMS RETRIEVED)      PST
   ( ) SERVICED AT STATION (SELF-PROPELLED)     PS

   OTHER
   ( ) SPACE STATION BASED                      SS
   ( ) SORTIE                                   SOR

CONSTRUCTION/SERVICING COMPLEXITY
   ( ) LOW
   ( ) MEDIUM
   ( ) HIGH

OPERATIONS TIMES
   OTV UP/DOWN                          DAYS
   OTV OR TMS ON ORBIT                  DAYS
   MISSION USE                          DAYS/YEAR
   IVA SERVICE                          MAN-DAYS/YEAR
   EVA SERVICE                          MAN-DAYS/YEAR
   EXPERIMENT OPS                       MAN-DAYS/YEAR
   SERVICE FREQUENCY                    TIMES/YEAR

DELTA VELOCITIES
   UP                       0.00
   DOWN                     0.00
   AERO RETURN              0.00

SUPPORT EQUIPMENT
             LENGTH:        0.00 METERS      WIDTH:     0.00 METERS         HEIGHT:     0.00 METERS      (STOWED)
             LENGTH:        0.00 METERS      WIDTH:     0.00 METERS         HEIGHT:     0.00 METERS      (DEPLOYED)

             MASS:             0 KG

MANIFEST RESTRICTIONS
   (X) NO RESTRICTIONS
   ( ) ONLY WITH COMPATIBLE PAYLOADS
   ( ) FLY-ALONE
   ( ) MUST HAVE DOCKING MODULE

LENGTH OF BEAM FAB                                     0.00
NUMBER OF APPENDAGES                                      0
NUMBER OF MODULES REQUIRED TO ASSEMBLE THE PAYLOAD        0
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PAYLOAD ELEMENT NAME
ELECTROEPITAXIAL CRYSTAL GROWTH

CODE
BACX1017

CONTACT
NAME ROBERT E. PACE, JR.
ADDRESS MICROGRAVITY RESEARCH AS
PO BOX 12426
HUNTSVILLE, AL 35802

TELEPHONE (205) 881-6670

TYPE
( ) SCIENCE AND APPLICATIONS (NON-COMM.)
(X) COMMERCIAL
( ) TECHNOLOGY DEVELOPMENT
( ) OPERATIONS
( ) OTHER
( ) NATIONAL SECURITY
TYPE NUMBER (SEE TABLE A) 8

IMPORTANCE OF THE SPACE STATION TO THIS ELEMENT
1 = LOW VALUE, BUT COULD USE
10 = VITAL
SCALE = 7

STATUS
( ) OPERATIONAL ( ) APPROVED (X) PLANNED ( ) CANDIDATE ( ) OPPORTUNITY

DESIRED FIRST FLIGHT, YEAR: 1996 NUMBER OF FLIGHTS 1 DURATION OF FLIGHT, DAYS 77

OBJECTIVE
DEVELOP AND COMMERCIALIZE A PROCESS FOR PRODUCING LARGE SINGLE CRYSTALS OF COMPOUND SEMICONDUCTOR MATERIALS.

DESCRIPTION
CRYSTALS ARE GROWN IN SPACE BY AN ELECTROEPITAXIAL GROWTH PROCESS. COMMERCIAL MANUFACTURING UNITS ARE PLACED IN MODULES ATTACHED TO THE SPACE STATION, AND GROWTH CELLS ARE REPLACED PERIODICALLY AND CRYSTALS RETURNED TO EARTH. A PROCESS DEVELOPMENT LABORATORY ON THE SPACE STATION IS USED TO CHARACTERIZE THE CRYSTALS AND DEVELOP THE PROCESS.

ORBIT CHARACTERISTICS
GEOSYNCHRONOUS ORBIT ( ) YES (X) NO
APOGEE, KM PERIGEE, KM TOLERANCE + -
INCLINATION, DEG . TOLERANCE + -
NODAL ANGLE, DEG EPHEMERIS ACCURACY, M
ESCAPE DV REQUIRED, M/S .

POINTING/ORIENTATION
VIEW DIRECTION ( ) INERTIAL ( ) SOLAR ( ) EARTH (X) ANY
TRUTH SITES (IF KNOWN) .
POINTING ACCURACY, ARC-SEC FIELD OF VIEW (DEG)
POINTING STABILITY (JITTER), ARC-SEC/SEC
SPECIAL RESTRICTIONS (AVOIDANCE)

POWER
( ) AC (X) DC

	POWER, W	DURATION, HRS/DAY	
OPERATING	60000	24.00	
STANDBY			
PEAK	60000	24.00	(X) CONTINUOUS
VOLTAGE, V	50	FREQUENCY, HZ	0

```
DATA/COMMUNICATIONS
   MONITORING REQUIREMENTS:
   ( ) NONE         ( ) REALTIME    (X) OFFLINE      ( ) OTHER:
   ( ) ENCRIPTION/DECRIPTION REQUIRED
   ( ) UPLINK REQUIRED:  COMMAND RATE (KBS):        0          FREQUENCY (MHZ):
   ( ) ON-BOARD DATA PROCESSING REQUIRED
       DESCRIPTION:
       DATA TYPES:    ( ) ANALOG      ( ) DIGITAL                HOURS/DAY
       FILM (AMOUNT):                                            VOICE (HOURS/DAY):
       LIVE TV (HOURS/DAY):                                      OTHER:
       ON-BOARD STORAGE (MBIT):
       DATA DUMP FREQUENCY (PER ORBIT)                           DOWNLINK COMMAND RATE:
       RECORDING RATE (KBPS)            0.10                     DOWNLINK FREQUENCY (MHZ):
--------------------------------------------------------------------------------------------------------
THERMAL
   (X) ACTIVE      ( ) PASSIVE
       TEMPERATURE, DEG C    OPERATIONAL MINIMUM          850         MAXIMUM    950
                             NON-OPERATIONAL MINIMUM        0         MAXIMUM    100
       HEAT REJECTION, W     OPERATIONAL MINIMUM        10000         MAXIMUM  60000
                             NON-OPERATIONAL MINIMUM        0         MAXIMUM
--------------------------------------------------------------------------------------------------------
EQUIPMENT PHYSICAL CHARACTERISTICS
   LOCATION        (X)  INTERNAL          ( ) EXTERNAL          ( ) REMOTE
   EQUIPMENT ID/FUNCTION                  (X) PRESSURIZED       ( ) UNPRESSURIZED
                L, M:       5.00      W, M:       1.00       H, M:       4.00      STOWED
                L, M:       5.00      W, M:       1.00       H, M:       4.00      DEPLOYED
                LAUNCH MASS, KG:      4000                   RETURN MASS, KG:      0
                CONSUMABLE TYPES
                ACCELERATION SENSITIVITY, (G)       MIN:  1.00E-06      MAX:  1.00E-04
--------------------------------------------------------------------------------------------------------
CREW REQUIREMENTS
   CREW SIZE           2             TASK ASSIGNMENTS
                                     ------------------------------------------------------------
   SKILLS (SEE TABLE B)              | SKILL      |        |        |        |        |        |
                                     ------------------------------------------------------------
                                     | LEVEL      |        |        |        |        |        |
                                     ------------------------------------------------------------
                                     | HOURS/DAY  |  4.00  |        |        |        |        |
                                     ------------------------------------------------------------
   EVA  ( ) YES   (X) NO             REASON                             HOURS/EVA
--------------------------------------------------------------------------------------------------------
SERVICING/MAINTENANCE
   SERVICE:                          INTERVAL,  DAYS        90          CONSUMABLES, KG
                                     RETURNABLES, KG      4000          MAN HOURS
   CONFIGURATION CHANGES:            INTERVAL, DAY                      MAN/HOURS REQUIRED
                                     DELIVERABLES, KG                   RETURNABLES, KG
--------------------------------------------------------------------------------------------------------
SPECIAL CONSIDERATIONS/SEE INSTRUCTIONS
LABORATORY FACILITIES REQUIRED: CLEAN ROOM, WORKSPACE, MINICOMUTER, DOWNLINK TERMINAL
CRYSTAL CHARACTERIZATION EQUIPMENT REQUIRED: CUTTING SAW, POLISHER, ETCHER, COMPACT EVAPORATOR, HALL
APPARATUS LIGHT SOURCE AND SPECTROMETER.

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                                          BOEING-SPECIFIC INPUT DATA
--------------------------------------------------------------------------------------------------------
MISSION TYPE                                      OPS CODE
   FREE FLYER
   ( ) NOT SERVICED                                  F
   ( ) REMOTE TMS                                    FT
   ( ) REMOTE MANNED                                 FM
   ( ) SERVICED AT STATION (TMS RETRIEVED)           FST
   ( ) SERVICED AT STATION (SELF-PROPELLED)          FS

   PLATFORM BASED
   ( ) NOT SERVICED                                  P
   ( ) REMOTE TMS                                    PT
   ( ) REMOTE MANNED                                 PM
   ( ) SERVICED AT STATION (TMS RETRIEVED)           PST
   ( ) SERVICED AT STATION (SELF-PROPELLED)          PS

   OTHER
   ( ) SPACE STATION BASED                           SS
   ( ) SORTIE                                        SOR

CONSTRUCTION/SERVICING COMPLEXITY
   ( ) LOW
   ( ) MEDIUM
   ( ) HIGH

OPERATIONS TIMES
   OTV UP/DOWN                          DAYS
   OTV OR TMS ON ORBIT                  DAYS
   MISSION USE                          DAYS/YEAR
   IVA SERVICE                          MAN-DAYS/YEAR
   EVA SERVICE                          MAN-DAYS/YEAR
   EXPERIMENT OPS                       MAN-DAYS/YEAR
   SERVICE FREQUENCY                    TIMES/YEAR

DELTA VELOCITIES
   UP                        0.00
   DOWN                      0.00
   AERO RETURN               0.00

SUPPORT EQUIPMENT
             LENGTH:         0.00 METERS      WIDTH:      0.00 METERS       HEIGHT:      0.00 METERS      (STOWED)
             LENGTH:         0.00 METERS      WIDTH:      0.00 METERS       HEIGHT:      0.00 METERS      (DEPLOYED)

             MASS:              0 KG

MANIFEST RESTRICTIONS
   (X) NO RESTRICTIONS
   ( ) ONLY WITH COMPATIBLE PAYLOADS
   ( ) FLY-ALONE
   ( ) MUST HAVE DOCKING MODULE

LENGTH OF BEAM FAB                                        0.00
NUMBER OF APPENDAGES                                         0
NUMBER OF MODULES REQUIRED TO ASSEMBLE THE PAYLOAD           0
--------------------------------------------------------------------------------------------------------
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PAYLOAD ELEMENT NAME
ELECTROEPITAXIAL CRYSTAL GROWTH

CODE
BACX1018

TYPE
( ) SCIENCE AND APPLICATIONS (NON-COMM.)
(X) COMMERCIAL
( ) TECHNOLOGY DEVELOPMENT
( ) OPERATIONS
( ) OTHER
( ) NATIONAL SECURITY
TYPE NUMBER (SEE TABLE A) 8

CONTACT
NAME ROBERT E. PACE, JR.
ADDRESS MICROGRAVITY RESEARCH AS
PO BOX 12426
HUNTSVILLE, AL 35802

TELEPHONE (205) 881-6670

IMPORTANCE OF THE SPACE STATION TO
THIS ELEMENT
1 = LOW VALUE, BUT COULD USE
10 = VITAL
SCALE = 7

STATUS
( ) OPERATIONAL ( ) APPROVED (X) PLANNED ( ) CANDIDATE ( ) OPPORTUNITY

DESIRED FIRST FLIGHT, YEAR: 1996 NUMBER OF FLIGHTS 1 DURATION OF FLIGHT, DAYS 77

OBJECTIVE
DEVELOP AND COMMERCIALIZE A PROCESS FOR PRODUCING LARGE SINGLE CRYSTALS OF COMPOUND SEMICONDUCTOR MATERIALS.

DESCRIPTION
CRYSTALS ARE GROWN IN SPACE BY AN ELECTROEPITAXIAL GROWTH PROCESS. COMMERCIAL MANUFACTURING UNITS ARE PLACED IN MODULES ATTACHED TO THE SPACE STATION, AND GROWTH CELLS ARE REPLACED PERIODICALLY AND CRYSTALS RETURNED TO EARTH. A PROCESS DEVELOPMENT LABORATORY ON THE SPACE STATION IS USED TO CHARACTERIZE THE CRYSTALS AND DEVELOP THE PROCESS.

ORBIT CHARACTERISTICS
GEOSYNCHRONOUS ORBIT ( ) YES (X) NO
APOGEE, KM PERIGEE, KM TOLERANCE + -
INCLINATION, DEG . TOLERANCE + -
NODAL ANGLE, DEG EPHEMERIS ACCURACY, M
ESCAPE DV REQUIRED, M/S .

POINTING/ORIENTATION
VIEW DIRECTION ( ) INERTIAL ( ) SOLAR ( ) EARTH (X) ANY
TRUTH SITES (IF KNOWN)
POINTING ACCURACY, ARC-SEC FIELD OF VIEW (DEG)
POINTING STABILITY (JITTER), ARC-SEC/SEC
SPECIAL RESTRICTIONS (AVOIDANCE)

POWER
( ) AC (X) DC

	POWER, W	DURATION, HRS/DAY
OPERATING	60000	24.00
STANDBY		
PEAK	60600	24.00

(X) CONTINUOUS

VOLTAGE, V 50 FREQUENCY, HZ 0

DATA/COMMUNICATIONS

MONITORING REQUIREMENTS:
( ) NONE ( ) REALTIME (X) OFFLINE ( ) OTHER:
( ) ENCRIPTION/DECRIPTION REQUIRED
( ) UPLINK REQUIRED: COMMAND RATE (KBS): 0 FREQUENCY (MHZ):
( ) ON-BOARD DATA PROCESSING REQUIRED
DESCRIPTION:
DATA TYPES: ( ) ANALOG ( ) DIGITAL HOURS/DAY
FILM (AMOUNT): VOICE (HOURS/DAY):
LIVE TV (HOURS/DAY): OTHER:
ON-BOARD STORAGE (MBIT):
DATA DUMP FREQUENCY (PER ORBIT) DOWNLINK COMMAND RATE:
RECORDING RATE (KBPS) 0.10 DOWNLINK FREQUENCY (MHZ):

THERMAL

(X) ACTIVE ( ) PASSIVE
TEMPERATURE, DEG C OPERATIONAL MINIMUM 850 MAXIMUM 950
NON-OPERATIONAL MINIMUM 0 MAXIMUM 100
HEAT REJECTION, W OPERATIONAL MINIMUM 10000 MAXIMUM 60000
NON-OPERATIONAL MINIMUM 0 MAXIMUM

EQUIPMENT PHYSICAL CHARACTERISTICS

LOCATION (X) INTERNAL ( ) EXTERNAL ( ) REMOTE
EQUIPMENT ID/FUNCTION (X) PRESSURIZED ( ) UNPRESSURIZED
L, M: 5.00 W, M: 1.00 H, M: 4.00 STOWED
L, M: 5.00 W, M: 1.00 H, M: 4.00 DEPLOYED
LAUNCH MASS, KG: 6600 RETURN MASS, KG: 6600
CONSUMABLE TYPES
ACCELERATION SENSITIVITY, (G) MIN: 1.00E-06 MAX: 1.00E-04

CREW REQUIREMENTS

CREW SIZE 2 TASK ASSIGNMENTS

SKILLS (SEE TABLE B)

SKILL						
LEVEL						
HOURS/DAY	4.00					

EVA ( ) YES (X) NO REASON HOURS/EVA

SERVICING/MAINTENANCE

SERVICE: INTERVAL, DAYS 90 CONSUMABLES, KG
RETURNABLES, KG 6600 MAN HOURS
CONFIGURATION CHANGES: INTERVAL, DAY MAN/HOURS REQUIRED
DELIVERABLES, KG RETURNABLES, KG

SPECIAL CONSIDERATIONS/SEE INSTRUCTIONS

LABORATORY FACILITIES REQUIRED: CLEAN ROOM, WORKSPACE, MINICOMUTER, DOWNLINK TERMINAL
CRYSTAL CHARACTERIZATION EQUIPMENT REQUIRED: CUTTING SAW, POLISHER, ETCHER, COMPACT EVAPORATOR, HALL APPARATUS LIGHT SOURCE AND SPECTROMETER.

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                                                        BOEING-SPECIFIC INPUT DATA
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MISSION TYPE                                      OPS CODE
   FREE FLYER
   ( ) NOT SERVICED                                  F
   ( ) REMOTE TMS                                    FT
   ( ) REMOTE MANNED                                 FM
   ( ) SERVICED AT STATION (TMS RETRIEVED)           FST
   ( ) SERVICED AT STATION (SELF-PROPELLED)          FS

   PLATFORM BASED
   ( ) NOT SERVICED                                  P
   ( ) REMOTE TMS                                    PT
   ( ) REMOTE MANNED                                 PM
   ( ) SERVICED AT STATION (TMS RETRIEVED)           PST
   ( ) SERVICED AT STATION (SELF-PROPELLED)          PS

   OTHER
   ( ) SPACE STATION BASED                           SS
   ( ) SORTIE                                        SOR

CONSTRUCTION/SERVICING COMPLEXITY
   ( ) LOW
   ( ) MEDIUM
   ( ) HIGH

OPERATIONS TIMES
   OTV UP/DOWN                          DAYS
   OTV OR TMS ON ORBIT                  DAYS
   MISSION USE                          DAYS/YEAR
   IVA SERVICE                          MAN-DAYS/YEAR
   EVA SERVICE                          MAN-DAYS/YEAR
   EXPERIMENT OPS                       MAN-DAYS/YEAR
   SERVICE FREQUENCY                    TIMES/YEAR

DELTA VELOCITIES
   UP                     0.00
   DOWN                   0.00
   AERO RETURN            0.00

SUPPORT EQUIPMENT
             LENGTH:      0.00 METERS      WIDTH:     0.00 METERS        HEIGHT:     0.00 METERS      (STOWED)
             LENGTH:      0.00 METERS      WIDTH:     0.00 METERS        HEIGHT:     0.00 METERS      (DEPLOYED)

             MASS:           0 KG

MANIFEST RESTRICTIONS
   (X) NO RESTRICTIONS
   ( ) ONLY WITH COMPATIBLE PAYLOADS
   ( ) FLY-ALONE
   ( ) MUST HAVE DOCKING MODULE

LENGTH OF BEAM FAB                                          0.00
NUMBER OF APPENDAGES                                           0
NUMBER OF MODULES REQUIRED TO ASSEMBLE THE PAYLOAD:            0
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PAYLOAD ELEMENT NAME
ELECTROEPITAXIAL CRYSTAL GROWTH

CODE
BACX1019

TYPE
( ) SCIENCE AND APPLICATIONS (NON-COMM.)
(X) COMMERCIAL
( ) TECHNOLOGY DEVELOPMENT
( ) OPERATIONS
( ) OTHER
( ) NATIONAL SECURITY
TYPE NUMBER (SEE TABLE A) 8

CONTACT
NAME ROBERT E. PACE, JR.
ADDRESS MICROGRAVITY RESEARCH AS
PO BOX 12426
HUNTSVILLE, AL 35802

TELEPHONE (205) 881-6670

IMPORTANCE OF THE SPACE STATION TO THIS ELEMENT
1 = LOW VALUE, BUT COULD USE
10 = VITAL
SCALE = 7

STATUS
( ) OPERATIONAL ( ) APPROVED (X) PLANNED ( ) CANDIDATE ( ) OPPORTUNITY

DESIRED FIRST FLIGHT, YEAR: 1996 NUMBER OF FLIGHTS 1 DURATION OF FLIGHT, DAYS 77

OBJECTIVE
DEVELOP AND COMMERCIALIZE A PROCESS FOR PRODUCING LARGE SINGLE CRYSTALS OF COMPOUND SEMICONDUCTOR MATERIALS.

DESCRIPTION
CRYSTALS ARE GROWN IN SPACE BY AN ELECTROEPITAXIAL GROWTH PROCESS. COMMERCIAL MANUFACTURING UNITS ARE PLACED IN MODULES ATTACHED TO THE SPACE STATION, AND GROWTH CELLS ARE REPLACED PERIODICALLY AND CRYSTALS RETURNED TO EARTH. A PROCESS DEVELOPMENT LABORATORY ON THE SPACE STATION IS USED TO CHARACTERIZE THE CRYSTALS AND DEVELOP THE PROCESS.

ORBIT CHARACTERISTICS
GEOSYNCHRONOUS ORBIT ( ) YES (X) NO
APOGEE, KM PERIGEE, KM TOLERANCE + -
INCLINATION, DEG TOLERANCE + -
NODAL ANGLE, DEG EPHEMERIS ACCURACY, M
ESCAPE DV REQUIRED, M/S

POINTING/ORIENTATION
VIEW DIRECTION ( ) INERTIAL ( ) SOLAR ( ) EARTH (X) ANY
TRUTH SITES (IF KNOWN)
POINTING ACCURACY, ARC-SEC FIELD OF VIEW (DEG)
POINTING STABILITY (JITTER), ARC-SEC/SEC
SPECIAL RESTRICTIONS (AVOIDANCE)

POWER
( ) AC (X) DC

	POWER, W	DURATION, HRS/DAY
OPERATING	60000	24.00
STANDBY		
PEAK	60000	24.00

(X) CONTINUOUS
VOLTAGE, V 50 FREQUENCY, HZ 0

```
DATA/COMMUN.   IONS
   MONITORING REQUIREMENTS:
   ( ) NONE        ( ) REALTIME   (X) OFFLINE    ( ) OTHER:
   ( ) ENCRIPTION/DECRIPTION REQUIRED
   ( ) UPLINK REQUIRED:  COMMAND RATE (KBS):        0          FREQUENCY (MHZ):
   ( ) ON-BOARD DATA PROCESSING REQUIRED
       DESCRIPTION:
       DATA TYPES:   ( ) ANALOG      ( ) DIGITAL               HOURS/DAY
       FILM (AMOUNT):                                          VOICE (HOURS/DAY):
       LIVE TV (HOURS/DAY):                                    OTHER:
       ON-BOARD STORAGE (MBIT):
       DATA DUMP FREQUENCY (PER ORBIT)                         DOWNLINK COMMAND RATE:
       RECORDING RATE (KBPS)          0.10                     DOWNLINK FREQUENCY (MHZ):
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THERMAL
   (X) ACTIVE     ( ) PASSIVE
       TEMPERATURE, DEG C   OPERATIONAL MINIMUM          850          MAXIMUM    950
                            NON-OPERATIONAL MINIMUM        0          MAXIMUM    100
       HEAT REJECTION, W    OPERATIONAL MINIMUM        10000          MAXIMUM  60000
                            NON-OPERATIONAL MINIMUM        0          MAXIMUM
-----------------------------------------------------------------------------------------------------------
EQUIPMENT PHYSICAL CHARACTERISTICS
   LOCATION        (X) INTERNAL        ( ) EXTERNAL        ( ) REMOTE
   EQUIPMENT ID/FUNCTION               (X) PRESSURIZED     ( ) UNPRESSURIZED
                 L, M:      5.00       W, M:     1.00      H, M:      4.00    STOWED
                 L, M:      5.00       W, M:     1.00      H, M:      4.00    DEPLOYED
                 LAUNCH MASS, KG:      7500                RETURN MASS, KG:    6600
                 CONSUMABLE TYPES
                 ACCELERATION SENSITIVITY, (G)       MIN:  1.00E-06      MAX:  1.00E-04
-----------------------------------------------------------------------------------------------------------
CREW REQUIREMENTS
   CREW SIZE              2             TASK ASSIGNMENTS
                                        ------------------------------------------------
   SKILLS (SEE TABLE B)                 | SKILL     |      |      |      |      |      |
                                        ------------------------------------------------
                                        | LEVEL     |      |      |      |      |      |
                                        ------------------------------------------------
                                        | HOURS/DAY | 4.00 |      |      |      |      |
                                        ------------------------------------------------
   EVA   ( ) YES    (X) NO              REASON                       HOURS/EVA
-----------------------------------------------------------------------------------------------------------
SERVICING/MAINTENANCE
   SERVICE:                          INTERVAL,  DAYS      90          CONSUMABLES, KG
                                     RETURNABLES, KG    7500          MAN HOURS
   CONFIGURATION CHANGES:            INTERVAL, DAY                    MAN/HOURS REQUIRED
                                     DELIVERABLES, KG                 RETURNABLES, KG
-----------------------------------------------------------------------------------------------------------
SPECIAL CONSIDERATIONS/SEE INSTRUCTIONS
LABORATORY FACILITIES REQUIRED: CLEAN ROOM, WORKSPACE, MINICOMUTER, DOWNLINK TERMINAL
CRYSTAL CHARACTERIZATION EQUIPMENT REQUIRED: CUTTING SAW, POLISHER, ETCHER, COMPACT EVAPORATOR, HALL
APPARATUS LIGHT SOURCE AND SPECTROMETER.


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                                              BOEING-SPECIFIC INPUT DATA
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MISSION TYPE                                OPS CODE
   FREE FLYER
   ( ) NOT SERVICED                            F
   ( ) REMOTE TMS                              FT
   ( ) REMOTE MANNED                           FM
   ( ) SERVICED AT STATION (TMS RETRIEVED)     FST
   ( ) SERVICED AT STATION (SELF-PROPELLED)    FS

   PLATFORM BASED
   ( ) NOT SERVICED                            P
   ( ) REMOTE TMS                              PT
   ( ) REMOTE MANNED                           PM
   ( ) SERVICED AT STATION (TMS RETRIEVED)     PST
   ( ) SERVICED AT STATION (SELF-PROPELLED)    PS

   OTHER
   ( ) SPACE STATION BASED                     SS
   ( ) SORTIE                                  SOR

CONSTRUCTION/SERVICING COMPLEXITY
   ( ) LOW
   ( ) MEDIUM
   ( ) HIGH

OPERATIONS TIMES
   OTV UP/DOWN                         DAYS
   OTV OR TMS ON ORBIT                 DAYS
   MISSION USE                         DAYS/YEAR
   IVA SERVICE                         MAN-DAYS/YEAR
   EVA SERVICE                         MAN-DAYS/YEAR
   EXPERIMENT OPS                      MAN-DAYS/YEAR
   SERVICE FREQUENCY                   TIMES/YEAR

DELTA VELOCITIES
   UP                       0.00
   DOWN                     0.00
   AERO RETURN              0.00

SUPPORT EQUIPMENT
             LENGTH:        0.00 METERS      WIDTH:     0.00 METERS        HEIGHT:     0.00 METERS     (STOWED)
             LENGTH:        0.00 METERS      WIDTH:     0.00 METERS        HEIGHT:     0.00 METERS     (DEPLOYED)

             MASS:             0 KG

MANIFEST RESTRICTIONS
   (X) NO RESTRICTIONS
   ( ) ONLY WITH COMPATIBLE PAYLOADS
   ( ) FLY-ALONE
   ( ) MUST HAVE DOCKING MODULE

LENGTH OF BEAM FAB                                      0.00
NUMBER OF APPENDAGES                                       0
NUMBER OF MODULES REQUIRED TO ASSEMBLE THE PAYLOAD:        0
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```

PAYLOAD ELEMENT NAME
ELECTROEPITAXIAL CRYSTAL GROWTH

CODE
BACX1020

TYPE
( ) SCIENCE AND APPLICATIONS (NON-COMM.)
(X) COMMERCIAL
( ) TECHNOLOGY DEVELOPMENT
( ) OPERATIONS
( ) OTHER
( ) NATIONAL SECURITY
TYPE NUMBER (SEE TABLE A) 8

CONTACT
NAME ROBERT E. PACE, JR.
ADDRESS MICROGRAVITY RESEARCH AS
PO BOX 12426
HUNTSVILLE, AL 35802

TELEPHONE (205) 881-6670

IMPORTANCE OF THE SPACE STATION TO THIS ELEMENT
1 = LOW VALUE, BUT COULD USE
10 = VITAL
SCALE = 7

STATUS
( ) OPERATIONAL ( ) APPROVED (X) PLANNED ( ) CANDIDATE ( ) OPPORTUNITY

DESIRED FIRST FLIGHT, YEAR: 1997 NUMBER OF FLIGHTS 1 DURATION OF FLIGHT, DAYS 77

OBJECTIVE
DEVELOP AND COMMERCIALIZE A PROCESS FOR PRODUCING LARGE SINGLE CRYSTALS OF COMPOUND SEMICONDUCTOR MATERIALS.

DESCRIPTION
CRYSTALS ARE GROWN IN SPACE BY AN ELECTROEPITAXIAL GROWTH PROCESS. COMMERCIAL MANUFACTURING UNITS ARE PLACED IN MODULES ATTACHED TO THE SPACE STATION, AND GROWTH CELLS ARE REPLACED PERIODICALLY AND CRYSTALS RETURNED TO EARTH. A PROCESS DEVELOPMENT LABORATORY ON THE SPACE STATION IS USED TO CHARACTERIZE THE CRYSTALS AND DEVELOP THE PROCESS.

ORBIT CHARACTERISTICS
GEOSYNCHRONOUS ORBIT ( ) YES (X) NO
APOGEE, KM PERIGEE, KM TOLERANCE + -
INCLINATION, DEG . TOLERANCE + -
NODAL ANGLE, DEG EPHEMERIS ACCURACY, M
ESCAPE DV REQUIRED, M/S .

POINTING/ORIENTATION
VIEW DIRECTION ( ) INERTIAL ( ) SOLAR ( ) EARTH (X) ANY
TRUTH SITES (IF KNOWN)
POINTING ACCURACY, ARC-SEC FIELD OF VIEW (DEG)
POINTING STABILITY (JITTER), ARC-SEC/SEC
SPECIAL RESTRICTIONS (AVOIDANCE)

POWER
( ) AC (X) DC

	POWER, W	DURATION, HRS/DAY
OPERATING	60000	24.00
STANDBY		
PEAK	60000	24.00

(X) CONTINUOUS

VOLTAGE, V 50 FREQUENCY, HZ 0

DATA/COMMUNICATIONS

MONITORING REQUIREMENTS:
( ) NONE ( ) REALTIME (X) OFFLINE ( ) OTHER:
( ) ENCRIPTION/DECRIPTION REQUIRED
( ) UPLINK REQUIRED: COMMAND RATE (KBS): 0 FREQUENCY (MHZ):
( ) ON-BOARD DATA PROCESSING REQUIRED
DESCRIPTION:
DATA TYPES: ( ) ANALOG ( ) DIGITAL HOURS/DAY
FILM (AMOUNT): VOICE (HOURS/DAY):
LIVE TV (HOURS/DAY): OTHER:
ON-BOARD STORAGE (MBIT):
DATA DUMP FREQUENCY (PER ORBIT) DOWNLINK COMMAND RATE:
RECORDING RATE (KBPS) 0.10 DOWNLINK FREQUENCY (MHZ):

THERMAL

(X) ACTIVE ( ) PASSIVE

TEMPERATURE, DEG C	OPERATIONAL MINIMUM	850	MAXIMUM	950
	NON-OPERATIONAL MINIMUM	0	MAXIMUM	100
HEAT REJECTION, W	OPERATIONAL MINIMUM	10000	MAXIMUM	60000
	NON-OPERATIONAL MINIMUM	0	MAXIMUM	

EQUIPMENT PHYSICAL CHARACTERISTICS

LOCATION (X) INTERNAL ( ) EXTERNAL ( ) REMOTE
EQUIPMENT ID/FUNCTION (X) PRESSURIZED ( ) UNPRESSURIZED
L, M: 5.00 W, M: 1.00 H, M: 4.00 STOWED
L, M: 5.00 W, M: 1.00 H, M: 4.00 DEPLOYED
LAUNCH MASS, KG: 9050 RETURN MASS, KG: 7600
CONSUMABLE TYPES
ACCELERATION SENSITIVITY, (G) MIN: 1.00E-06 MAX: 1.00E-04

CREW REQUIREMENTS

CREW SIZE 2 TASK ASSIGNMENTS

SKILLS (SEE TABLE B)

SKILL						
LEVEL						
HOURS/DAY	4.00					

EVA ( ) YES (X) NO REASON HOURS/EVA

SERVICING/MAINTENANCE

SERVICE: INTERVAL, DAYS 90 CONSUMABLES, KG
RETURNABLES, KG 9050 MAN HOURS
CONFIGURATION CHANGES: INTERVAL, DAY MAN/HOURS REQUIRED
DELIVERABLES, KG RETURNABLES, KG

SPECIAL CONSIDERATIONS/SEE INSTRUCTIONS

LABORATORY FACILITIES REQUIRED: CLEAN ROOM, WORKSPACE, MINICOMUTER, DOWNLINK TERMINAL
CRYSTAL CHARACTERIZATION EQUIPMENT REQUIRED: CUTTING SAW, POLISHER, ETCHER, COMPACT EVAPORATOR, HALL APPARATUS LIGHT SOURCE AND SPECTROMETER.

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                                        BOEING-SPECIFIC INPUT DATA
-------------------------------------------------------------------------------------------------------
MISSION TYPE
  FREE FLYER                                      OPS CODE
  ( ) NOT SERVICED                                  F
  ( ) REMOTE TMS                                    FT
  ( ) REMOTE MANNED                                 FM
  ( ) SERVICED AT STATION (TMS RETRIEVED)           FST
  ( ) SERVICED AT STATION (SELF-PROPELLED)          FS

  PLATFORM BASED
  ( ) NOT SERVICED                                  P
  ( ) REMOTE TMS                                    PT
  ( ) REMOTE MANNED                                 PM
  ( ) SERVICED AT STATION (TMS RETRIEVED)           PST
  ( ) SERVICED AT STATION (SELF-PROPELLED)          PS

  OTHER
  ( ) SPACE STATION BASED                           SS
  ( ) SORTIE                                        SOR

CONSTRUCTION/SERVICING COMPLEXITY
  ( ) LOW
  ( ) MEDIUM
  ( ) HIGH

OPERATIONS TIMES
  OTV UP/DOWN                         DAYS
  OTV OR TMS ON ORBIT                 DAYS
  MISSION USE                         DAYS/YEAR
  IVA SERVICE                         MAN-DAYS/YEAR
  EVA SERVICE                         MAN-DAYS/YEAR
  EXPERIMENT OPS                      MAN-DAYS/YEAR
  SERVICE FREQUENCY                   TIMES/YEAR

DELTA VELOCITIES
  UP                       0.00
  DOWN                     0.00
  AERO RETURN              0.00

SUPPORT EQUIPMENT
            LENGTH:        0.00 METERS      WIDTH:     0.00 METERS        HEIGHT:     0.00 METERS     (STOWED)
            LENGTH:        0.00 METERS      WIDTH:     0.00 METERS        HEIGHT:     0.00 METERS     (DEPLOYED)

            MASS:             0 KG

MANIFEST RESTRICTIONS
  (X) NO RESTRICTIONS
  ( ) ONLY WITH COMPATIBLE PAYLOADS
  ( ) FLY-ALONE
  ( ) MUST HAVE DOCKING MODULE

LENGTH OF BEAM FAB                                      0.00
NUMBER OF APPENDAGES                                       0
NUMBER OF MODULES REQUIRED TO ASSEMBLE THE PAYLOAD         0
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PAYLOAD ELEMENT NAME
ELECTROEPITAXIAL CRYSTAL GROWTH

CODE
BACX1021

TYPE
( ) SCIENCE AND APPLICATIONS (NON-COMM.)
(X) COMMERCIAL
( ) TECHNOLOGY DEVELOPMENT
( ) OPERATIONS
( ) OTHER
( ) NATIONAL SECURITY
TYPE NUMBER (SEE TABLE A) 8

CONTACT
NAME ROBERT E. PACE, JR.
ADDRESS MICROGRAVITY RESEARCH AS
PO BOX 12426
HUNTSVILLE, AL 35802

TELEPHONE (205) 881-6670

IMPORTANCE OF THE SPACE STATION TO THIS ELEMENT
1 = LOW VALUE, BUT COULD USE
10 = VITAL
SCALE = 7

STATUS
( ) OPERATIONAL ( ) APPROVED (X) PLANNED ( ) CANDIDATE ( ) OPPORTUNITY

DESIRED FIRST FLIGHT, YEAR: 1997 NUMBER OF FLIGHTS 1 DURATION OF FLIGHT, DAYS 105

OBJECTIVE
DEVELOP AND COMMERCIALIZE A PROCESS FOR PRODUCING LARGE SINGLE CRYSTALS OF COMPOUND SEMICONDUCTOR MATERIALS.

ORIGINAL PAGE IS OF POOR QUALITY

DESCRIPTION
CRYSTALS ARE GROWN IN SPACE BY AN ELECTROEPITAXIAL GROWTH PROCESS. COMMERCIAL MANUFACTURING UNITS ARE PLACED IN MODULES ATTACHED TO THE SPACE STATION, AND GROWTH CELLS ARE REPLACED PERIODICALLY AND CRYSTALS RETURNED TO EARTH. A PROCESS DEVELOPMENT LABORATORY ON THE SPACE STATION IS USED TO CHARACTERIZE THE CRYSTALS AND DEVELOP THE PROCESS.

ORBIT CHARACTERISTICS
GEOSYNCHRONOUS ORBIT ( ) YES (X) NO
APOGEE, KM PERIGEE, KM TOLERANCE + -
INCLINATION, DEG . TOLERANCE + -
NODAL ANGLE, DEG EPHEMERIS ACCURACY, M
ESCAPE DV REQUIRED, M/S .

POINTING/ORIENTATION
VIEW DIRECTION ( ) INERTIAL ( ) SOLAR ( ) EARTH (X) ANY
TRUTH SITES (IF KNOWN)
POINTING ACCURACY, ARC-SEC FIELD OF VIEW (DEG)
POINTING STABILITY (JITTER), ARC-SEC/SEC
SPECIAL RESTRICTIONS (AVOIDANCE)

POWER
( ) AC (X) DC

	POWER, W	DURATION, HRS/DAY	
OPERATING	80000	24.00	
STANDBY			(X) CONTINUOUS
PEAK	80000	24.00	
VOLTAGE, V	50	FREQUENCY, HZ	0

```
DATA/COMMUNICATIONS
   MONITORING REQUIREMENTS:
   ( ) NONE        ( ) REALTIME   (X) OFFLINE    ( ) OTHER:
   ( ) ENCRIPTION/DECRIPTION REQUIRED
   ( ) UPLINK REQUIRED:  COMMAND RATE (KBS):       0          FREQUENCY (MHZ):
   ( ) ON-BOARD DATA PROCESSING REQUIRED
       DESCRIPTION:
       DATA TYPES:   ( ) ANALOG     ( ) DIGITAL               HOURS/DAY
       FILM (AMOUNT):                                         VOICE (HOURS/DAY):
       LIVE TV (HOURS/DAY):                                   OTHER:
       ON-BOARD STORAGE (MBIT):
       DATA DUMP FREQUENCY (PER ORBIT)                        DOWNLINK COMMAND RATE:
       RECORDING RATE (KBPS)          0.10                    DOWNLINK FREQUENCY (MHZ):
--------------------------------------------------------------------------------------------
THERMAL
   (X) ACTIVE      ( ) PASSIVE
       TEMPERATURE, DEG C  OPERATIONAL MINIMUM          850        MAXIMUM    950
                           NON-OPERATIONAL MINIMUM        0        MAXIMUM    100
       HEAT REJECTION, W   OPERATIONAL MINIMUM        10000        MAXIMUM  80000
                           NON-OPERATIONAL MINIMUM        0        MAXIMUM
--------------------------------------------------------------------------------------------
EQUIPMENT PHYSICAL CHARACTERISTICS
   LOCATION         (X) INTERNAL         ( ) EXTERNAL         ( ) REMOTE
   EQUIPMENT ID/FUNCTION                 (X) PRESSURIZED      ( ) UNPRESSURIZED
                  L, M:      5.00       W, M:      1.00      H, M:      4.00     STOWED
                  L, M:      5.00       W, M:      1.00      H, M:      4.00     DEPLOYED
                  LAUNCH MASS, KG:      13500                RETURN MASS, KG:    7250
                  CONSUMABLE TYPES
                  ACCELERATION SENSITIVITY, (G)       MIN:  1.00E-06     MAX:  1.00E-04
--------------------------------------------------------------------------------------------
CREW REQUIREMENTS
   CREW SIZE          2            TASK ASSIGNMENTS
                                   ------------------------------------------------------
   SKILLS (SEE TABLE B)            | SKILL     |        |     |     |     |     |     |
                                   ------------------------------------------------------
                                   | LEVEL     |        |     |     |     |     |     |
                                   ------------------------------------------------------
                                   | HOURS/DAY |  4.00  |     |     |     |     |     |
                                   ------------------------------------------------------
   EVA   ( ) YES    (X) NO         REASON                      HOURS/EVA
--------------------------------------------------------------------------------------------
SERVICING/MAINTENANCE
   SERVICE:                         INTERVAL,  DAYS       90          CONSUMABLES, KG
                                    RETURNABLES, KG    13500          MAN HOURS
   CONFIGURATION CHANGES:           INTERVAL, DAY                     MAN/HOURS REQUIRED
                                    DELIVERABLES, KG                  RETURNABLES, KG
--------------------------------------------------------------------------------------------
SPECIAL CONSIDERATIONS/SEE INSTRUCTIONS
LABORATORY FACILITIES REQUIRED: CLEAN ROOM, WORKSPACE, MINICOMUTER, DOWNLINK TERMINAL
CRYSTAL CHARACTERIZATION EQUIPMENT REQUIRED: CUTTING SAW, POLISHER, ETCHER, COMPACT EVAPORATOR, HALL
APPARATUS LIGHT SOURCE AND SPECTROMETER.


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                                                BOEING-SPECIFIC INPUT DATA
---------------------------------------------------------------------------------------------------------------------
MISSION TYPE                                  OPS CODE
   FREE FLYER
   ( ) NOT SERVICED                             F
   ( ) REMOTE TMS                               FT
   ( ) REMOTE MANNED                            FM
   ( ) SERVICED AT STATION (TMS RETRIEVED)      FST
   ( ) SERVICED AT STATION (SELF-PROPELLED)     FS

   PLATFORM BASED
   ( ) NOT SERVICED                             P
   ( ) REMOTE TMS                               PT
   ( ) REMOTE MANNED                            PM
   ( ) SERVICED AT STATION (TMS RETRIEVED)      PST
   ( ) SERVICED AT STATION (SELF-PROPELLED)     PS

   OTHER
   ( ) SPACE STATION BASED                      SS
   ( ) SORTIE                                   SOR

CONSTRUCTION/SERVICING COMPLEXITY
   ( ) LOW
   ( ) MEDIUM
   ( ) HIGH

OPERATIONS TIMES
   OTV UP/DOWN                        DAYS
   OTV OR TMS ON ORBIT                DAYS
   MISSION USE                        DAYS/YEAR
   IVA SERVICE                        MAN-DAYS/YEAR
   EVA SERVICE                        MAN-DAYS/YEAR
   EXPERIMENT OPS                     MAN-DAYS/YEAR
   SERVICE FREQUENCY                  TIMES/YEAR

DELTA VELOCITIES
   UP                     0.00
   DOWN                   0.00
   AERO RETURN            0.00

SUPPORT EQUIPMENT
            LENGTH:       0.00 METERS      WIDTH:      0.00 METERS        HEIGHT:      0.00 METERS      (STOWED)
            LENGTH:       0.00 METERS      WIDTH:      0.00 METERS        HEIGHT:      0.00 METERS      (DEPLOYED)

            MASS:            0 KG

MANIFEST RESTRICTIONS
   (X) NO RESTRICTIONS
   ( ) ONLY WITH COMPATIBLE PAYLOADS
   ( ) FLY-ALONE
   ( ) MUST HAVE DOCKING MODULE

LENGTH OF BEAM FAB                                        0.00
NUMBER OF APPENDAGES                                         0
NUMBER OF MODULES REQUIRED TO ASSEMBLE THE PAYLOAD           0
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PAYLOAD ELEMENT NAME
ELECTROEPITAXIAL CRYSTAL GROWTH

CODE
BACX1022

TYPE
( ) SCIENCE AND APPLICATIONS (NON-COMM.)
(X) COMMERCIAL
( ) TECHNOLOGY DEVELOPMENT
( ) OPERATIONS
( ) OTHER
( ) NATIONAL SECURITY
TYPE NUMBER (SEE TABLE A) 8

CONTACT
NAME ROBERT E. PACE, JR.
ADDRESS MICROGRAVITY RESEARCH AS
PO BOX 12426
HUNTSVILLE, AL 35802

TELEPHONE (205) 881-6670

IMPORTANCE OF THE SPACE STATION TO THIS ELEMENT
1 = LOW VALUE, BUT COULD USE
10 = VITAL
SCALE = 7

STATUS
( ) OPERATIONAL ( ) APPROVED (X) PLANNED ( ) CANDIDATE ( ) OPPORTUNITY

DESIRED FIRST FLIGHT, YEAR: 1997 NUMBER OF FLIGHTS 1 DURATION OF FLIGHT, DAYS 105

OBJECTIVE
DEVELOP AND COMMERCIALIZE A PROCESS FOR PRODUCING LARGE SINGLE CRYSTALS OF COMPOUND SEMICONDUCTOR MATERIALS.

DESCRIPTION
CRYSTALS ARE GROWN IN SPACE BY AN ELECTROEPITAXIAL GROWTH PROCESS. COMMERCIAL MANUFACTURING UNITS ARE PLACED IN MODULES ATTACHED TO THE SPACE STATION, AND GROWTH CELLS ARE REPLACED PERIODICALLY AND CRYSTALS RETURNED TO EARTH. A PROCESS DEVELOPMENT LABORATORY ON THE SPACE STATION IS USED TO CHARACTERIZE THE CRYSTALS AND DEVELOP THE PROCESS.

ORBIT CHARACTERISTICS
GEOSYNCHRONOUS ORBIT ( ) YES (X) NO
APOGEE, KM PERIGEE, KM TOLERANCE + -
INCLINATION, DEG . TOLERANCE + -
NODAL ANGLE, DEG EPHEMERIS ACCURACY, M
ESCAPE DV REQUIRED, M/S .

POINTING/ORIENTATION
VIEW DIRECTION ( ) INERTIAL ( ) SOLAR ( ) EARTH (X) ANY
TRUTH SITES (IF KNOWN)
POINTING ACCURACY, ARC-SEC FIELD OF VIEW (DEG)
POINTING STABILITY (JITTER), ARC-SEC/SEC
SPECIAL RESTRICTIONS (AVOIDANCE)

POWER
( ) AC (X) DC

	POWER, W	DURATION, HRS/DAY
OPERATING	80000	24.00
STANDBY		
PEAK	80000	24.00
VOLTAGE, V	50	

(X) CONTINUOUS
FREQUENCY, HZ 0

```
DATA/COMMUNICATIONS
   MONITORING REQUIREMENTS:
   ( ) NONE          ( ) REALTIME   (X) OFFLINE     ( ) OTHER:
   ( ) ENCRIPTION/DECRIPTION REQUIRED
   ( ) UPLINK REQUIRED:  COMMAND RATE (KBS):       0          FREQUENCY (MHZ):
   ( ) ON-BOARD DATA PROCESSING REQUIRED
       DESCRIPTION:
       DATA TYPES:   ( ) ANALOG     ( ) DIGITAL               HOURS/DAY
       FILM (AMOUNT):                                         VOICE (HOURS/DAY):
       LIVE TV (HOURS/DAY):                                   OTHER:
       ON-BOARD STORAGE (MBIT):
       DATA DUMP FREQUENCY (PER ORBIT)                        DOWNLINK COMMAND RATE:
       RECORDING RATE (KBPS)         0.10                     DOWNLINK FREQUENCY (MHZ):
------------------------------------------------------------------------------------------------------------
THERMAL
   (X) ACTIVE     ( ) PASSIVE
       TEMPERATURE, DEG C   OPERATIONAL MINIMUM         850          MAXIMUM    950
                            NON-OPERATIONAL MINIMUM       0          MAXIMUM    100
       HEAT REJECTION, W    OPERATIONAL MINIMUM       10000          MAXIMUM  80000
                            NON-OPERATIONAL MINIMUM       0          MAXIMUM
------------------------------------------------------------------------------------------------------------
EQUIPMENT PHYSICAL CHARACTERISTICS
   LOCATION          (X) INTERNAL          ( ) EXTERNAL         ( ) REMOTE
   EQUIPMENT ID/FUNCTION                   (X) PRESSURIZED      ( ) UNPRESSURIZED
                  L, M:       5.00         W, M:       1.00     H, M:       4.00    STOWED
                  L, M:       5.00         W, M:       1.00     H, M:       4.00    DEPLOYED
                  LAUNCH MASS, KG:         12000                RETURN MASS, KG:     12000
                  CONSUMABLE TYPES
                  ACCELERATION SENSITIVITY, (G)      MIN:  1.00E-06     MAX:  1.00E-04
------------------------------------------------------------------------------------------------------------
CREW REQUIREMENTS
   CREW SIZE           2            TASK ASSIGNMENTS
                                    ------------------------------------------------------------
   SKILLS (SEE TABLE B)             | SKILL     |        |        |        |        |        |
                                    ------------------------------------------------------------
                                    | LEVEL     |        |        |        |        |        |
                                    ------------------------------------------------------------
                                    | HOURS/DAY |  4.00  |        |        |        |        |
                                    ------------------------------------------------------------
   EVA  ( ) YES   (X) NO            REASON                             HOURS/EVA
------------------------------------------------------------------------------------------------------------
SERVICING/MAINTENANCE
   SERVICE:                             INTERVAL,  DAYS        90            CONSUMABLES, KG
                                        RETURNABLES, KG     12000            MAN HOURS
   CONFIGURATION CHANGES:               INTERVAL, DAY                        MAN/HOURS REQUIRED
                                        DELIVERABLES, KG                     RETURNABLES, KG
------------------------------------------------------------------------------------------------------------
SPECIAL CONSIDERATIONS/SEE INSTRUCTIONS
LABORATORY FACILITIES REQUIRED: CLEAN ROOM, WORKSPACE, MINICOMUTER, DOWNLINK TERMINAL
CRYSTAL CHARACTERIZATION EQUIPMENT REQUIRED: CUTTING SAW, POLISHER, ETCHER, COMPACT EVAPORATOR, HALL
APPARATUS LIGHT SOURCE AND SPECTROMETER.

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                                        BOEING-SPECIFIC INPUT DATA
----------------------------------------------------------------------------------------------------
MISSION TYPE
  FREE FLYER                                  OPS CODE
   ( ) NOT SERVICED                              F
   ( ) REMOTE TMS                                FT
   ( ) REMOTE MANNED                             FM
   ( ) SERVICED AT STATION (TMS RETRIEVED)       FST
   ( ) SERVICED AT STATION (SELF-PROPELLED)      FS

  PLATFORM BASED
   ( ) NOT SERVICED                              P
   ( ) REMOTE TMS                                PT
   ( ) REMOTE MANNED                             PM
   ( ) SERVICED AT STATION (TMS RETRIEVED)       PST
   ( ) SERVICED AT STATION (SELF-PROPELLED)      PS

  OTHER
   ( ) SPACE STATION BASED                       SS
   ( ) SORTIE                                    SOR

CONSTRUCTION/SERVICING COMPLEXITY
   ( ) LOW
   ( ) MEDIUM
   ( ) HIGH

OPERATIONS TIMES
   OTV UP/DOWN                          DAYS
   OTV OR TMS ON ORBIT                  DAYS
   MISSION USE                          DAYS/YEAR
   IVA SERVICE                          MAN-DAYS/YEAR
   EVA SERVICE                          MAN-DAYS/YEAR
   EXPERIMENT OPS                       MAN-DAYS/YEAR
   SERVICE FREQUENCY                    TIMES/YEAR

DELTA VELOCITIES
   UP                        0.00
   DOWN                      0.00
   AERO RETURN               0.00

SUPPORT EQUIPMENT
             LENGTH:         0.00 METERS      WIDTH:     0.00 METERS      HEIGHT:     0.00 METERS     (STOWED)
             LENGTH:         0.00 METERS      WIDTH:     0.00 METERS      HEIGHT:     0.00 METERS     (DEPLOYED)

             MASS:              0 KG

MANIFEST RESTRICTIONS
   (X) NO RESTRICTIONS
   ( ) ONLY WITH COMPATIBLE PAYLOADS
   ( ) FLY-ALONE
   ( ) MUST HAVE DOCKING MODULE

LENGTH OF BEAM FAB                                          0.00
NUMBER OF APPENDAGES                                           0
NUMBER OF MODULES REQUIRED TO ASSEMBLE THE PAYLOAD             0
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PAYLOAD ELEMENT NAME
ELECTROEPITAXIAL CRYSTAL GROWTH

CODE
BACX1023

TYPE
( ) SCIENCE AND APPLICATIONS (NON-COMM.)
(X) COMMERCIAL
( ) TECHNOLOGY DEVELOPMENT
( ) OPERATIONS
( ) OTHER
( ) NATIONAL SECURITY
TYPE NUMBER (SEE TABLE A) 8

CONTACT
NAME ROBERT E. PACE, JR.
ADDRESS MICROGRAVITY RESEARCH AS
PO BOX 12426
HUNTSVILLE, AL 35802

TELEPHONE (205) 881-6670

IMPORTANCE OF THE SPACE STATION TO THIS ELEMENT
1 = LOW VALUE, BUT COULD USE
10 = VITAL
SCALE = 7

STATUS
( ) OPERATIONAL ( ) APPROVED (X) PLANNED ( ) CANDIDATE ( ) OPPORTUNITY

DESIRED FIRST FLIGHT, YEAR: 1998 NUMBER OF FLIGHTS 1 DURATION OF FLIGHT, DAYS 79

OBJECTIVE
DEVELOP AND COMMERCIALIZE A PROCESS FOR PRODUCING LARGE SINGLE CRYSTALS OF COMPOUND SEMICONDUCTOR MATERIALS.

DESCRIPTION
CRYSTALS ARE GROWN IN SPACE BY AN ELECTROEPITAXIAL GROWTH PROCESS. COMMERCIAL MANUFACTURING UNITS ARE PLACED IN MODULES ATTACHED TO THE SPACE STATION, AND GROWTH CELLS ARE REPLACED PERIODICALLY AND CRYSTALS RETURNED TO EARTH. A PROCESS DEVELOPMENT LABORATORY ON THE SPACE STATION IS USED TO CHARACTERIZE THE CRYSTALS AND DEVELOP
THE PROCESS.

ORBIT CHARACTERISTICS
GEOSYNCHRONOUS ORBIT ( ) YES (X) NO
APOGEE, KM PERIGEE, KM TOLERANCE + -
INCLINATION, DEG . TOLERANCE + -
NODAL ANGLE, DEG EPHEMERIS ACCURACY, M
ESCAPE DV REQUIRED, M/S .

POINTING/ORIENTATION
VIEW DIRECTION ( ) INERTIAL ( ) SOLAR ( ) EARTH (X) ANY
TRUTH SITES (IF KNOWN)
POINTING ACCURACY, ARC-SEC FIELD OF VIEW (DEG)
POINTING STABILITY (JITTER), ARC-SEC/SEC
SPECIAL RESTRICTIONS (AVOIDANCE)

POWER
( ) AC (X) DC

	POWER, W	DURATION, HRS/DAY
OPERATING	120000	24.00
STANDBY		
PEAK	120000	24.00

(X) CONTINUOUS

VOLTAGE, V 50 FREQUENCY, HZ 0

DATA/COMMU ATIONS

MONITORING REQUIREMENTS:
( ) NONE ( ) REALTIME (X) OFFLINE ( ) OTHER:
( ) ENCRIPTION/DECRIPTION REQUIRED
( ) UPLINK REQUIRED: COMMAND RATE (KBS): 0 FREQUENCY (MHZ):
( ) ON-BOARD DATA PROCESSING REQUIRED
DESCRIPTION:
DATA TYPES: ( ) ANALOG ( ) DIGITAL HOURS/DAY
FILM (AMOUNT): VOICE (HOURS/DAY):
LIVE TV (HOURS/DAY): OTHER:
ON-BOARD STORAGE (MBIT):
DATA DUMP FREQUENCY (PER ORBIT) DOWNLINK COMMAND RATE:
RECORDING RATE (KBPS) 0.10 DOWNLINK FREQUENCY (MHZ):

THERMAL

(X) ACTIVE ( ) PASSIVE
TEMPERATURE, DEG C OPERATIONAL MINIMUM 850 MAXIMUM 950
NON-OPERATIONAL MINIMUM 0 MAXIMUM 100
HEAT REJECTION, W OPERATIONAL MINIMUM 10000 MAXIMUM 120000
NON-OPERATIONAL MINIMUM 0 MAXIMUM

EQUIPMENT PHYSICAL CHARACTERISTICS

LOCATION (X) INTERNAL ( ) EXTERNAL ( ) REMOTE
EQUIPMENT ID/FUNCTION (X) PRESSURIZED ( ) UNPRESSURIZED
L, M: 5.00 W, M: 1.00 H, M: 4.00 STOWED
L, M: 5.00 W, M: 1.00 H, M: 4.00 DEPLOYED
LAUNCH MASS, KG: 11900 RETURN MASS, KG: 12000
CONSUMABLE TYPES
ACCELERATION SENSITIVITY, (G) MIN: 1.00E-06 MAX: 1.00E-04

CREW REQUIREMENTS

CREW SIZE 2

TASK ASSIGNMENTS

SKILLS (SEE TABLE B)

SKILL						
LEVEL						
HOURS/DAY	4.00					

EVA ( ) YES (X) NO REASON HOURS/EVA

SERVICING/MAINTENANCE

SERVICE: INTERVAL, DAYS 90 CONSUMABLES, KG
RETURNABLES, KG 11900 MAN HOURS
CONFIGURATION CHANGES: INTERVAL, DAY MAN/HOURS REQUIRED
DELIVERABLES, KG RETURNABLES, KG

SPECIAL CONSIDERATIONS/SEE INSTRUCTIONS

LABORATORY FACILITIES REQUIRED: CLEAN ROOM, WORKSPACE, MINICOMUTER, DOWNLINK TERMINAL
CRYSTAL CHARACTERIZATION EQUIPMENT REQUIRED: CUTTING SAW, POLISHER, ETCHER, COMPACT EVAPORATOR, HALL APPARATUS LIGHT SOURCE AND SPECTROMETER.

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                                              BOEING-SPECIFIC INPUT DATA
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MISSION TYPE                                 OPS CODE
   FREE FLYER
   ( ) NOT SERVICED                             F
   ( ) REMOTE TMS                               FT
   ( ) REMOTE MANNED                            FM
   ( ) SERVICED AT STATION (TMS RETRIEVED)      FST
   ( ) SERVICED AT STATION (SELF-PROPELLED)     FS

   PLATFORM BASED
   ( ) NOT SERVICED                             P
   ( ) REMOTE TMS                               PT
   ( ) REMOTE MANNED                            PM
   ( ) SERVICED AT STATION (TMS RETRIEVED)      PST
   ( ) SERVICED AT STATION (SELF-PROPELLED)     PS

   OTHER
   ( ) SPACE STATION BASED                      SS
   ( ) SORTIE                                   SOR

CONSTRUCTION/SERVICING COMPLEXITY
   ( ) LOW
   ( ) MEDIUM
   ( ) HIGH

OPERATIONS TIMES
   OTV UP/DOWN                          DAYS
   OTV OR TMS ON ORBIT                  DAYS
   MISSION USE                          DAYS/YEAR
   IVA SERVICE                          MAN-DAYS/YEAR
   EVA SERVICE                          MAN-DAYS/YEAR
   EXPERIMENT OPS                       MAN-DAYS/YEAR
   SERVICE FREQUENCY                    TIMES/YEAR

DELTA VELOCITIES
   UP                          0.00
   DOWN                        0.00
   AERO RETURN                 0.00

SUPPORT EQUIPMENT
               LENGTH:         0.00 METERS      WIDTH:      0.00 METERS        HEIGHT:      0.00 METERS      (STOWED)
               LENGTH:         0.00 METERS      WIDTH:      0.00 METERS        HEIGHT:      0.00 METERS      (DEPLOYED)

               MASS:              0 KG

MANIFEST RESTRICTIONS
   (X) NO RESTRICTIONS
   ( ) ONLY WITH COMPATIBLE PAYLOADS
   ( ) FLY-ALONE
   ( ) MUST HAVE DOCKING MODULE

LENGTH OF BEAM FAB                                       0.00
NUMBER OF APPENDAGES                                        0
NUMBER OF MODULES REQUIRED TO ASSEMBLE THE PAYLOAD          0
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PAYLOAD ELEMENT NAME
ELECTROEPITAXIAL CRYSTAL GROWTH

CODE
BACX1024

TYPE
( ) SCIENCE AND APPLICATIONS (NON-COMM.)
(X) COMMERCIAL
( ) TECHNOLOGY DEVELOPMENT
( ) OPERATIONS
( ) OTHER
( ) NATIONAL SECURITY
TYPE NUMBER (SEE TABLE A) 8

CONTACT
NAME ROBERT E. PACE, JR.
ADDRESS MICROGRAVITY RESEARCH AS
PO BOX 12426
HUNTSVILLE, AL 35802

TELEPHONE (205) 881-6670

IMPORTANCE OF THE SPACE STATION TO THIS ELEMENT
1 = LOW VALUE, BUT COULD USE
10 = VITAL
SCALE = 7

STATUS
( ) OPERATIONAL ( ) APPROVED (X) PLANNED ( ) CANDIDATE ( ) OPPORTUNITY

DESIRED FIRST FLIGHT, YEAR: 1998 NUMBER OF FLIGHTS 2 DURATION OF FLIGHT, DAYS 79

OBJECTIVE
DEVELOP AND COMMERCIALIZE A PROCESS FOR PRODUCING LARGE SINGLE CRYSTALS OF COMPOUND SEMICONDUCTOR MATERIALS.

DESCRIPTION
CRYSTALS ARE GROWN IN SPACE BY AN ELECTROEPITAXIAL GROWTH PROCESS. COMMERCIAL MANUFACTURING UNITS ARE PLACED IN MODULES ATTACHED TO THE SPACE STATION, AND GROWTH CELLS ARE REPLACED PERIODICALLY AND CRYSTALS RETURNED TO EARTH. A PROCESS DEVELOPMENT LABORATORY ON THE SPACE STATION IS USED TO CHARACTERIZE THE CRYSTALS AND DEVELOP THE PROCESS.

ORBIT CHARACTERISTICS
GEOSYNCHRONOUS ORBIT ( ) YES (X) NO
APOGEE, KM PERIGEE, KM TOLERANCE + -
INCLINATION, DEG . TOLERANCE + -
NODAL ANGLE, DEG EPHEMERIS ACCURACY, M
ESCAPE DV REQUIRED, M/S .

POINTING/ORIENTATION
VIEW DIRECTION ( ) INERTIAL ( ) SOLAR ( ) EARTH (X) ANY
TRUTH SITES (IF KNOWN)
POINTING ACCURACY, ARC-SEC FIELD OF VIEW (DEG)
POINTING STABILITY (JITTER), ARC-SEC/SEC
SPECIAL RESTRICTIONS (AVOIDANCE)

POWER
( ) AC (X) DC

	POWER, W	DURATION, HRS/DAY
OPERATING	120000	24.00
STANDBY		
PEAK	120000	24.00

(X) CONTINUOUS

VOLTAGE, V 50 FREQUENCY, HZ 0

DATA/COMMUNICATIONS
MONITORING REQUIREMENTS:
( ) NONE ( ) REALTIME (X) OFFLINE ( ) OTHER:
( ) ENCRIPTION/DECRIPTION REQUIRED
( ) UPLINK REQUIRED: COMMAND RATE (KBS): 0 FREQUENCY (MHZ):
( ) ON-BOARD DATA PROCESSING REQUIRED
DESCRIPTION:
DATA TYPES: ( ) ANALOG ( ) DIGITAL
FILM (AMOUNT):
LIVE TV (HOURS/DAY):
ON-BOARD STORAGE (MBIT):
DATA DUMP FREQUENCY (PER ORBIT)
RECORDING RATE (KBPS) 0.10

HOURS/DAY
VOICE (HOURS/DAY):
OTHER:

DOWNLINK COMMAND RATE:
DOWNLINK FREQUENCY (MHZ):

THERMAL
(X) ACTIVE ( ) PASSIVE
TEMPERATURE, DEG C OPERATIONAL MINIMUM 850 MAXIMUM 950
NON-OPERATIONAL MINIMUM 0 MAXIMUM 100
HEAT REJECTION, W OPERATIONAL MINIMUM 10000 MAXIMUM 120000
NON-OPERATIONAL MINIMUM 0 MAXIMUM

EQUIPMENT PHYSICAL CHARACTERISTICS
LOCATION (X) INTERNAL ( ) EXTERNAL ( ) REMOTE
EQUIPMENT ID/FUNCTION (X) PRESSURIZED ( ) UNPRESSURIZED
L, M: 5.00 W, M: 1.00 H, M: 4.00 STOWED
L, M: 5.00 W, M: 1.00 H, M: 4.00 DEPLOYED
LAUNCH MASS, KG: 11250 RETURN MASS, KG: 11250
CONSUMABLE TYPES
ACCELERATION SENSITIVITY, (G) MIN: 1.00E-06 MAX: 1.00E-04

CREW REQUIREMENTS
CREW SIZE 2

SKILLS (SEE TABLE B)

TASK ASSIGNMENTS

SKILL						
LEVEL						
HOURS/DAY	4.00					

EVA ( ) YES (X) NO REASON HOURS/EVA

SERVICING/MAINTENANCE
SERVICE: INTERVAL, DAYS 90 CONSUMABLES, KG
RETURNABLES, KG 11250 MAN HOURS
CONFIGURATION CHANGES: INTERVAL, DAY MAN/HOURS REQUIRED
DELIVERABLES, KG RETURNABLES, KG

SPECIAL CONSIDERATIONS/SEE INSTRUCTIONS
LABORATORY FACILITIES REQUIRED: CLEAN ROOM, WORKSPACE, MINICOMUTER, DOWNLINK TERMINAL
CRYSTAL CHARACTERIZATION EQUIPMENT REQUIRED: CUTTING SAW, POLISHER, ETCHER, COMPACT EVAPORATOR, HALL APPARATUS LIGHT SOURCE AND SPECTROMETER.

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                                                    BOEING-SPECIFIC INPUT DATA
----------------------------------------------------------------------------------------------------------------------------------
MISSION TYPE                                 OPS CODE
   FREE FLYER
   ( ) NOT SERVICED                             F
   ( ) REMOTE TMS                               FT
   ( ) REMOTE MANNED                            FM
   ( ) SERVICED AT STATION (TMS RETRIEVED)      FST
   ( ) SERVICED AT STATION (SELF-PROPELLED)     FS

   PLATFORM BASED
   ( ) NOT SERVICED                             P
   ( ) REMOTE TMS                               PT
   ( ) REMOTE MANNED                            PM
   ( ) SERVICED AT STATION (TMS RETRIEVED)      PST
   ( ) SERVICED AT STATION (SELF-PROPELLED)     PS

   OTHER
   ( ) SPACE STATION BASED                      SS
   ( ) SORTIE                                   SOR

CONSTRUCTION/SERVICING COMPLEXITY
   ( ) LOW
   ( ) MEDIUM
   ( ) HIGH

OPERATIONS TIMES
   OTV UP/DOWN                          DAYS
   OTV OR TMS ON ORBIT                  DAYS
   MISSION USE                          DAYS/YEAR
   IVA SERVICE                          MAN-DAYS/YEAR
   EVA SERVICE                          MAN-DAYS/YEAR
   EXPERIMENT OPS                       MAN-DAYS/YEAR
   SERVICE FREQUENCY                    TIMES/YEAR

DELTA VELOCITIES
   UP                    0.00
   DOWN                  0.00
   AERO RETURN           0.00

SUPPORT EQUIPMENT
             LENGTH:     0.00 METERS      WIDTH:     0.00 METERS        HEIGHT:     0.00 METERS      (STOWED)
             LENGTH:     0.00 METERS      WIDTH:     0.00 METERS        HEIGHT:     0.00 METERS      (DEPLOYED)

             MASS:          0 KG

MANIFEST RESTRICTIONS
   (X) NO RESTRICTIONS
   ( ) ONLY WITH COMPATIBLE PAYLOADS
   ( ) FLY-ALONE
   ( ) MUST HAVE DOCKING MODULE

LENGTH OF BEAM FAB                                     0.00
NUMBER OF APPENDAGES                                      0
NUMBER OF MODULES REQUIRED TO ASSEMBLE THE PAYLOAD        0
----------------------------------------------------------------------------------------------------------------------------------
```

ORIGINAL PAGE IS
OF POOR QUALITY

PAYLOAD ELEMENT NAME
ELECTROEPITAXIAL CRYSTAL GROWTH

CODE
BACX1025

TYPE
( ) SCIENCE AND APPLICATIONS (NON-COMM.)
(X) COMMERCIAL
( ) TECHNOLOGY DEVELOPMENT
( ) OPERATIONS
( ) OTHER
( ) NATIONAL SECURITY
TYPE NUMBER (SEE TABLE A) 8

CONTACT
NAME ROBERT E. PACE, JR.
ADDRESS MICROGRAVITY RESEARCH AS
PO BOX 12426
HUNTSVILLE, AL 35802

TELEPHONE (205) 881-6670

IMPORTANCE OF THE SPACE STATION TO THIS ELEMENT
1 = LOW VALUE, BUT COULD USE
10 = VITAL
SCALE = 7

STATUS
( ) OPERATIONAL ( ) APPROVED: (X) PLANNED ( ) CANDIDATE ( ) OPPORTUNITY

DESIRED FIRST FLIGHT, YEAR: 1998 NUMBER OF FLIGHTS 1 DURATION OF FLIGHT, DAYS 79

OBJECTIVE
DEVELOP AND COMMERCIALIZE A PROCESS FOR PRODUCING LARGE SINGLE CRYSTALS OF COMPOUND SEMICONDUCTOR MATERIALS.

DESCRIPTION
CRYSTALS ARE GROWN IN SPACE BY AN ELECTROEPITAXIAL GROWTH PROCESS. COMMERCIAL MANUFACTURING UNITS ARE PLACED IN MODULES ATTACHED TO THE SPACE STATION, AND GROWTH CELLS ARE REPLACED PERIODICALLY AND CRYSTALS RETURNED TO EARTH. A PROCESS DEVELOPMENT LABORATORY ON THE SPACE STATION IS USED TO CHARACTERIZE THE CRYSTALS AND DEVELOP THE PROCESS..

ORIGINAL PAGE IS OF POOR QUALITY

ORBIT CHARACTERISTICS
GEOSYNCHRONOUS ORBIT ( ) YES (X) NO
APOGEE, KM PERIGEE, KM TOLERANCE + -
INCLINATION, DEG . TOLERANCE + -
NODAL ANGLE, DEG EPHEMERIS ACCURACY, M
ESCAPE DV REQUIRED, M/S .

POINTING/ORIENTATION
VIEW DIRECTION ( ) INERTIAL ( ) SOLAR ( ) EARTH (X) ANY
TRUTH SITES (IF KNOWN)
POINTING ACCURACY, ARC-SEC FIELD OF VIEW (DEG)
POINTING STABILITY (JITTER), ARC-SEC/SEC
SPECIAL RESTRICTIONS (AVOIDANCE)

POWER
( ) AC (X) DC

	POWER, W	DURATION, HRS/DAY
OPERATING	120000	24.00
STANDBY		
PEAK	120000	24.00
VOLTAGE, V	50	FREQUENCY, HZ 0

(X) CONTINUOUS

```
DATA/COMMUN   IONS
   MONITORING REQUIREMENTS:
   ( ) NONE       ( ) REALTIME    (X) OFFLINE     ( ) OTHER:
   ( ) ENCRIPTION/DECRIPTION REQUIRED
   ( ) UPLINK REQUIRED:  COMMAND RATE (KBS):       0          FREQUENCY (MHZ):
   ( ) ON-BOARD DATA PROCESSING REQUIRED
       DESCRIPTION:
       DATA TYPES:   ( ) ANALOG     ( ) DIGITAL               HOURS/DAY
       FILM (AMOUNT):                                         VOICE (HOURS/DAY):
       LIVE TV (HOURS/DAY):                                   OTHER:
       ON-BOARD STORAGE (MBIT):
       DATA DUMP FREQUENCY (PER ORBIT)                        DOWNLINK COMMAND RATE:
       RECORDING RATE (KBPS)          0.10                    DOWNLINK FREQUENCY (MHZ):
---------------------------------------------------------------------------------------------------------
THERMAL
   (X) ACTIVE     ( ) PASSIVE
       TEMPERATURE, DEG C   OPERATIONAL MINIMUM          850         MAXIMUM    950
                            NON-OPERATIONAL MINIMUM        0         MAXIMUM    100
       HEAT REJECTION, W    OPERATIONAL MINIMUM        10000         MAXIMUM  120000
                            NON-OPERATIONAL MINIMUM        0         MAXIMUM
---------------------------------------------------------------------------------------------------------
EQUIPMENT PHYSICAL CHARACTERISTICS
   LOCATION          (X) INTERNAL       ( ) EXTERNAL       ( ) REMOTE
   EQUIPMENT ID/FUNCTION                (X) PRESSURIZED    ( ) UNPRESSURIZED
                L, M:     5.00      W, M:     1.00      H, M:     4.00     STOWED
                L, M:     5.00      W, M:     1.00      H, M:     4.00     DEPLOYED
                LAUNCH MASS, KG:   11750                RETURN MASS, KG:   11250
                CONSUMABLE TYPES
                ACCELERATION SENSITIVITY, (G)       MIN:  1.00E-06     MAX:  1.00E-04
---------------------------------------------------------------------------------------------------------
CREW REQUIREMENTS
   CREW SIZE          2          TASK ASSIGNMENTS
                                 ------------------------------------------------------------
   SKILLS (SEE TABLE B)          | SKILL     |         |         |         |         |         |         |
                                 ------------------------------------------------------------
                                 | LEVEL     |         |         |         |         |         |         |
                                 ------------------------------------------------------------
                                 | HOURS/DAY |  4.00   |         |         |         |         |         |
                                 ------------------------------------------------------------
   EVA   ( ) YES   (X) NO        REASON                              HOURS/EVA
---------------------------------------------------------------------------------------------------------
SERVICING/MAINTENANCE
   SERVICE:                         INTERVAL,  DAYS        90          CONSUMABLES, KG
                                    RETURNABLES, KG     11750          MAN HOURS
   CONFIGURATION CHANGES:           INTERVAL, DAY                      MAN/HOURS REQUIRED
                                    DELIVERABLES, KG                   RETURNABLES, KG
---------------------------------------------------------------------------------------------------------
SPECIAL CONSIDERATIONS/SEE INSTRUCTIONS
LABORATORY FACILITIES REQUIRED: CLEAN ROOM, WORKSPACE, MINICOMUTER, DOWNLINK TERMINAL
CRYSTAL CHARACTERIZATION EQUIPMENT REQUIRED: CUTTING SAW, POLISHER, ETCHER, COMPACT EVAPORATOR, HALL
APPARATUS LIGHT SOURCE AND SPECTROMETER.


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                                               BOEING-SPECIFIC INPUT DATA
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MISSION TYPE                                       OPS CODE
   FREE FLYER
   ( ) NOT SERVICED                                   F
   ( ) REMOTE TMS                                     FT
   ( ) REMOTE MANNED                                  FM
   ( ) SERVICED AT STATION (TMS RETRIEVED)            FST
   ( ) SERVICED AT STATION (SELF-PROPELLED)           FS

   PLATFORM BASED
   ( ) NOT SERVICED                                   P
   ( ) REMOTE TMS                                     PT
   ( ) REMOTE MANNED                                  PM
   ( ) SERVICED AT STATION (TMS RETRIEVED)            PST
   ( ) SERVICED AT STATION (SELF-PROPELLED)           PS

   OTHER
   ( ) SPACE STATION BASED                            SS
   ( ) SORTIE                                         SOR

CONSTRUCTION/SERVICING COMPLEXITY
   ( ) LOW
   ( ) MEDIUM
   ( ) HIGH

OPERATIONS TIMES
   OTV UP/DOWN                         DAYS
   OTV OR TMS ON ORBIT                 DAYS
   MISSION USE                         DAYS/YEAR
   IVA SERVICE                         MAN-DAYS/YEAR
   EVA SERVICE                         MAN-DAYS/YEAR
   EXPERIMENT OPS                      MAN-DAYS/YEAR
   SERVICE FREQUENCY                   TIMES/YEAR

DELTA VELOCITIES
   UP                          0.00
   DOWN                        0.00
   AERO RETURN                 0.00

SUPPORT EQUIPMENT
             LENGTH:           0.00 METERS       WIDTH:        0.00 METERS       HEIGHT:       0.00 METERS      (STOWED)
             LENGTH:           0.00 METERS       WIDTH:        0.00 METERS       HEIGHT:       0.00 METERS      (DEPLOYED)

             MASS:                0 KG

MANIFEST RESTRICTIONS
    (X) NO RESTRICTIONS
    ( ) ONLY WITH COMPATIBLE PAYLOADS
    ( ) FLY-ALONE
    ( ) MUST HAVE DOCKING MODULE

LENGTH OF BEAM FAB                                         0.00
NUMBER OF APPENDAGES                                          0
NUMBER OF MODULES REQUIRED TO ASSEMBLE THE PAYLOAD:           0
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OF POOR QUALITY

PAYLOAD ELEMENT NAME
ELECTROEPITAXIAL CRYSTAL GROWTH

CODE
BACX1026

TYPE
( ) SCIENCE AND APPLICATIONS (NON-COMM.)
(X) COMMERCIAL
( ) TECHNOLOGY DEVELOPMENT
( ) OPERATIONS
( ) OTHER
( ) NATIONAL SECURITY
TYPE NUMBER (SEE TABLE A), 8

CONTACT
NAME ROBERT E. PACE, JR.
ADDRESS MICROGRAVITY RESEARCH AS
PO BOX 12426
HUNTSVILLE, AL 35802

TELEPHONE (205) 881-6670

IMPORTANCE OF THE SPACE STATION TO THIS ELEMENT
1 = LOW VALUE, BUT COULD USE
10 = VITAL
SCALE = 7

STATUS
( ) OPERATIONAL ( ) APPROVED (X) PLANNED ( ) CANDIDATE ( ) OPPORTUNITY

DESIRED FIRST FLIGHT, YEAR: 1993 NUMBER OF FLIGHTS 1 DURATION OF FLIGHT, DAYS 70

OBJECTIVE
DEVELOP AND COMMERCIALIZE A PROCESS FOR PRODUCING LARGE SINGLE CRYSTALS OF COMPOUND SEMICONDUCTOR MATERIALS.

DESCRIPTION
CRYSTALS ARE GROWN IN SPACE BY AN ELECTROEPITAXIAL GROWTH PROCESS. COMMERCIAL MANUFACTURING UNITS ARE PLACED IN MODULES ATTACHED TO THE SPACE STATION, AND GROWTH CELLS ARE REPLACED PERIODICALLY AND CRYSTALS RETURNED TO EARTH. A PROCESS DEVELOPMENT LABORATORY ON THE SPACE STATION IS USED TO CHARACTERIZE THE CRYSTALS AND DEVELOP THE PROCESS.

ORBIT CHARACTERISTICS
GEOSYNCHRONOUS ORBIT ( ) YES (X) NO
APOGEE, KM PERIGEE, KM TOLERANCE + -
INCLINATION, DEG . TOLERANCE + -
NODAL ANGLE, DEG EPHEMERIS ACCURACY, M
ESCAPE DV REQUIRED, M/S .

POINTING/ORIENTATION
VIEW DIRECTION ( ) INERTIAL ( ) SOLAR ( ) EARTH (X) ANY
TRUTH SITES (IF KNOWN)
POINTING ACCURACY, ARC-SEC FIELD OF VIEW (DEG)
POINTING STABILITY (JITTER), ARC-SEC/SEC
SPECIAL RESTRICTIONS (AVOIDANCE)

POWER
( ) AC (X) DC

	POWER, W	DURATION, HRS/DAY
OPERATING	120000	24.00
STANDBY		
PEAK	120000	24.00

(X) CONTINUOUS

VOLTAGE, V 50 FREQUENCY, HZ 0

DATA/COMMUN. .TIONS
MONITORING REQUIREMENTS:
( ) NONE ( ) REALTIME (X) OFFLINE ( ) OTHER:
( ) ENCRIPTION/DECRIPTION REQUIRED
( ) UPLINK REQUIRED: COMMAND RATE (KBS): 0 FREQUENCY (MHZ):
( ) ON-BOARD DATA PROCESSING REQUIRED
DESCRIPTION:
DATA TYPES: ( ) ANALOG ( ) DIGITAL HOURS/DAY
FILM (AMOUNT): VOICE (HOURS/DAY):
LIVE TV (HOURS/DAY): OTHER:
ON-BOARD STORAGE (MBIT):
DATA DUMP FREQUENCY (PER ORBIT) DOWNLINK COMMAND RATE:
RECORDING RATE (KBPS) 0.10 DOWNLINK FREQUENCY (MHZ):

THERMAL
(X) ACTIVE ( ) PASSIVE
TEMPERATURE, DEG C OPERATIONAL MINIMUM 850 MAXIMUM 950
NON-OPERATIONAL MINIMUM 0 MAXIMUM 100
HEAT REJECTION, W OPERATIONAL MINIMUM 10000 MAXIMUM 120000
NON-OPERATIONAL MINIMUM 0 MAXIMUM

EQUIPMENT PHYSICAL CHARACTERISTICS
LOCATION (X) INTERNAL ( ) EXTERNAL ( ) REMOTE
EQUIPMENT ID/FUNCTION (X) PRESSURIZED ( ) UNPRESSURIZED
L, M: 5.00 W, M: 1.00 H, M: 4.00 STOWED
L, M: 5.00 W, M: 1.00 H, M: 4.00 DEPLOYED
LAUNCH MASS, KG: 12650 RETURN MASS, KG: 11250
CONSUMABLE TYPES
ACCELERATION SENSITIVITY, (G) MIN: 1.00E-06 MAX: 1.00E-04

CREW REQUIREMENTS
CREW SIZE 2

TASK ASSIGNMENTS

SKILLS (SEE TABLE B)

SKILL						
LEVEL						
HOURS/DAY	4.00					

EVA ( ) YES (X) NO REASON HOURS/EVA

SERVICING/MAINTENANCE
SERVICE: INTERVAL, DAYS 90 CONSUMABLES, KG
RETURNABLES, KG 12650 MAN HOURS
CONFIGURATION CHANGES: INTERVAL, DAY MAN/HOURS REQUIRED
DELIVERABLES, KG RETURNABLES, KG

SPECIAL CONSIDERATIONS/SEE INSTRUCTIONS
LABORATORY FACILITIES REQUIRED: CLEAN ROOM, WORKSPACE, MINICOMUTER, DOWNLINK TERMINAL
CRYSTAL CHARACTERIZATION EQUIPMENT REQUIRED: CUTTING SAW, POLISHER, ETCHER, COMPACT EVAPORATOR, HALL APPARATUS LIGHT SOURCE AND SPECTROMETER.

ORIGINAL PAGE IS
OF POOR QUALITY

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                                              BOEING-SPECIFIC INPUT DATA
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MISSION TYPE                                OPS CODE
   FREE FLYER
   ( ) NOT SERVICED                            F
   ( ) REMOTE TMS                              FT
   ( ) REMOTE MANNED                           FM
   ( ) SERVICED AT STATION (TMS RETRIEVED)     FST
   ( ) SERVICED AT STATION (SELF-PROPELLED)    FS

   PLATFORM BASED
   ( ) NOT SERVICED                            P
   ( ) REMOTE TMS                              PT
   ( ) REMOTE MANNED                           PM
   ( ) SERVICED AT STATION (TMS RETRIEVED)     PST
   ( ) SERVICED AT STATION (SELF-PROPELLED)    PS

   OTHER
   ( ) SPACE STATION BASED                     SS
   ( ) SORTIE                                  SOR

CONSTRUCTION/SERVICING COMPLEXITY
   ( ) LOW
   ( ) MEDIUM
   ( ) HIGH

OPERATIONS TIMES
   OTV UP/DOWN                        DAYS
   OTV OR TMS ON ORBIT                DAYS
   MISSION USE                        DAYS/YEAR
   IVA SERVICE                        MAN-DAYS/YEAR
   EVA SERVICE                        MAN-DAYS/YEAR
   EXPERIMENT OPS                     MAN-DAYS/YEAR
   SERVICE FREQUENCY                  TIMES/YEAR

DELTA VELOCITIES
   UP                     0.00
   DOWN                   0.00
   AERO RETURN            0.00

SUPPORT EQUIPMENT
             LENGTH:      0.00 METERS       WIDTH:      0.00 METERS        HEIGHT:      0.00 METERS      (STOWED)
             LENGTH:      0.00 METERS       WIDTH:      0.00 METERS        HEIGHT:      0.00 METERS      (DEPLOYED)

             MASS:           0 KG

MANIFEST RESTRICTIONS
   (X) NO RESTRICTIONS
   ( ) ONLY WITH COMPATIBLE PAYLOADS
   ( ) FLY-ALONE
   ( ) MUST HAVE DOCKING MODULE

LENGTH OF BEAM FAB                                   0.00
NUMBER OF APPENDAGES                                    0
NUMBER OF MODULES REQUIRED TO ASSEMBLE THE PAYLOAD?     0
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PAYLOAD ELEMENT NAME
ELECTROEPITAXIAL CRYSTAL GROWTH

CODE
BACX1027

TYPE
( ) SCIENCE AND APPLICATIONS (NON-COMM.)
(X) COMMERCIAL
( ) TECHNOLOGY DEVELOPMENT
( ) OPERATIONS
( ) OTHER
( ) NATIONAL SECURITY
TYPE NUMBER (SEE TABLE A) 8

CONTACT
NAME ROBERT E. PACE, JR.
ADDRESS MICROGRAVITY RESEARCH AS
PO BOX 12426
HUNTSVILLE, AL 35802

TELEPHONE (205) 881-6670

IMPORTANCE OF THE SPACE STATION TO THIS ELEMENT
1 = LOW VALUE, BUT COULD USE
10 = VITAL
SCALE = 7

STATUS
( ) OPERATIONAL ( ) APPROVED (X) PLANNED ( ) CANDIDATE ( ) OPPORTUNITY

DESIRED FIRST FLIGHT, YEAR: 1999 NUMBER OF FLIGHTS 4 DURATION OF FLIGHT, DAYS 78

OBJECTIVE
DEVELOP AND COMMERCIALIZE A PROCESS FOR PRODUCING LARGE SINGLE CRYSTALS OF COMPOUND SEMICONDUCTOR MATERIALS.

DESCRIPTION
CRYSTALS ARE GROWN IN SPACE BY AN ELECTROEPITAXIAL GROWTH PROCESS. COMMERCIAL MANUFACTURING UNITS ARE PLACED IN MODULES ATTACHED TO THE SPACE STATION, AND GROWTH CELLS ARE REPLACED PERIODICALLY AND CRYSTALS RETURNED TO EARTH. A PROCESS DEVELOPMENT LABORATORY ON THE SPACE STATION IS USED TO CHARACTERIZE THE CRYSTALS AND DEVELOP THE PROCESS.

ORBIT CHARACTERISTICS
GEOSYNCHRONOUS ORBIT ( ) YES (X) NO
APOGEE, KM PERIGEE, KM TOLERANCE + -
INCLINATION, DEG . TOLERANCE + -
NODAL ANGLE, DEG EPHEMERIS ACCURACY, M
ESCAPE DV REQUIRED, M/S .

POINTING/ORIENTATION
VIEW DIRECTION ( ) INERTIAL ( ) SOLAR ( ) EARTH (X) ANY
TRUTH SITES (IF KNOWN)
POINTING ACCURACY, ARC-SEC FIELD OF VIEW (DEG)
POINTING STABILITY (JITTER), ARC-SEC/SEC
SPECIAL RESTRICTIONS (AVOIDANCE)

POWER
( ) AC (X) DC

	POWER, W	DURATION, HRS/DAY
OPERATING	120000	24.00
STANDBY		
PEAK	120000	24.00
VOLTAGE, V	50	FREQUENCY, HZ 0

(X) CONTINUOUS

```
DATA/COMML  ATIONS
   MONITORING REQUIREMENTS:
   ( ) NONE        ( ) REALTIME    (X) OFFLINE     ( ) OTHER:
   ( ) ENCRIPTION/DECRIPTION REQUIRED
   ( ) UPLINK REQUIRED:  COMMAND RATE (KBS):      0              FREQUENCY (MHZ):
   ( ) ON-BOARD DATA PROCESSING REQUIRED
       DESCRIPTION:
       DATA TYPES:    ( ) ANALOG      ( ) DIGITAL                HOURS/DAY
       FILM (AMOUNT):                                            VOICE (HOURS/DAY):
       LIVE TV (HOURS/DAY):                                      OTHER:
       ON-BOARD STORAGE (MBIT):
       DATA DUMP FREQUENCY (PER ORBIT)                           DOWNLINK COMMAND RATE:
       RECORDING RATE (KBPS)            0.10                     DOWNLINK FREQUENCY (MHZ):
--------------------------------------------------------------------------------------------
THERMAL
   (X) ACTIVE      ( ) PASSIVE
       TEMPERATURE, DEG C   OPERATIONAL MINIMUM          850        MAXIMUM     950
                            NON-OPERATIONAL MINIMUM        0        MAXIMUM     100
       HEAT REJECTION, W    OPERATIONAL MINIMUM        10000        MAXIMUM  120000
                            NON-OPERATIONAL MINIMUM        0        MAXIMUM
--------------------------------------------------------------------------------------------
EQUIPMENT PHYSICAL CHARACTERISTICS
   LOCATION           (X) INTERNAL          ( ) EXTERNAL          ( ) REMOTE
   EQUIPMENT ID/FUNCTION                    (X) PRESSURIZED       ( ) UNPRESSURIZED
                  L, M:      5.00       W, M:       1.00          H, M:      4.00     STOWED
                  L, M:      5.00       W, M:       1.00          H, M:      4.00     DEPLOYED
                  LAUNCH MASS, KG:   12000                        RETURN MASS, KG:    12000
                  CONSUMABLE TYPES
                  ACCELERATION SENSITIVITY, (G)        MIN:  1.00E-06      MAX:  1.00E-04
--------------------------------------------------------------------------------------------
CREW REQUIREMENTS
   CREW SIZE          2             TASK ASSIGNMENTS
                                    ---------------------------------------------------------
   SKILLS (SEE TABLE B)             | SKILL     |         |         |         |         |         |         |
                                    ---------------------------------------------------------
                                    | LEVEL     |         |         |         |         |         |         |
                                    ---------------------------------------------------------
                                    | HOURS/DAY |  4.00   |         |         |         |         |         |
                                    ---------------------------------------------------------
   EVA  ( ) YES   (X) NO            REASON                                HOURS/EVA
--------------------------------------------------------------------------------------------
SERVICING/MAINTENANCE
   SERVICE:                              INTERVAL,  DAYS        90          CONSUMABLES, KG
                                         RETURNABLES, KG     12000          MAN HOURS
   CONFIGURATION CHANGES:                INTERVAL, DAY                      MAN/HOURS REQUIRED
                                         DELIVERABLES, KG                   RETURNABLES, KG
--------------------------------------------------------------------------------------------
SPECIAL CONSIDERATIONS/SEE INSTRUCTIONS
LABORATORY FACILITIES REQUIRED: CLEAN ROOM, WORKSPACE, MINICOMUTER, DOWNLINK TERMINAL
CRYSTAL CHARACTERIZATION EQUIPMENT REQUIRED: CUTTING SAW, POLISHER, ETCHER, COMPACT EVAPORATOR, HALL
APPARATUS LIGHT SOURCE AND SPECTROMETER.

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                                          BOEING-SPECIFIC INPUT DATA
------------------------------------------------------------------------------------------------------------
MISSION TYPE                                     OPS CODE
   FREE FLYER
   ( ) NOT SERVICED                                F
   ( ) REMOTE TMS                                  FT
   ( ) REMOTE MANNED                               FM
   ( ) SERVICED AT STATION (TMS RETRIEVED)         FST
   ( ) SERVICED AT STATION (SELF-PROPELLED)        FS

   PLATFORM BASED
   ( ) NOT SERVICED                                P
   ( ) REMOTE TMS                                  PT
   ( ) REMOTE MANNED                               PM
   ( ) SERVICED AT STATION (TMS RETRIEVED)         PST
   ( ) SERVICED AT STATION (SELF-PROPELLED)        PS

   OTHER
   ( ) SPACE STATION BASED                         SS
   ( ) SORTIE                                      SOR

CONSTRUCTION/SERVICING COMPLEXITY
   ( ) LOW
   ( ) MEDIUM
   ( ) HIGH

OPERATIONS TIMES
   OTV UP/DOWN                           DAYS
   OTV OR TMS ON ORBIT                   DAYS
   MISSION USE                           DAYS/YEAR
   IVA SERVICE                           MAN-DAYS/YEAR
   EVA SERVICE                           MAN-DAYS/YEAR
   EXPERIMENT OPS                        MAN-DAYS/YEAR
   SERVICE FREQUENCY                     TIMES/YEAR

DELTA VELOCITIES
   UP                          0.00
   DOWN                        0.00
   AERO RETURN                 0.00

SUPPORT EQUIPMENT
             LENGTH:           0.00 METERS     WIDTH:     0.00 METERS      HEIGHT:     0.00 METERS     (STOWED)
             LENGTH:           0.00 METERS     WIDTH:     0.00 METERS      HEIGHT:     0.00 METERS     (DEPLOYED)

             MASS:               0 KG

MANIFEST RESTRICTIONS
   (X) NO RESTRICTIONS
   ( ) ONLY WITH COMPATIBLE PAYLOADS
   ( ) FLY-ALONE
   ( ) MUST HAVE DOCKING MODULE

LENGTH OF BEAM FAB                                          0.00
NUMBER OF APPENDAGES                                           0
NUMBER OF MODULES REQUIRED TO ASSEMBLE THE PAYLOAD:            0
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```

PAYLOAD ELEMENT NAME
ELECTROEPITAXIAL CRYSTAL GROWTH

CODE
BACX1028

TYPE
( ) SCIENCE AND APPLICATIONS (NON-COMM.)
(X) COMMERCIAL
( ) TECHNOLOGY DEVELOPMENT
( ) OPERATIONS
( ) OTHER
( ) NATIONAL SECURITY
TYPE NUMBER (SEE TABLE A) 8

CONTACT
NAME ROBERT E. PACE, JR.
ADDRESS MICROGRAVITY RESEARCH AS
PO BOX 12426
HUNTSVILLE, AL 35802

TELEPHONE (205) 881-6670

IMPORTANCE OF THE SPACE STATION TO THIS ELEMENT
1 = LOW VALUE, BUT COULD USE
10 = VITAL
SCALE = 7

STATUS
( ) OPERATIONAL ( ) APPROVED (X) PLANNED ( ) CANDIDATE ( ) OPPORTUNITY

DESIRED FIRST FLIGHT, YEAR: 2000 NUMBER OF FLIGHTS 1 DURATION OF FLIGHT, DAYS 70

OBJECTIVE
DEVELOP AND COMMERCIALIZE A PROCESS FOR PRODUCING LARGE SINGLE CRYSTALS OF COMPOUND SEMICONDUCTOR MATERIALS.

DESCRIPTION
CRYSTALS ARE GROWN IN SPACE BY AN ELECTROEPITAXIAL GROWTH PROCESS. COMMERCIAL MANUFACTURING UNITS ARE PLACED IN MODULES ATTACHED TO THE SPACE STATION, AND GROWTH CELLS ARE REPLACED PERIODICALLY AND CRYSTALS RETURNED TO EARTH. A PROCESS DEVELOPMENT LABORATORY ON THE SPACE STATION IS USED TO CHARACTERIZE THE CRYSTALS AND DEVELOP THE PROCESS.

ORBIT CHARACTERISTICS
GEOSYNCHRONOUS ORBIT ( ) YES (X) NO
APOGEE, KM PERIGEE, KM TOLERANCE + -
INCLINATION, DEG . TOLERANCE + -
NODAL ANGLE, DEG EPHEMERIS ACCURACY, M
ESCAPE DV REQUIRED, M/S .

POINTING/ORIENTATION
VIEW DIRECTION ( ) INERTIAL ( ) SOLAR ( ) EARTH (X) ANY
TRUTH SITES (IF KNOWN)
POINTING ACCURACY, ARC-SEC FIELD OF VIEW (DEG)
POINTING STABILITY (JITTER), ARC-SEC/SEC
SPECIAL RESTRICTIONS (AVOIDANCE)

POWER
( ) AC (X) DC

	POWER, W	DURATION, HRS/DAY
OPERATING	160000	24.00
STANDBY		
PEAK	160000	24.00

(X) CONTINUOUS

VOLTAGE, V 50 FREQUENCY, HZ 0

DATA/COMMUN TIONS
MONITORING REQUIREMENTS:
( ) NONE ( ) REALTIME (X) OFFLINE ( ) OTHER:
( ) ENCRIPTION/DECRIPTION REQUIRED
( ) UPLINK REQUIRED: COMMAND RATE (KBS): 0 FREQUENCY (MHZ):
( ) ON-BOARD DATA PROCESSING REQUIRED
DESCRIPTION:
DATA TYPES: ( ) ANALOG ( ) DIGITAL HOURS/DAY
FILM (AMOUNT): VOICE (HOURS/DAY):
LIVE TV (HOURS/DAY): OTHER:
ON-BOARD STORAGE (MBIT):
DATA DUMP FREQUENCY (PER ORBIT) DOWNLINK COMMAND RATE:
RECORDING RATE (KBPS) 0.10 DOWNLINK FREQUENCY (MHZ):

THERMAL
(X) ACTIVE ( ) PASSIVE

TEMPERATURE, DEG C	OPERATIONAL MINIMUM	850	MAXIMUM	950
	NON-OPERATIONAL MINIMUM	0	MAXIMUM	100
HEAT REJECTION, W	OPERATIONAL MINIMUM	10000	MAXIMUM	160000
	NON-OPERATIONAL MINIMUM	0	MAXIMUM	

EQUIPMENT PHYSICAL CHARACTERISTICS
LOCATION (X) INTERNAL ( ) EXTERNAL ( ) REMOTE
EQUIPMENT ID/FUNCTION (X) PRESSURIZED ( ) UNPRESSURIZED
L, M: 5.00 W, M: 1.00 H, M: 4.00 STOWED
L, M: 5.00 W, M: 1.00 H, M: 4.00 DEPLOYED
LAUNCH MASS, KG: 16000 RETURN MASS, KG: 12000
CONSUMABLE TYPES
ACCELERATION SENSITIVITY, (G) MIN: 1.00E-06 MAX: 1.00E-04

CREW REQUIREMENTS
CREW SIZE 2

SKILLS (SEE TABLE B)

TASK ASSIGNMENTS

SKILL						
LEVEL						
HOURS/DAY	4.00					

EVA ( ) YES (X) NO REASON HOURS/EVA

SERVICING/MAINTENANCE
SERVICE: INTERVAL, DAYS 90 CONSUMABLES, KG
RETURNABLES, KG 16000 MAN HOURS
CONFIGURATION CHANGES: INTERVAL, DAY MAN/HOURS REQUIRED
DELIVERABLES, KG RETURNABLES, KG

SPECIAL CONSIDERATIONS/SEE INSTRUCTIONS
LABORATORY FACILITIES REQUIRED: CLEAN ROOM, WORKSPACE, MINICOMUTER, DOWNLINK TERMINAL
CRYSTAL CHARACTERIZATION EQUIPMENT REQUIRED: CUTTING SAW, POLISHER, ETCHER, COMPACT EVAPORATOR, HALL APPARATUS LIGHT SOURCE AND SPECTROMETER.

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                                          BOEING-SPECIFIC INPUT DATA
--------------------------------------------------------------------------------------------------------------
MISSION TYPE                                  OPS CODE
   FREE FLYER
   ( ) NOT SERVICED                              F
   ( ) REMOTE TMS                                FT
   ( ) REMOTE MANNED                             FM
   ( ) SERVICED AT STATION (TMS RETRIEVED)       FST
   ( ) SERVICED AT STATION (SELF-PROPELLED)      FS

   PLATFORM BASED
   ( ) NOT SERVICED                              P
   ( ) REMOTE TMS                                PT
   ( ) REMOTE MANNED                             PM
   ( ) SERVICED AT STATION (TMS RETRIEVED)       PST
   ( ) SERVICED AT STATION (SELF-PROPELLED)      PS

   OTHER
   ( ) SPACE STATION BASED                       SS
   ( ) SORTIE                                    SOR

CONSTRUCTION/SERVICING COMPLEXITY
   ( ) LOW
   ( ) MEDIUM
   ( ) HIGH

OPERATIONS TIMES
   OTV UP/DOWN                        DAYS
   OTV OR TMS ON ORBIT                DAYS
   MISSION USE                        DAYS/YEAR
   IVA SERVICE                        MAN-DAYS/YEAR
   EVA SERVICE                        MAN-DAYS/YEAR
   EXPERIMENT OPS                     MAN-DAYS/YEAR
   SERVICE FREQUENCY                  TIMES/YEAR

DELTA VELOCITIES
   UP                         0.00
   DOWN                       0.00
   AERO RETURN                0.00

SUPPORT EQUIPMENT
             LENGTH:          0.00 METERS      WIDTH:      0.00 METERS        HEIGHT:       0.00 METERS       (STOWED)
             LENGTH:          0.00 METERS      WIDTH:      0.00 METERS        HEIGHT:       0.00 METERS       (DEPLOYED)

             MASS:               0 KG

MANIFEST RESTRICTIONS
   (X) NO RESTRICTIONS
   ( ) ONLY WITH COMPATIBLE PAYLOADS
   ( ) FLY-ALONE
   ( ) MUST HAVE DOCKING MODULE

LENGTH OF BEAM FAB                                         0.00
NUMBER OF APPENDAGES                                          0
NUMBER OF MODULES REQUIRED TO ASSEMBLE THE PAYLOAD:           0
--------------------------------------------------------------------------------------------------------------
```

PAYLOAD ELEMENT NAME
ELECTROEPITAXIAL CRYSTAL GROWTH

CODE
BACX1029

TYPE
( ) SCIENCE AND APPLICATIONS (NON-COMM.)
(X) COMMERCIAL
( ) TECHNOLOGY DEVELOPMENT
( ) OPERATIONS
( ) OTHER
( ) NATIONAL SECURITY
TYPE NUMBER (SEE TABLE A) 8

CONTACT
NAME ROBERT E. PACE, JR.
ADDRESS MICROGRAVITY RESEARCH AS
PO BOX 12426
HUNTSVILLE, AL 35802

TELEPHONE (205) 881-6670

IMPORTANCE OF THE SPACE STATION TO THIS ELEMENT
1 = LOW VALUE, BUT COULD USE
10 = VITAL
SCALE = 7

STATUS
( ) OPERATIONAL ( ) APPROVED ! (X) PLANNED ( ) CANDIDATE ( ) OPPORTUNITY

DESIRED FIRST FLIGHT, YEAR: 2000 NUMBER OF FLIGHTS 5 DURATION OF FLIGHT, DAYS 70

OBJECTIVE
DEVELOP AND COMMERCIALIZE A PROCESS FOR PRODUCING LARGE SINGLE CRYSTALS OF COMPOUND SEMICONDUCTOR MATERIALS.

DESCRIPTION
CRYSTALS ARE GROWN IN SPACE BY AN ELECTROEPITAXIAL GROWTH PROCESS. COMMERCIAL MANUFACTURING UNITS ARE PLACED IN MODULES ATTACHED TO THE SPACE STATION, AND GROWTH CELLS ARE REPLACED PERIODICALLY AND CRYSTALS RETURNED TO EARTH. A PROCESS DEVELOPMENT LABORATORY ON THE SPACE STATION IS USED TO CHARACTERIZE THE CRYSTALS AND DEVELOP
THE PROCESS.

ORBIT CHARACTERISTICS
GEOSYNCHRONOUS ORBIT ( ) YES (X) NO
APOGEE, KM PERIGEE, KM TOLERANCE + -
INCLINATION, DEG . TOLERANCE + -
NODAL ANGLE, DEG EPHEMERIS ACCURACY, M
ESCAPE DV REQUIRED, M/S .

POINTING/ORIENTATION
VIEW DIRECTION ( ) INERTIAL ( ) SOLAR ( ) EARTH (X) ANY
TRUTH SITES (IF KNOWN)
POINTING ACCURACY, ARC-SEC FIELD OF VIEW (DEG)
POINTING STABILITY (JITTER), ARC-SEC/SEC
SPECIAL RESTRICTIONS (AVOIDANCE)

POWER
( ) AC (X) DC

	POWER, W	DURATION, HRS/DAY
OPERATING	160000	24.00
STANDBY		
PEAK	160000	24.00

(X) CONTINUOUS
VOLTAGE, V 50 FREQUENCY, HZ 0

```
DATA/COMMUNICATIONS
   MONITORING REQUIREMENTS:
   ( ) NONE        ( ) REALTIME    (X) OFFLINE     ( ) OTHER:
   ( ) ENCRIPTION/DECRIPTION REQUIRED
   ( ) UPLINK REQUIRED:  COMMAND RATE (KBS):      0           FREQUENCY (MHZ):
   ( ) ON-BOARD DATA PROCESSING REQUIRED
       DESCRIPTION:
       DATA TYPES:   ( ) ANALOG      ( ) DIGITAL              HOURS/DAY
       FILM (AMOUNT):                                         VOICE (HOURS/DAY):
       LIVE TV (HOURS/DAY):                                   OTHER:
       ON-BOARD STORAGE (MBIT):
       DATA DUMP FREQUENCY (PER ORBIT)                        DOWNLINK COMMAND RATE:
       RECORDING RATE (KBPS)          0.10                    DOWNLINK FREQUENCY (MHZ):
--------------------------------------------------------------------------------------------------------------
THERMAL
   (X) ACTIVE     ( ) PASSIVE
       TEMPERATURE, DEG C   OPERATIONAL MINIMUM         850          MAXIMUM     950
                            NON-OPERATIONAL MINIMUM       0          MAXIMUM     100
       HEAT REJECTION, W    OPERATIONAL MINIMUM       10000          MAXIMUM  160000
                            NON-OPERATIONAL MINIMUM       0          MAXIMUM
--------------------------------------------------------------------------------------------------------------
EQUIPMENT PHYSICAL CHARACTERISTICS
   LOCATION            (X) INTERNAL         ( ) EXTERNAL         ( ) REMOTE
   EQUIPMENT ID/FUNCTION                    (X) PRESSURIZED      ( ) UNPRESSURIZED
                  L, M:       5.00        W, M:       1.00       H, M:      4.00      STOWED
                  L, M:       5.00        W, M:       1.00       H, M:      4.00      DEPLOYED
                  LAUNCH MASS, KG:   16000                       RETURN MASS, KG:     16000
                  CONSUMABLE TYPES
                  ACCELERATION SENSITIVITY, (G)       MIN:  1.00E-06      MAX:  1.00E-04
--------------------------------------------------------------------------------------------------------------
CREW REQUIREMENTS
   CREW SIZE            2          TASK ASSIGNMENTS
                                   -------------------------------------------------------------
   SKILLS (SEE TABLE B)            | SKILL     |      |      |      |      |      |      |
                                   -------------------------------------------------------------
                                   | LEVEL     |      |      |      |      |      |      |
                                   -------------------------------------------------------------
                                   | HOURS/DAY | 4.00 |      |      |      |      |      |
                                   -------------------------------------------------------------
   EVA  ( ) YES   (X) NO           REASON                           HOURS/EVA
--------------------------------------------------------------------------------------------------------------
SERVICING/MAINTENANCE
   SERVICE:                           INTERVAL,  DAYS        90              CONSUMABLES, KG
                                      RETURNABLES, KG     16000              MAN HOURS
   CONFIGURATION CHANGES:             INTERVAL, DAY                          MAN/HOURS REQUIRED
                                      DELIVERABLES, KG                       RETURNABLES, KG
--------------------------------------------------------------------------------------------------------------
SPECIAL CONSIDERATIONS/SEE INSTRUCTIONS
LABORATORY FACILITIES REQUIRED: CLEAN ROOM, WORKSPACE, MINICOMUTER, DOWNLINK TERMINAL
CRYSTAL CHARACTERIZATION EQUIPMENT REQUIRED: CUTTING SAW, POLISHER, ETCHER, COMPACT EVAPORATOR, HALL
APPARATUS LIGHT SOURCE AND SPECTROMETER.

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                                                 BOEING-SPECIFIC INPUT DATA
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MISSION TYPE                                   OPS CODE
   FREE FLYER
   ( ) NOT SERVICED                              F
   ( ) REMOTE TMS                                FT
   ( ) REMOTE MANNED                             FM
   ( ) SERVICED AT STATION (TMS RETRIEVED)       FST
   ( ) SERVICED AT STATION (SELF-PROPELLED)      FS

   PLATFORM BASED
   ( ) NOT SERVICED                              P
   ( ) REMOTE TMS                                PT
   ( ) REMOTE MANNED                             PM
   ( ) SERVICED AT STATION (TMS RETRIEVED)       PST
   ( ) SERVICED AT STATION (SELF-PROPELLED)      PS

   OTHER
   ( ) SPACE STATION BASED                       SS
   ( ) SORTIE                                    SOR

CONSTRUCTION/SERVICING COMPLEXITY
   ( ) LOW
   ( ) MEDIUM
   ( ) HIGH

OPERATIONS TIMES
   OTV UP/DOWN                           DAYS
   OTV OR TMS ON ORBIT                   DAYS
   MISSION USE                           DAYS/YEAR
   IVA SERVICE                           MAN-DAYS/YEAR
   EVA SERVICE                           MAN-DAYS/YEAR
   EXPERIMENT OPS                        MAN-DAYS/YEAR
   SERVICE FREQUENCY                     TIMES/YEAR

DELTA VELOCITIES
   UP                        0.00
   DOWN                      0.00
   AERO RETURN               0.00

SUPPORT EQUIPMENT
             LENGTH:         0.00 METERS      WIDTH:      0.00 METERS         HEIGHT:      0.00 METERS     (STOWED)
             LENGTH:         0.00 METERS      WIDTH:      0.00 METERS         HEIGHT:      0.00 METERS     (DEPLOYED)

             MASS:              0 KG

MANIFEST RESTRICTIONS
   (X) NO RESTRICTIONS
   ( ) ONLY WITH COMPATIBLE PAYLOADS
   ( ) FLY-ALONE
   ( ) MUST HAVE DOCKING MODULE

LENGTH OF BEAM FAB                                        0.00
NUMBER OF APPENDAGES                                         0
NUMBER OF MODULES REQUIRED TO ASSEMBLE THE PAYLOAD           0
------------------------------------------------------------------------------------------------------------------------------
```

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OF POOR QUALITY

PAYLOAD ELEMENT NAME
CONTINUOUS FLOW ELECTROPHORESIS

CODE
BACX1030

TYPE
( ) SCIENCE AND APPLICATIONS (NON-COMM.)
(X) COMMERCIAL
( ) TECHNOLOGY DEVELOPMENT
( ) OPERATIONS
( ) OTHER
( ) NATIONAL SECURITY
TYPE NUMBER (SEE TABLE A) 8

CONTACT
NAME DR. HARVEY J. WILLENBERG
ADDRESS BOEING AEROSPACE COMPANY
PO BOX 3999, MS 84-86
SEATTLE, WA 98124

TELEPHONE (206) 773-2020

IMPORTANCE OF THE SPACE STATION TO THIS ELEMENT
1 = LOW VALUE, BUT COULD USE
10 = VITAL
SCALE = 6

STATUS
( ) OPERATIONAL ( ) APPROVED (X) PLANNED ( ) CANDIDATE ( ) OPPORTUNITY

DESIRED FIRST FLIGHT, YEAR: 1991 NUMBER OF FLIGHTS 2 DURATION OF FLIGHT, DAYS 21

OBJECTIVE
PROVIDE BIOCHEMICAL LABORATORY FOR DEVELOPING NEW ELECTROPHORESIS PRODUCTS, TESTING NEW EQUIPMENT AND PROCEDURES, AND PRODUCING RESEARCH QUANTITIES OF BIOLOGICAL MATERIALS.

DESCRIPTION
A BIOCHEMICAL LABORATORY IS NEEDED TO DEVELOP ELECTROPHORESIS TECHNOLOGY BEYOND PROTOTYPE COMMERCIAL PRODUCTION FREE-FLYER. THE LABORATORY WOULD INCLUDE 5-10 ELECTROPHORESIS UNITS FOR SEVERAL RESEARCH AND COMMERCIAL USERS. A CONTROL LABORATORY STORAGE RACKS, AND CREW ACCOMMODATIONS. THESE UNITS WOULD PROVIDE SEPARATIONS FOR A NUMBER OF DIFFERENT PHARMACEUTICALS AND DIFFERENT COMMERCIAL USERS. THE CONTROL LABORATORY WOULD BE FOR PROCESS CONTROL OF THE ELECTROPHORESIS UNITS, QUALITY CONTROL OF THE PRODUCT, AND REPAIR OF THE PROCESS UNITS. IT IS BELIEVED THAT THIS CAN BE A SHARED MULTI-USER FACILITY, OF ROUGHLY 50 M3, WITH FLUID, THERMAL, AND ELECTRICAL CONTROL SYSTEMS AND BIOLOGICAL LABORATORY EQUIPMENT. ABOUT 5 M3 0 STORAGE RACKS WOULD BE REQUIRED.

ORBIT CHARACTERISTICS
GEOSYNCHRONOUS ORBIT ( ) YES (X) NO
APOGEE, KM 300 PERIGEE, KM 300 TOLERANCE + 200 - 100
INCLINATION, DEG TOLERANCE + -
NODAL ANGLE, DEG EPHEMERIS ACCURACY, M
ESCAPE DV REQUIRED, M/S

POINTING/ORIENTATION
VIEW DIRECTION ( ) INERTIAL ( ) SOLAR ( ) EARTH (X) ANY
TRUTH SITES (IF KNOWN)
POINTING ACCURACY, ARC-SEC FIELD OF VIEW (DEG)
POINTING STABILITY (JITTER), ARC-SEC/SEC
SPECIAL RESTRICTIONS (AVOIDANCE)

POWER
( ) AC (X) DC

	POWER, W	DURATION, HRS/DAY	
OPERATING	10000	24.00	
STANDBY	3000	0.00	(X) CONTINUOUS
PEAK	10000	0.00	
VOLTAGE, V	2000	FREQUENCY, HZ	0

DATA/COMMUNICATIONS
MONITORING REQUIREMENTS:
( ) NONE ( ) REALTIME (X) OFFLINE ( ) OTHER:
( ) ENCRIPTION/DECRIPTION REQUIRED
( ) UPLINK REQUIRED: COMMAND RATE (KBS): FREQUENCY (MHZ):
( ) ON-BOARD DATA PROCESSING REQUIRED
DESCRIPTION:
DATA TYPES: ( ) ANALOG ( ) DIGITAL
FILM (AMOUNT):
LIVE TV (HOURS/DAY):
ON-BOARD STORAGE (MBIT):
DATA DUMP FREQUENCY (PER ORBIT)
RECORDING RATE (KBPS)

HOURS/DAY
VOICE (HOURS/DAY):
OTHER:

DOWNLINK COMMAND RATE:
DOWNLINK FREQUENCY (MHZ):

THERMAL
( ) ACTIVE (X) PASSIVE

TEMPERATURE, DEG C	OPERATIONAL MINIMUM	20	MAXIMUM	40
	NON-OPERATIONAL MINIMUM	4	MAXIMUM	40
HEAT REJECTION, W	OPERATIONAL MINIMUM	9000	MAXIMUM	11000
	NON-OPERATIONAL MINIMUM	0	MAXIMUM	

EQUIPMENT PHYSICAL CHARACTERISTICS
LOCATION (X) INTERNAL ( ) EXTERNAL ( ) REMOTE
EQUIPMENT ID/FUNCTION (X) PRESSURIZED ( ) UNPRESSURIZED
L, M: 12.00 W, M: 5.00 H, M: 5.00 STOWED
L, M: 35.00 W, M: 2.00 H, M: 5.00 DEPLOYED
LAUNCH MASS, KG: 30000 RETURN MASS, KG: 15000
CONSUMABLE TYPES
ACCELERATION SENSITIVITY, (G) MIN: E+00 MAX: E+00

CREW REQUIREMENTS
CREW SIZE 18

TASK ASSIGNMENTS

SKILLS (SEE TABLE B)

SKILL						
LEVEL						
HOURS/DAY						

EVA ( ) YES (X) NO REASON HOURS/EVA

SERVICING/MAINTENANCE
SERVICE: INTERVAL, DAYS CONSUMABLES, KG
RETURNABLES, KG MAN HOURS
CONFIGURATION CHANGES: INTERVAL, DAY MAN/HOURS REQUIRED
DELIVERABLES, KG RETURNABLES, KG

SPECIAL CONSIDERATIONS/SEE INSTRUCTIONS

ORIGINAL PAGE IS
OF POOR QUALITY

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                                              BOEING-SPECIFIC INPUT DATA
------------------------------------------------------------------------------------------------------------
MISSION TYPE
   FREE FLYER                                        OPS CODE
   ( ) NOT SERVICED                                     F
   ( ) REMOTE TMS                                       FT
   ( ) REMOTE MANNED                                    FM
   ( ) SERVICED AT STATION (TMS RETRIEVED)              FST
   ( ) SERVICED AT STATION (SELF-PROPELLED)             FS

   PLATFORM BASED
   ( ) NOT SERVICED                                     P
   ( ) REMOTE TMS                                       PT
   ( ) REMOTE MANNED                                    PM
   ( ) SERVICED AT STATION (TMS RETRIEVED)              PST
   ( ) SERVICED AT STATION (SELF-PROPELLED)             PS

   OTHER
   ( ) SPACE STATION BASED                              SS
   ( ) SORTIE                                           SOR

CONSTRUCTION/SERVICING COMPLEXITY
   ( ) LOW
   ( ) MEDIUM
   ( ) HIGH

OPERATIONS TIMES
   OTV UP/DOWN                             DAYS
   OTV OR TMS ON ORBIT                     DAYS
   MISSION USE                             DAYS/YEAR
   IVA SERVICE                             MAN-DAYS/YEAR
   EVA SERVICE                             MAN-DAYS/YEAR
   EXPERIMENT OPS                          MAN-DAYS/YEAR
   SERVICE FREQUENCY                       TIMES/YEAR

DELTA VELOCITIES
   UP                          0.00
   DOWN                        0.00
   AERO RETURN                 0.00

SUPPORT EQUIPMENT
             LENGTH:           0.00 METERS      WIDTH:      0.00 METERS      HEIGHT:      0.00 METERS      (STOWED)
             LENGTH:           0.00 METERS      WIDTH:      0.00 METERS      HEIGHT:      0.00 METERS      (DEPLOYED)

             MASS:                0 KG

MANIFEST RESTRICTIONS
   (X) NO RESTRICTIONS
   ( ) ONLY WITH COMPATIBLE PAYLOADS
   ( ) FLY-ALONE
   ( ) MUST HAVE DOCKING MODULE

LENGTH OF BEAM FAD                                        0.00
NUMBER OF APPENDAGES                                         0
NUMBER OF MODULES REQUIRED TO ASSEMBLE THE PAYLOAD           0
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ORIGINAL PAGE IS
OF POOR QUALITY

PAYLOAD ELEMENT NAME
CONTINUOUS FLOW ELECTROPHORESIS

CODE
BACX1031

CONTACT
NAME DR. HARVEY J. WILLENBERG
ADDRESS BOEING AEROSPACE COMPANY
PO BOX 3999, MS 84-86
SEATTLE, WA 98124

TELEPHONE (206) 773-2020

TYPE
( ) SCIENCE AND APPLICATIONS (NON-COMM.)
(X) COMMERCIAL
( ) TECHNOLOGY DEVELOPMENT
( ) OPERATIONS
( ) OTHER
( ) NATIONAL SECURITY
TYPE NUMBER (SEE TABLE A) 8

IMPORTANCE OF THE SPACE STATION TO
THIS ELEMENT
1 = LOW VALUE, BUT COULD USE
10 = VITAL
SCALE = 6

STATUS
( ) OPERATIONAL ( ) APPROVED (X) PLANNED ( ) CANDIDATE ( ) OPPORTUNITY

DESIRED FIRST FLIGHT, YEAR: 1992 NUMBER OF FLIGHTS 3 DURATION OF FLIGHT, DAYS 21

OBJECTIVE
PROVIDE BIOCHEMICAL LABORATORY FOR DEVELOPING NEW ELECTROPHORESIS PRODUCTS, TESTING NEW EQUIPMENT AND PROCEDURES, AND PRODUCING RESEARCH QUANTITIES OF BIOLOGICAL MATERIALS.

DESCRIPTION
A BIOCHEMICAL LABORATORY IS NEEDED TO DEVELOP ELECTROPHORESIS TECHNOLOGY BEYOND PROTOTYPE COMMERCIAL PRODUCTION FREE-FLYER. THE LABORATORY WOULD INCLUDE 5-10 ELECTROPHORESIS UNITS FOR SEVERAL RESEARCH AND COMMERCIAL USERS. A CONTROL LABORATORY STORAGE RACKS, AND CREW ACCOMMODATIONS. THESE UNITS WOULD PROVIDE SEPARATIONS FOR A NUMBER OF DIFFERENT PHARMACEUTICALS AND DIFFERENT COMMERCIAL USERS. THE CONTROL LABORATORY WOULD BE FOR PROCESS CONTROL OF THE ELECTROPHORESIS UNITS, QUALITY CONTROL OF THE PRODUCT, AND REPAIR OF THE PROCESS UNITS. IT IS BELIEVED THAT THIS CAN BE A SHARED MULTI-USER FACILITY, OF ROUGHLY 50 M3, WITH FLUID, THERMAL, AND ELECTRICAL CONTROL SYSTEMS AND BIOLOGICAL LABORATORY EQUIPMENT. ABOUT 5 M3 0 STORAGE RACKS WOULD BE REQUIRED.

ORBIT CHARACTERISTICS
GEOSYNCHRONOUS ORBIT ( ) YES (X) NO
APOGEE, KM 300 PERIGEE, KM 300 TOLERANCE + 200 - 100
INCLINATION, DEG TOLERANCE + -
NODAL ANGLE, DEG EPHEMERIS ACCURACY, M
ESCAPE DV REQUIRED, M/S .

POINTING/ORIENTATION
VIEW DIRECTION ( ) INERTIAL ( ) SOLAR ( ) EARTH (X) ANY
TRUTH SITES (IF KNOWN)
POINTING ACCURACY, ARC-SEC FIELD OF VIEW (DEG)
POINTING STABILITY (JITTER), ARC-SEC/SEC
SPECIAL RESTRICTIONS (AVOIDANCE)

POWER
( ) AC (X) DC

	POWER, W	DURATION, HRS/DAY	
OPERATING	10000	24.00	
STANDBY	3000	0.00	(X) CONTINUOUS
PEAK	10000	0.00	
VOLTAGE, V	2000	FREQUENCY, HZ	0

DATA/COMMUNICATIONS

MONITORING REQUIREMENTS:
( ) NONE ( ) REALTIME (X) OFFLINE ( ) OTHER:
( ) ENCRIPTION/DECRIPTION REQUIRED
( ) UPLINK REQUIRED: COMMAND RATE (KBS): FREQUENCY (MHZ):
( ) ON-BOARD DATA PROCESSING REQUIRED
DESCRIPTION:
DATA TYPES: ( ) ANALOG ( ) DIGITAL HOURS/DAY
FILM (AMOUNT): VOICE (HOURS/DAY):
LIVE TV (HOURS/DAY): OTHER:
ON-BOARD STORAGE (MBIT):
DATA DUMP FREQUENCY (PER ORBIT) DOWNLINK COMMAND RATE:
RECORDING RATE (KBPS) DOWNLINK FREQUENCY (MHZ):

THERMAL

( ) ACTIVE (X) PASSIVE

TEMPERATURE, DEG C	OPERATIONAL MINIMUM	20	MAXIMUM	40
	NON-OPERATIONAL MINIMUM	4	MAXIMUM	40
HEAT REJECTION, W	OPERATIONAL MINIMUM	9000	MAXIMUM	11000
	NON-OPERATIONAL MINIMUM	0	MAXIMUM	

EQUIPMENT PHYSICAL CHARACTERISTICS

LOCATION (X) INTERNAL ( ) EXTERNAL ( ) REMOTE
EQUIPMENT ID/FUNCTION (X) PRESSURIZED ( ) UNPRESSURIZED
L, M: 12.00 W, M: 5.00 H, M: 5.00 STOWED
L, M: 35.00 W, M: 2.00 H, M: 5.00 DEPLOYED
LAUNCH MASS, KG: 30000 RETURN MASS, KG: 15000
CONSUMABLE TYPES
ACCELERATION SENSITIVITY, (G) MIN: E+00 MAX: E+00

CREW REQUIREMENTS

CREW SIZE 18

SKILLS (SEE TABLE B)

TASK ASSIGNMENTS

SKILL						
LEVEL						
HOURS/DAY						

EVA ( ) YES (X) NO REASON HOURS/EVA

SERVICING/MAINTENANCE

SERVICE: INTERVAL, DAYS CONSUMABLES, KG
RETURNABLES, KG MAN HOURS
CONFIGURATION CHANGES: INTERVAL, DAY MAN/HOURS REQUIRED
DELIVERABLES, KG RETURNABLES, KG

SPECIAL CONSIDERATIONS/SEE INSTRUCTIONS

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                                             BOEING-SPECIFIC INPUT DATA
------------------------------------------------------------------------------------------------------------------------------------------
MISSION TYPE                                   OPS CODE
   FREE FLYER
   ( ) NOT SERVICED                               F
   ( ) REMOTE TMS                                 FT
   ( ) REMOTE MANNED                              FM
   ( ) SERVICED AT STATION (TMS RETRIEVED)        FST
   ( ) SERVICED AT STATION (SELF-PROPELLED)       FS

   PLATFORM BASED
   ( ) NOT SERVICED                               P
   ( ) REMOTE TMS                                 PT
   ( ) REMOTE MANNED                              PM
   ( ) SERVICED AT STATION (TMS RETRIEVED)        PST
   ( ) SERVICED AT STATION (SELF-PROPELLED)       PS

   OTHER
   ( ) SPACE STATION BASED                        SS
   ( ) SORTIE                                     SOR

CONSTRUCTION/SERVICING COMPLEXITY
   ( ) LOW
   ( ) MEDIUM
   ( ) HIGH

OPERATIONS TIMES
   OTV UP/DOWN                          DAYS
   OTV OR TMS ON ORBIT                  DAYS
   MISSION USE                          DAYS/YEAR
   IVA SERVICE                          MAN-DAYS/YEAR
   EVA SERVICE                          MAN-DAYS/YEAR
   EXPERIMENT OPS                       MAN-DAYS/YEAR
   SERVICE FREQUENCY                    TIMES/YEAR

DELTA VELOCITIES
   UP                        0.00
   DOWN                      0.00
   AERO RETURN               0.00

SUPPORT EQUIPMENT
             LENGTH:         0.00 METERS      WIDTH:      0.00 METERS      HEIGHT:      0.00 METERS      (STOWED)
             LENGTH:         0.00 METERS      WIDTH:      0.00 METERS      HEIGHT:      0.00 METERS      (DEPLOYED)

             MASS:              0 KG

MANIFEST RESTRICTIONS
   (X) NO RESTRICTIONS
   ( ) ONLY WITH COMPATIBLE PAYLOADS
   ( ) FLY-ALONE
   ( ) MUST HAVE DOCKING MODULE

LENGTH OF BEAM FAB                                        0.00
NUMBER OF APPENDAGES                                         0
NUMBER OF MODULES REQUIRED TO ASSEMBLE THE PAYLOAD           0
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PAYLOAD ELEMENT NAME
CONTINUOUS FLOW ELECTROPHORESIS

CODE
BACX1032

CONTACT
NAME DR. HARVEY J. WILLENBERG
ADDRESS BOEING AEROSPACE COMPANY
PO BOX 3999, MS 84-86
SEATTLE, WA 98124

TELEPHONE (206) 773-2020

TYPE
( ) SCIENCE AND APPLICATIONS (NON-COMM.)
(X) COMMERCIAL
( ) TECHNOLOGY DEVELOPMENT
( ) OPERATIONS
( ) OTHER
( ) NATIONAL SECURITY
TYPE NUMBER (SEE TABLE A) 8

IMPORTANCE OF THE SPACE STATION TO THIS ELEMENT
1 = LOW VALUE, BUT COULD USE
10 = VITAL
SCALE = 6

STATUS
( ) OPERATIONAL ( ) APPROVED ! (X) PLANNED ( ) CANDIDATE ( ) OPPORTUNITY

DESIRED FIRST FLIGHT, YEAR: 1993 NUMBER OF FLIGHTS 5 DURATION OF FLIGHT, DAYS 21

OBJECTIVE
PROVIDE BIOCHEMICAL LABORATORY FOR DEVELOPING NEW ELECTROPHORESIS PRODUCTS, TESTING NEW EQUIPMENT AND PROCEDURES, AND PRODUCING RESEARCH QUANTITIES OF BIOLOGICAL MATERIALS.

DESCRIPTION
A BIOCHEMICAL LABORATORY IS NEEDED TO DEVELOP ELECTROPHORESIS TECHNOLOGY BEYOND PROTOTYPE COMMERCIAL PRODUCTION FREE-FLYER. THE LABORATORY WOULD INCLUDE 5-10 ELECTROPHORESIS UNITS FOR SEVERAL RESEARCH AND COMMERCIAL USERS. A CONTROL LABORATORY STORAGE RACKS, AND CREW ACCOMMODATIONS. THESE UNITS WOULD PROVIDE SEPARATIONS FOR A NUMBER OF DIFFERENT PHARMACEUTICALS AND DIFFERENT COMMERCIAL USERS. THE CONTROL LABORATORY WOULD BE FOR PROCESS CONTROL OF THE ELECTROPHORESIS UNITS, QUALITY CONTROL OF THE PRODUCT, AND REPAIR OF THE PROCESS UNITS. IT IS BELIEVED THAT THIS CAN BE A SHARED MULTI-USER FACILITY, OF ROUGHLY 50 M3, WITH FLUID, THERMAL, AND ELECTRICAL CONTROL SYSTEMS AND BIOLOGICAL LABORATORY EQUIPMENT. ABOUT 5 M3 O STORAGE RACKS WOULD BE REQUIRED.

ORBIT CHARACTERISTICS
GEOSYNCHRONOUS ORBIT ( ) YES (X) NO
APOGEE, KM 300 PERIGEE, KM 300 TOLERANCE + 200 - 100
INCLINATION, DEG TOLERANCE + -
NODAL ANGLE, DEG EPHEMERIS ACCURACY, M
ESCAPE DV REQUIRED, M/S .

POINTING/ORIENTATION
VIEW DIRECTION ( ) INERTIAL ( ) SOLAR ( ) EARTH (X) ANY
TRUTH SITES (IF KNOWN)
POINTING ACCURACY, ARC-SEC FIELD OF VIEW (DEG)
POINTING STABILITY (JITTER), ARC-SEC/SEC
SPECIAL RESTRICTIONS (AVOIDANCE)

POWER
( ) AC (X) DC

	POWER, W	DURATION, HRS/DAY	
OPERATING	10000	24.00	
STANDBY	3000	0.00	(X) CONTINUOUS
PEAK	10000	0.00	
VOLTAGE, V	2000	FREQUENCY, HZ	0

```
DATA/COMMUNICATIONS
   MONITORING REQUIREMENTS:
   ( ) NONE          ( ) REALTIME    (X) OFFLINE     ( ) OTHER:
   ( ) ENCRIPTION/DECRIPTION REQUIRED
   ( ) UPLINK REQUIRED:  COMMAND RATE (KBS):                        FREQUENCY (MHZ):
   ( ) ON-BOARD DATA PROCESSING REQUIRED
       DESCRIPTION:
       DATA TYPES:    ( ) ANALOG      ( ) DIGITAL                   HOURS/DAY
       FILM (AMOUNT):                                               VOICE (HOURS/DAY):
       LIVE TV (HOURS/DAY):                                         OTHER:
       ON-BOARD STORAGE (MBIT):
       DATA DUMP FREQUENCY (PER ORBIT)                              DOWNLINK COMMAND RATE:
       RECORDING RATE (KBPS)                                        DOWNLINK FREQUENCY (MHZ):
-----------------------------------------------------------------------------------------------------------------------------------
THERMAL
   ( ) ACTIVE      (X) PASSIVE
       TEMPERATURE, DEG C    OPERATIONAL MINIMUM          20           MAXIMUM      40
                             NON-OPERATIONAL MINIMUM       4           MAXIMUM      40
       HEAT REJECTION, W     OPERATIONAL MINIMUM        9000           MAXIMUM   11000
                             NON-OPERATIONAL MINIMUM       0           MAXIMUM
-----------------------------------------------------------------------------------------------------------------------------------
EQUIPMENT PHYSICAL CHARACTERISTICS
   LOCATION        (X) INTERNAL        ( ) EXTERNAL        ( ) REMOTE
   EQUIPMENT ID/FUNCTION               (X) PRESSURIZED     ( ) UNPRESSURIZED
                   L, M:     12.00     W, M:       5.00    H, M:       5.00    STOWED
                   L, M:     35.00     W, M:       2.00    H, M:       5.00    DEPLOYED
                   LAUNCH MASS, KG:   30000                RETURN MASS, KG:    15000
                   CONSUMABLE TYPES
                   ACCELERATION SENSITIVITY, (G)      MIN:       E+00      MAX:        E+00
-----------------------------------------------------------------------------------------------------------------------------------
CREW REQUIREMENTS
   CREW SIZE          18             TASK ASSIGNMENTS
                                     ----------------------------------------------------------
   SKILLS (SEE TABLE B)              I SKILL      I       I       I       I       I       I       I
                                     ----------------------------------------------------------
                                     I LEVEL      I       I       I       I       I       I       I
                                     ----------------------------------------------------------
                                     I HOURS/DAY  I       I       I       I       I       I       I
                                     ----------------------------------------------------------
   EVA   ( ) YES    (X) NO           REASON                              HOURS/EVA
-----------------------------------------------------------------------------------------------------------------------------------
SERVICING/MAINTENANCE
   SERVICE:                              INTERVAL,  DAYS                        CONSUMABLES, KG
                                         RETURNABLES, KG                        MAN HOURS
   CONFIGURATION CHANGES:                INTERVAL, DAY                          MAN/HOURS REQUIRED
                                         DELIVERABLES, KG                       RETURNABLES, KG
-----------------------------------------------------------------------------------------------------------------------------------
SPECIAL CONSIDERATIONS/SEE INSTRUCTIONS



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ORIGINAL PAGE IS
OF POOR QUALITY

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                                                         BOEING-SPECIFIC INPUT DATA
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MISSION TYPE                                       OPS CODE
   FREE FLYER
   ( ) NOT SERVICED                                   F
   ( ) REMOTE TMS                                     FT
   ( ) REMOTE MANNED                                  FM
   ( ) SERVICED AT STATION (TMS RETRIEVED)            FST
   ( ) SERVICED AT STATION (SELF-PROPELLED)           FS

   PLATFORM BASED
   ( ) NOT SERVICED                                   P
   ( ) REMOTE TMS                                     PT
   ( ) REMOTE MANNED                                  PM
   ( ) SERVICED AT STATION (TMS RETRIEVED)            PST
   ( ) SERVICED AT STATION (SELF-PROPELLED)           PS

   OTHER
   ( ) SPACE STATION BASED                            SS
   ( ) SORTIE                                         SOR

CONSTRUCTION/SERVICING COMPLEXITY
   ( ) LOW
   ( ) MEDIUM
   ( ) HIGH

OPERATIONS TIMES
   OTV UP/DOWN                              DAYS
   OTV OR TMS ON ORBIT                      DAYS
   MISSION USE                              DAYS/YEAR
   IVA SERVICE                              MAN-DAYS/YEAR
   EVA SERVICE                              MAN-DAYS/YEAR
   EXPERIMENT OPS                           MAN-DAYS/YEAR
   SERVICE FREQUENCY                        TIMES/YEAR

DELTA VELOCITIES
   UP                      0.00
   DOWN                    0.00
   AERO RETURN             0.00

SUPPORT EQUIPMENT
             LENGTH:       0.00 METERS       WIDTH:     0.00 METERS          HEIGHT:      0.00 METERS      (STOWED)
             LENGTH:       0.00 METERS       WIDTH:     0.00 METERS          HEIGHT:      0.00 METERS      (DEPLOYED)

             MASS:            0 KG

MANIFEST RESTRICTIONS
   (X) NO RESTRICTIONS
   ( ) ONLY WITH COMPATIBLE PAYLOADS
   ( ) FLY-ALONE
   ( ) MUST HAVE DOCKING MODULE

LENGTH OF BEAM FAB                                          0.00
NUMBER OF APPENDAGES                                           0
NUMBER OF MODULES REQUIRED TO ASSEMBLE THE PAYLOAD             0
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PAYLOAD ELEMENT NAME	CODE
CONTINUOUS FLOW ELECTROPHORESIS	BACX1033

TYPE
( ) SCIENCE AND APPLICATIONS (NON-COMM.)
(X) COMMERCIAL
( ) TECHNOLOGY DEVELOPMENT
( ) OPERATIONS
( ) OTHER
( ) NATIONAL SECURITY
TYPE NUMBER (SEE TABLE A) 8

CONTACT
NAME DR. HARVEY J. WILLENBERG
ADDRESS BOEING AEROSPACE COMPANY
PO BOX 3999, MS 84-86
SEATTLE, WA 98124

TELEPHONE (206) 773-2020

IMPORTANCE OF THE SPACE STATION TO THIS ELEMENT
1 = LOW VALUE, BUT COULD USE
10 = VITAL
SCALE = 6

STATUS
( ) OPERATIONAL ( ) APPROVED (X) PLANNED ( ) CANDIDATE ( ) OPPORTUNITY

DESIRED FIRST FLIGHT, YEAR: 1994 NUMBER OF FLIGHTS 7 DURATION OF FLIGHT, DAYS 21

OBJECTIVE
PROVIDE BIOCHEMICAL LABORATORY FOR DEVELOPING NEW ELECTROPHORESIS PRODUCTS, TESTING NEW EQUIPMENT AND PROCEDURES, AND PRODUCING RESEARCH QUANTITIES OF BIOLOGICAL MATERIALS.

DESCRIPTION
A BIOCHEMICAL LABORATORY IS NEEDED TO DEVELOP ELECTROPHORESIS TECHNOLOGY BEYOND PROTOTYPE COMMERCIAL PRODUCTION FREE-FLYER. THE LABORATORY WOULD INCLUDE 5-10 ELECTROPHORESIS UNITS FOR SEVERAL RESEARCH AND COMMERCIAL USERS. A CONTROL LABORATORY STORAGE RACKS, AND CREW ACCOMMODATIONS. THESE UNITS WOULD PROVIDE SEPARATIONS FOR A NUMBER OF DIFFERENT PHARMACEUTICALS AND DIFFERENT COMMERCIAL USERS. THE CONTROL LABORATORY WOULD BE FOR PROCESS CONTROL OF THE ELECTROPHORESIS UNITS, QUALITY CONTROL OF THE PRODUCT, AND REPAIR OF THE PROCESS UNITS. IT IS BELIEVED THAT THIS CAN BE A SHARED MULTI-USER FACILITY, OF ROUGHLY 50 M3, WITH FLUID, THERMAL, AND ELECTRICAL CONTROL SYSTEMS AND BIOLOGICAL LABORATORY EQUIPMENT. ABOUT 5 M3 O STORAGE RACKS WOULD BE REQUIRED.

ORBIT CHARACTERISTICS
GEOSYNCHRONOUS ORBIT ( ) YES (X) NO
APOGEE, KM 300 PERIGEE, KM 300 TOLERANCE + 200 - 100
INCLINATION, DEG TOLERANCE + -
NODAL ANGLE, DEG EPHEMERIS ACCURACY, M
ESCAPE DV REQUIRED, M/S .

POINTING/ORIENTATION
VIEW DIRECTION ( ) INERTIAL ( ) SOLAR ( ) EARTH (X) ANY
TRUTH SITES (IF KNOWN)
POINTING ACCURACY, ARC-SEC FIELD OF VIEW (DEG)
POINTING STABILITY (JITTER), ARC-SEC/SEC
SPECIAL RESTRICTIONS (AVOIDANCE)

POWER
( ) AC (X) DC

	POWER, W	DURATION, HRS/DAY	
OPERATING	10000	24.00	
STANDBY	3000	0.00	(X) CONTINUOUS
PEAK	10000	0.00	
VOLTAGE, V	2000	FREQUENCY, HZ	0

DATA/COMMUNICATIONS
MONITORING REQUIREMENTS:
( ) NONE ( ) REALTIME (X) OFFLINE ( ) OTHER:
( ) ENCRIPTION/DECRIPTION REQUIRED
( ) UPLINK REQUIRED: COMMAND RATE (KBS):
FREQUENCY (MHZ):
( ) ON-BOARD DATA PROCESSING REQUIRED
DESCRIPTION:
DATA TYPES: ( ) ANALOG ( ) DIGITAL
HOURS/DAY
FILM (AMOUNT):
VOICE (HOURS/DAY):
LIVE TV (HOURS/DAY):
OTHER:
ON-BOARD STORAGE (MBIT):
DATA DUMP FREQUENCY (PER ORBIT)
DOWNLINK COMMAND RATE:
RECORDING RATE (KBPS)
DOWNLINK FREQUENCY (MHZ):

THERMAL
( ) ACTIVE (X) PASSIVE

TEMPERATURE, DEG C	OPERATIONAL MINIMUM	20	MAXIMUM	40
	NON-OPERATIONAL MINIMUM	4	MAXIMUM	40
HEAT REJECTION, W	OPERATIONAL MINIMUM	9000	MAXIMUM	11000
	NON-OPERATIONAL MINIMUM	0	MAXIMUM	

EQUIPMENT PHYSICAL CHARACTERISTICS
LOCATION (X) INTERNAL ( ) EXTERNAL ( ) REMOTE
EQUIPMENT ID/FUNCTION (X) PRESSURIZED ( ) UNPRESSURIZED
L, M: 12.00 W, M: 5.00 H, M: 5.00 STOWED
L, M: 35.00 W, M: 2.00 H, M: 5.00 DEPLOYED
LAUNCH MASS, KG: 30000 RETURN MASS, KG: 15000
CONSUMABLE TYPES
ACCELERATION SENSITIVITY, (G) MIN: E+00 MAX: E+00

CREW REQUIREMENTS
CREW SIZE 18

SKILLS (SEE TABLE B)

TASK ASSIGNMENTS

SKILL						
LEVEL						
HOURS/DAY						

EVA ( ) YES (X) NO REASON HOURS/EVA

SERVICING/MAINTENANCE
SERVICE:
INTERVAL, DAYS
CONSUMABLES, KG
RETURNABLES, KG
MAN HOURS
CONFIGURATION CHANGES:
INTERVAL, DAY
MAN/HOURS REQUIRED
DELIVERABLES, KG
RETURNABLES, KG

SPECIAL CONSIDERATIONS/SEE INSTRUCTIONS

```
                              BOEING-SPECIFIC INPUT DATA
-----------------------------------------------------------------------------------------
MISSION TYPE                              OPS CODE
   FREE FLYER
   ( ) NOT SERVICED                          F
   ( ) REMOTE TMS                            FT
   ( ) REMOTE MANNED                         FM
   ( ) SERVICED AT STATION (TMS RETRIEVED)   FST
   ( ) SERVICED AT STATION (SELF-PROPELLED)  FS

   PLATFORM BASED
   ( ) NOT SERVICED                          P
   ( ) REMOTE TMS                            PT
   ( ) REMOTE MANNED                         PM
   ( ) SERVICED AT STATION (TMS RETRIEVED)   PST
   ( ) SERVICED AT STATION (SELF-PROPELLED)  PS

   OTHER
   ( ) SPACE STATION BASED                   SS
   ( ) SORTIE                                SOR

CONSTRUCTION/SERVICING COMPLEXITY
   ( ) LOW
   ( ) MEDIUM
   ( ) HIGH

OPERATIONS TIMES
   OTV UP/DOWN                       DAYS
   OTV OR TMS ON ORBIT               DAYS
   MISSION USE                       DAYS/YEAR
   IVA SERVICE                      'MAN-DAYS/YEAR
   EVA SERVICE                       MAN-DAYS/YEAR
   EXPERIMENT OPS                    MAN-DAYS/YEAR
   SERVICE FREQUENCY                 TIMES/YEAR

DELTA VELOCITIES
   UP                      0.00
   DOWN                    0.00
   AERO RETURN             0.00

SUPPORT EQUIPMENT
             LENGTH:       0.00 METERS    WIDTH:    0.00 METERS     HEIGHT:    0.00 METERS    (STOWED)
             LENGTH:       0.00 METERS    WIDTH:    0.00 METERS     HEIGHT:    0.00 METERS    (DEPLOYED)

             MASS:            0 KG

MANIFEST RESTRICTIONS
   (X) NO RESTRICTIONS
   ( ) ONLY WITH COMPATIBLE PAYLOADS
   ( ) FLY-ALONE
   ( ) MUST HAVE DOCKING MODULE

LENGTH OF BEAM FAB                                   0.00
NUMBER OF APPENDAGES                                    0
NUMBER OF MODULES REQUIRED TO ASSEMBLE THE PAYLOAD      0
-----------------------------------------------------------------------------------------
```

PAYLOAD ELEMENT NAME
CONTINUOUS FLOW ELECTROPHORESIS

CODE
BACX1034

TYPE
( ) SCIENCE AND APPLICATIONS (NON-COMM.)
(X) COMMERCIAL
( ) TECHNOLOGY DEVELOPMENT
( ) OPERATIONS
( ) OTHER
( ) NATIONAL SECURITY
TYPE NUMBER (SEE TABLE A) 8

CONTACT
NAME DR. HARVEY J. WILLENBERG
ADDRESS BOEING AEROSPACE COMPANY
PO BOX 3999, MS 84-86
SEATTLE, WA 98124

TELEPHONE (206) 773-2020

IMPORTANCE OF THE SPACE STATION TO THIS ELEMENT
1 = LOW VALUE, BUT COULD USE
10 = VITAL
SCALE = 6

STATUS
( ) OPERATIONAL ( ) APPROVED (X) PLANNED ( ) CANDIDATE ( ) OPPORTUNITY

DESIRED FIRST FLIGHT, YEAR: 1995 NUMBER OF FLIGHTS 8 DURATION OF FLIGHT, DAYS 21

OBJECTIVE
PROVIDE BIOCHEMICAL LABORATORY FOR DEVELOPING NEW ELECTROPHORESIS PRODUCTS, TESTING NEW EQUIPMENT AND PROCEDURES, AND PRODUCING RESEARCH QUANTITIES OF BIOLOGICAL MATERIALS.

DESCRIPTION
A BIOCHEMICAL LABORATORY IS NEEDED TO DEVELOP ELECTROPHORESIS TECHNOLOGY BEYOND PROTOTYPE COMMERCIAL PRODUCTION FREE-FLYER. THE LABORATORY WOULD INCLUDE 5-10 ELECTROPHORESIS UNITS FOR SEVERAL RESEARCH AND COMMERCIAL USERS. A CONTROL LABORATORY STORAGE RACKS, AND CREW ACCOMMODATIONS. THESE UNITS WOULD PROVIDE SEPARATIONS FOR A NUMBER OF DIFFERENT PHARMACEUTICALS AND DIFFERENT COMMERCIAL USERS. THE CONTROL LABORATORY WOULD BE FOR PROCESS CONTROL OF THE ELECTROPHORESIS UNITS, QUALITY CONTROL OF THE PRODUCT, AND REPAIR OF THE PROCESS UNITS. IT IS BELIEVED THAT THIS CAN BE A SHARED MULTI-USER FACILITY, OF ROUGHLY 50 M3, WITH FLUID, THERMAL, AND ELECTRICAL CONTROL SYSTEMS AND BIOLOGICAL LABORATORY EQUIPMENT. ABOUT 5 M3 O STORAGE RACKS WOULD BE REQUIRED.

ORBIT CHARACTERISTICS
GEOSYNCHRONOUS ORBIT ( ) YES (X) NO
APOGEE, KM 300 PERIGEE, KM 300 TOLERANCE + 200 - 100
INCLINATION, DEG TOLERANCE + -
NODAL ANGLE, DEG EPHEMERIS ACCURACY, M
ESCAPE DV REQUIRED, M/S

POINTING/ORIENTATION
VIEW DIRECTION ( ) INERTIAL ( ) SOLAR ( ) EARTH (X) ANY
TRUTH SITES (IF KNOWN)
POINTING ACCURACY, ARC-SEC FIELD OF VIEW (DEG)
POINTING STABILITY (JITTER), ARC-SEC/SEC
SPECIAL RESTRICTIONS (AVOIDANCE)

POWER
( ) AC (X) DC

	POWER, W	DURATION, HRS/DAY	
OPERATING	10000	24.00	
STANDBY	3000	0.00	
PEAK	10000	0.00	(X) CONTINUOUS
VOLTAGE, V	2000	FREQUENCY, HZ	0

DATA/COMMUN. .IONS

MONITORING REQUIREMENTS:

( ) NONE ( ) REALTIME (X) OFFLINE ( ) OTHER:

( ) ENCRIPTION/DECRIPTION REQUIRED

( ) UPLINK REQUIRED: COMMAND RATE (KBS): FREQUENCY (MHZ):

( ) ON-BOARD DATA PROCESSING REQUIRED

DESCRIPTION:

DATA TYPES: ( ) ANALOG ( ) DIGITAL HOURS/DAY

FILM (AMOUNT): VOICE (HOURS/DAY):

LIVE TV (HOURS/DAY): OTHER:

ON-BOARD STORAGE (MBIT):

DATA DUMP FREQUENCY (PER ORBIT) DOWNLINK COMMAND RATE:

RECORDING RATE (KBPS) DOWNLINK FREQUENCY (MHZ):

THERMAL

( ) ACTIVE (X) PASSIVE

TEMPERATURE, DEG C	OPERATIONAL MINIMUM	20	MAXIMUM	40
	NON-OPERATIONAL MINIMUM	4	MAXIMUM	40
HEAT REJECTION, W	OPERATIONAL MINIMUM	9000	MAXIMUM	11000
	NON-OPERATIONAL MINIMUM	0	MAXIMUM	

EQUIPMENT PHYSICAL CHARACTERISTICS

LOCATION (X) INTERNAL ( ) EXTERNAL ( ) REMOTE

EQUIPMENT ID/FUNCTION (X) PRESSURIZED ( ) UNPRESSURIZED

L, M: 12.00 W, M: 5.00 H, M: 5.00 STOWED

L, M: 35.00 W, M: 2.00 H, M: 5.00 DEPLOYED

LAUNCH MASS, KG: 30000 RETURN MASS, KG: 15000

CONSUMABLE TYPES

ACCELERATION SENSITIVITY, (G) MIN: E+00 MAX: E+00

CREW REQUIREMENTS

CREW SIZE 18

SKILLS (SEE TABLE B)

TASK ASSIGNMENTS

SKILL						
LEVEL						
HOURS/DAY						

EVA ( ) YES (X) NO REASON HOURS/EVA

SERVICING/MAINTENANCE

SERVICE: INTERVAL, DAYS CONSUMABLES, KG

RETURNABLES, KG MAN HOURS

CONFIGURATION CHANGES: INTERVAL, DAY MAN/HOURS REQUIRED

DELIVERABLES, KG RETURNABLES, KG

SPECIAL CONSIDERATIONS/SEE INSTRUCTIONS

```
                                        BOEING-SPECIFIC INPUT DATA
MISSION TYPE
   FREE FLYER                                   OPS CODE
   ( ) NOT SERVICED                                F
   ( ) REMOTE TMS                                  FT
   ( ) REMOTE MANNED                               FM
   ( ) SERVICED AT STATION (TMS RETRIEVED)         FST
   ( ) SERVICED AT STATION (SELF-PROPELLED)        FS

   PLATFORM BASED
   ( ) NOT SERVICED                                P
   ( ) REMOTE TMS                                  PT
   ( ) REMOTE MANNED                               PM
   ( ) SERVICED AT STATION (TMS RETRIEVED)         PST
   ( ) SERVICED AT STATION (SELF-PROPELLED)        PS

   OTHER
   ( ) SPACE STATION BASED                         SS
   ( ) SORTIE                                      SOR

CONSTRUCTION/SERVICING COMPLEXITY
   ( ) LOW
   ( ) MEDIUM
   ( ) HIGH

OPERATIONS TIMES
   OTV UP/DOWN                          DAYS
   OTV OR TMS ON ORBIT                  DAYS
   MISSION USE                          DAYS/YEAR
   IVA SERVICE                          MAN-DAYS/YEAR
   EVA SERVICE                          MAN-DAYS/YEAR
   EXPERIMENT OPS                       MAN-DAYS/YEAR
   SERVICE FREQUENCY                    TIMES/YEAR

DELTA VELOCITIES
   UP                         0.00
   DOWN                       0.00
   AERO RETURN                0.00

SUPPORT EQUIPMENT
            LENGTH:           0.00 METERS     WIDTH:      0.00 METERS          HEIGHT:      0.00 METERS      (STOWED)
            LENGTH:           0.00 METERS     WIDTH:      0.00 METERS          HEIGHT:      0.00 METERS      (DEPLOYED)

            MASS:                0 KG

MANIFEST RESTRICTIONS
   (X) NO RESTRICTIONS
   ( ) ONLY WITH COMPATIBLE PAYLOADS
   ( ) FLY-ALONE
   ( ) MUST HAVE DOCKING MODULE

LENGTH OF BEAM FAB                                      0.00
NUMBER OF APPENDAGES                                       0
NUMBER OF MODULES REQUIRED TO ASSEMBLE THE PAYLOAD         0
```

PAYLOAD ELEMENT NAME
CONTINUOUS FLOW ELECTROPHORESIS

CODE
BACX1035

TYPE
( ) SCIENCE AND APPLICATIONS (NON-COMM.)
(X) COMMERCIAL
( ) TECHNOLOGY DEVELOPMENT
( ) OPERATIONS
( ) OTHER
( ) NATIONAL SECURITY
TYPE NUMBER (SEE TABLE A) 8

CONTACT
NAME DR. HARVEY J. WILLENBERG
ADDRESS BOEING AEROSPACE COMPANY
PO BOX 3999, MS 84-86
SEATTLE, WA 98124

TELEPHONE (206) 773-2020

IMPORTANCE OF THE SPACE STATION TO THIS ELEMENT
1 = LOW VALUE, BUT COULD USE
10 = VITAL
SCALE = 6

STATUS
( ) OPERATIONAL ( ) APPROVED (X) PLANNED ( ) CANDIDATE ( ) OPPORTUNITY

DESIRED FIRST FLIGHT, YEAR: 1996 NUMBER OF FLIGHTS 10 DURATION OF FLIGHT, DAYS 21

OBJECTIVE
PROVIDE BIOCHEMICAL LABORATORY FOR DEVELOPING NEW ELECTROPHORESIS PRODUCTS, TESTING NEW EQUIPMENT AND PROCEDURES, AND PRODUCING RESEARCH QUANTITIES OF BIOLOGICAL MATERIALS.

DESCRIPTION
A BIOCHEMICAL LABORATORY IS NEEDED TO DEVELOP ELECTROPHORESIS TECHNOLOGY BEYOND PROTOTYPE COMMERCIAL PRODUCTION FREE-FLYER. THE LABORATORY WOULD INCLUDE 5-10 ELECTROPHORESIS UNITS FOR SEVERAL RESEARCH AND COMMERCIAL USERS. A CONTROL LABORATORY STORAGE RACKS, AND CREW ACCOMMODATIONS. THESE UNITS WOULD PROVIDE SEPARATIONS FOR A NUMBER OF DIFFERENT PHARMACEUTICALS AND DIFFERENT COMMERCIAL USERS. THE CONTROL LABORATORY WOULD BE FOR PROCESS CONTROL OF THE ELECTROPHORESIS UNITS, QUALITY CONTROL OF THE PRODUCT, AND REPAIR OF THE PROCESS UNITS. IT IS BELIEVED THAT THIS CAN BE A SHARED MULTI-USER FACILITY, OF ROUGHLY 50 M3, WITH FLUID, THERMAL, AND ELECTRICAL CONTROL SYSTEMS AND BIOLOGICAL LABORATORY EQUIPMENT. ABOUT 5 M3 O STORAGE RACKS WOULD BE REQUIRED.

ORBIT CHARACTERISTICS
GEOSYNCHRONOUS ORBIT ( ) YES (X) NO
APOGEE, KM 300 PERIGEE, KM 300 TOLERANCE + 200 - 100
INCLINATION, DEG TOLERANCE + -
NODAL ANGLE, DEG EPHEMERIS ACCURACY, M
ESCAPE DV REQUIRED, M/S

POINTING/ORIENTATION
VIEW DIRECTION ( ) INERTIAL ( ) SOLAR ( ) EARTH (X) ANY
TRUTH SITES (IF KNOWN)
POINTING ACCURACY, ARC-SEC FIELD OF VIEW (DEG)
POINTING STABILITY (JITTER), ARC-SEC/SEC
SPECIAL RESTRICTIONS (AVOIDANCE)

POWER
( ) AC (X) DC

	POWER, W	DURATION, HRS/DAY	
OPERATING	10000	24.00	
STANDBY	3000	0.00	(X) CONTINUOUS
PEAK	10000	0.00	
VOLTAGE, V	2000	FREQUENCY, HZ	0

DATA/COMMUNICATIONS

MONITORING REQUIREMENTS:

( ) NONE ( ) REALTIME (X) OFFLINE ( ) OTHER:

( ) ENCRIPTION/DECRIPTION REQUIRED

( ) UPLINK REQUIRED: COMMAND RATE (KBS): FREQUENCY (MHZ):

( ) ON-BOARD DATA PROCESSING REQUIRED

DESCRIPTION:

DATA TYPES: ( ) ANALOG ( ) DIGITAL HOURS/DAY

FILM (AMOUNT): VOICE (HOURS/DAY):

LIVE TV (HOURS/DAY): OTHER:

ON-BOARD STORAGE (MBIT):

DATA DUMP FREQUENCY (PER ORBIT) DOWNLINK COMMAND RATE:

RECORDING RATE (KBPS) DOWNLINK FREQUENCY (MHZ):

THERMAL

( ) ACTIVE (X) PASSIVE

TEMPERATURE, DEG C	OPERATIONAL MINIMUM	20	MAXIMUM	40
	NON-OPERATIONAL MINIMUM	4	MAXIMUM	40
HEAT REJECTION, W	OPERATIONAL MINIMUM	9000	MAXIMUM	11000
	NON-OPERATIONAL MINIMUM	0	MAXIMUM	

EQUIPMENT PHYSICAL CHARACTERISTICS

LOCATION (X) INTERNAL ( ) EXTERNAL ( ) REMOTE

EQUIPMENT ID/FUNCTION (X) PRESSURIZED ( ) UNPRESSURIZED

L, M: 12.00 W, M: 5.00 H, M: 5.00 STOWED

L, M: 35.00 W, M: 2.00 H, M: 5.00 DEPLOYED

LAUNCH MASS, KG: 30000 RETURN MASS, KG: 15000

CONSUMABLE TYPES

ACCELERATION SENSITIVITY, (G) MIN: E+00 MAX: E+00

CREW REQUIREMENTS

CREW SIZE 18 TASK ASSIGNMENTS

SKILLS (SEE TABLE 6)

SKILL						
LEVEL						
HOURS/DAY						

EVA ( ) YES (X) NO REASON HOURS/EVA

SERVICING/MAINTENANCE

SERVICE: INTERVAL, DAYS CONSUMABLES, KG

RETURNABLES, KG MAN HOURS

CONFIGURATION CHANGES: INTERVAL, DAY MAN/HOURS REQUIRED

DELIVERABLES, KG RETURNABLES, KG

SPECIAL CONSIDERATIONS/SEE INSTRUCTIONS

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                                          BOEING-SPECIFIC INPUT DATA
-------------------------------------------------------------------------------------------------------------------
MISSION TYPE                                          OPS CODE
   FREE FLYER
   ( ) NOT SERVICED                                      F
   ( ) REMOTE TMS                                        FT
   ( ) REMOTE MANNED                                     FM
   ( ) SERVICED AT STATION (TMS RETRIEVED)               FST
   ( ) SERVICED AT STATION (SELF-PROPELLED)              FS

   PLATFORM BASED
   ( ) NOT SERVICED                                      P
   ( ) REMOTE TMS                                        PT
   ( ) REMOTE MANNED                                     PM
   ( ) SERVICED AT STATION (TMS RETRIEVED)               PST
   ( ) SERVICED AT STATION (SELF-PROPELLED)              PS

   OTHER
   ( ) SPACE STATION BASED                               SS
   ( ) SORTIE                                            SOR

CONSTRUCTION/SERVICING COMPLEXITY
   ( ) LOW
   ( ) MEDIUM
   ( ) HIGH

OPERATIONS TIMES
   OTV UP/DOWN                          DAYS
   OTV OR TMS ON ORBIT                  DAYS
   MISSION USE                          DAYS/YEAR
   IVA SERVICE                          MAN-DAYS/YEAR
   EVA SERVICE                          MAN-DAYS/YEAR
   EXPERIMENT OPS                       MAN-DAYS/YEAR
   SERVICE FREQUENCY                    TIMES/YEAR

DELTA VELOCITIES
   UP                      0.00
   DOWN                    0.00
   AERO RETURN             0.00

SUPPORT EQUIPMENT
             LENGTH:       0.00 METERS       WIDTH:      0.00 METERS        HEIGHT:      0.00 METERS       (STOWED)
             LENGTH:       0.00 METERS       WIDTH:      0.00 METERS        HEIGHT:      0.00 METERS       (DEPLOYED)

             MASS:            0 KG

MANIFEST RESTRICTIONS
   (X) NO RESTRICTIONS
   ( ) ONLY WITH COMPATIBLE PAYLOADS
   ( ) FLY-ALONE
   ( ) MUST HAVE DOCKING MODULE

LENGTH OF BEAM FAB                                         0.00
NUMBER OF APPENDAGES                                          0
NUMBER OF MODULES REQUIRED TO ASSEMBLE THE PAYLOAD            0
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PAYLOAD ELEMENT NAME CONTINUOUS FLOW ELECTROPHORESIS
CODE BACX1036

TYPE
( ) SCIENCE AND APPLICATIONS (NON-COMM.)
(X) COMMERCIAL
( ) TECHNOLOGY DEVELOPMENT
( ) OPERATIONS
( ) OTHER
( ) NATIONAL SECURITY
TYPE NUMBER (SEE TABLE A) 8

CONTACT
NAME DR. HARVEY J. WILLENBERG
ADDRESS BOEING AEROSPACE COMPANY
PO BOX 3999, MS 84-86
SEATTLE, WA 98124

TELEPHONE (206) 773-2020

IMPORTANCE OF THE SPACE STATION TO THIS ELEMENT
1 = LOW VALUE, BUT COULD USE
10 = VITAL
SCALE = 6

STATUS
( ) OPERATIONAL ( ) APPROVED (X) PLANNED ( ) CANDIDATE ( ) OPPORTUNITY

DESIRED FIRST FLIGHT, YEAR: 1997 NUMBER OF FLIGHTS 12 DURATION OF FLIGHT, DAYS 21

OBJECTIVE
PROVIDE BIOCHEMICAL LABORATORY FOR DEVELOPING NEW ELECTROPHORESIS PRODUCTS, TESTING NEW EQUIPMENT AND PROCEDURES, AND PRODUCING RESEARCH QUANTITIES OF BIOLOGICAL MATERIALS.

DESCRIPTION
A BIOCHEMICAL LABORATORY IS NEEDED TO DEVELOP ELECTROPHORESIS TECHNOLOGY BEYOND PROTOTYPE COMMERCIAL PRODUCTION FREE-FLYER. THE LABORATORY WOULD INCLUDE 5-10 ELECTROPHORESIS UNITS FOR SEVERAL RESEARCH AND COMMERCIAL USERS. A CONTROL LABORATORY STORAGE RACKS, AND CREW ACCOMMODATIONS. THESE UNITS WOULD PROVIDE SEPARATIONS FOR A NUMBER OF DIFFERENT PHARMACEUTICALS AND DIFFERENT COMMERCIAL USERS. THE CONTROL LABORATORY WOULD BE FOR PROCESS CONTROL OF THE ELECTROPHORESIS UNITS, QUALITY CONTROL OF THE PRODUCT, AND REPAIR OF THE PROCESS UNITS. IT IS BELIEVED THAT THIS CAN BE A SHARED MULTI-USER FACILITY, OF ROUGHLY 50 M3, WITH FLUID, THERMAL, AND ELECTRICAL CONTROL SYSTEMS AND BIOLOGICAL LABORATORY EQUIPMENT. ABOUT 5 M3 O STORAGE RACKS WOULD BE REQUIRED.

ORBIT CHARACTERISTICS
GEOSYNCHRONOUS ORBIT ( ) YES (X) NO
APOGEE, KM 300 PERIGEE, KM 300 TOLERANCE + 200 - 100
INCLINATION, DEG TOLERANCE + -
NODAL ANGLE, DEG EPHEMERIS ACCURACY, M
ESCAPE DV REQUIRED, M/S .

POINTING/ORIENTATION
VIEW DIRECTION ( ) INERTIAL ( ) SOLAR ( ) EARTH (X) ANY
TRUTH SITES (IF KNOWN)
POINTING ACCURACY, ARC-SEC FIELD OF VIEW (DEG)
POINTING STABILITY (JITTER), ARC-SEC/SEC
SPECIAL RESTRICTIONS (AVOIDANCE)

POWER
( ) AC (X) DC

	POWER, W	DURATION, HRS/DAY
OPERATING	10000	24.00
STANDBY	3000	0.00
PEAK	10000	0.00

(X) CONTINUOUS
VOLTAGE, V 2000 FREQUENCY, HZ 0

DATA/COMMUN IONS

MONITORING REQUIREMENTS:

( ) NONE ( ) REALTIME (X) OFFLINE ( ) OTHER:

( ) ENCRIPTION/DECRIPTION REQUIRED

( ) UPLINK REQUIRED: COMMAND RATE (KBS): FREQUENCY (MHZ):

( ) ON-BOARD DATA PROCESSING REQUIRED

DESCRIPTION:

DATA TYPES: ( ) ANALOG ( ) DIGITAL

HOURS/DAY

FILM (AMOUNT):

VOICE (HOURS/DAY):

LIVE TV (HOURS/DAY):

OTHER:

ON-BOARD STORAGE (MBIT):

DATA DUMP FREQUENCY (PER ORBIT)

DOWNLINK COMMAND RATE:

RECORDING RATE (KBPS)

DOWNLINK FREQUENCY (MHZ):

THERMAL

( ) ACTIVE (X) PASSIVE

TEMPERATURE, DEG C	OPERATIONAL MINIMUM	20	MAXIMUM	40
	NON-OPERATIONAL MINIMUM	4	MAXIMUM	40
HEAT REJECTION, W	OPERATIONAL MINIMUM	9000	MAXIMUM	11000
	NON-OPERATIONAL MINIMUM	0	MAXIMUM	

EQUIPMENT PHYSICAL CHARACTERISTICS

LOCATION (X) INTERNAL ( ) EXTERNAL ( ) REMOTE

EQUIPMENT ID/FUNCTION (X) PRESSURIZED ( ) UNPRESSURIZED

L, M: 12.00 W, M: 5.00 H, M: 5.00 STOWED

L, M: 35.00 W, M: 2.00 H, M: 5.00 DEPLOYED

LAUNCH MASS, KG: 30000 RETURN MASS, KG: 15000

CONSUMABLE TYPES

ACCELERATION SENSITIVITY, (G) MIN: E+00 MAX: E+00

CREW REQUIREMENTS

CREW SIZE 18

TASK ASSIGNMENTS

SKILLS (SEE TABLE B)

SKILL						
LEVEL						
HOURS/DAY						

EVA ( ) YES (X) NO REASON HOURS/EVA

SERVICING/MAINTENANCE

SERVICE: INTERVAL, DAYS CONSUMABLES, KG

RETURNABLES, KG MAN HOURS

CONFIGURATION CHANGES: INTERVAL, DAY MAN/HOURS REQUIRED

DELIVERABLES, KG RETURNABLES, KG

SPECIAL CONSIDERATIONS/SEE INSTRUCTIONS

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                                                     BOEING-SPECIFIC INPUT DATA
-----------------------------------------------------------------------------------------------------------------------------------
MISSION TYPE                                    OPS CODE
   FREE FLYER
   ( ) NOT SERVICED                                F
   ( ) REMOTE TMS                                  FT
   ( ) REMOTE MANNED                               FM
   ( ) SERVICED AT STATION (TMS RETRIEVED)         FST
   ( ) SERVICED AT STATION (SELF-PROPELLED)        FS

   PLATFORM BASED
   ( ) NOT SERVICED                                P
   ( ) REMOTE TMS                                  PT
   ( ) REMOTE MANNED                               PM
   ( ) SERVICED AT STATION (TMS RETRIEVED)         PST
   ( ) SERVICED AT STATION (SELF-PROPELLED)        PS

   OTHER
   ( ) SPACE STATION BASED                         SS
   ( ) SORTIE                                      SOR

CONSTRUCTION/SERVICING COMPLEXITY
   ( ) LOW
   ( ) MEDIUM
   ( ) HIGH

OPERATIONS TIMES
   OTV UP/DOWN                        DAYS
   OTV OR TMS ON ORBIT                DAYS
   MISSION USE                        DAYS/YEAR
   IVA SERVICE                        MAN-DAYS/YEAR
   EVA SERVICE                        MAN-DAYS/YEAR
   EXPERIMENT OPS                     MAN-DAYS/YEAR
   SERVICE FREQUENCY                  TIMES/YEAR

DELTA VELOCITIES
   UP                        0.00
   DOWN                      0.00
   AERO RETURN               0.00

SUPPORT EQUIPMENT
             LENGTH:         0.00 METERS      WIDTH:     0.00 METERS       HEIGHT:     0.00 METERS      (STOWED)
             LENGTH:         0.00 METERS      WIDTH:     0.00 METERS       HEIGHT:     0.00 METERS      (DEPLOYED)

             MASS:              0 KG

MANIFEST RESTRICTIONS
   (X) NO RESTRICTIONS
   ( ) ONLY WITH COMPATIBLE PAYLOADS
   ( ) FLY-ALONE
   ( ) MUST HAVE DOCKING MODULE

LENGTH OF BEAM FAB                                        0.00
NUMBER OF APPENDAGES                                         0
NUMBER OF MODULES REQUIRED TO ASSEMBLE THE PAYLOAD           0
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OF POOR QUALITY

PAYLOAD ELEMENT NAME
CONTINUOUS FLOW ELECTROPHORESIS

CODE
BACX1037

TYPE
( ) SCIENCE AND APPLICATIONS (NON-COMM.)
(X) COMMERCIAL
( ) TECHNOLOGY DEVELOPMENT
( ) OPERATIONS
( ) OTHER
( ) NATIONAL SECURITY
TYPE NUMBER (SEE TABLE A) 8

CONTACT
NAME DR. HARVEY J. WILLENBERG
ADDRESS BOEING AEROSPACE COMPANY
PO BOX 3999, MS 84-86
SEATTLE, WA 98124

TELEPHONE (206) 773-2020

IMPORTANCE OF THE SPACE STATION TO THIS ELEMENT
1 = LOW VALUE, BUT COULD USE
10 = VITAL
SCALE = 6

STATUS
( ) OPERATIONAL ( ) APPROVED ( ) PLANNED (X) PLANNED ( ) CANDIDATE ( ) OPPORTUNITY

DESIRED FIRST FLIGHT, YEAR: 1998 NUMBER OF FLIGHTS 14 DURATION OF FLIGHT, DAYS 21

OBJECTIVE
PROVIDE BIOCHEMICAL LABORATORY FOR DEVELOPING NEW ELECTROPHORESIS PRODUCTS, TESTING NEW EQUIPMENT AND PROCEDURES, AND PRODUCING RESEARCH QUANTITIES OF BIOLOGICAL MATERIALS.

DESCRIPTION
A BIOCHEMICAL LABORATORY IS NEEDED TO DEVELOP ELECTROPHORESIS TECHNOLOGY BEYOND PROTOTYPE COMMERCIAL PRODUCTION FREE-FLYER. THE LABORATORY WOULD INCLUDE 5-10 ELECTROPHORESIS UNITS FOR SEVERAL RESEARCH AND COMMERCIAL USERS. A CONTROL LABORATORY STORAGE RACKS, AND CREW ACCOMMODATIONS. THESE UNITS WOULD PROVIDE SEPARATIONS FOR A NUMBER OF DIFFERENT PHARMACEUTICALS AND DIFFERENT COMMERCIAL USERS. THE CONTROL LABORATORY WOULD BE FOR PROCESS CONTROL OF THE ELECTROPHORESIS UNITS, QUALITY CONTROL OF THE PRODUCT, AND REPAIR OF THE PROCESS UNITS. IT IS BELIEVED THAT THIS CAN BE A SHARED MULTI-USER FACILITY, OF ROUGHLY 50 M3, WITH FLUID, THERMAL, AND ELECTRICAL CONTROL SYSTEMS AND BIOLOGICAL LABORATORY EQUIPMENT. ABOUT 5 M3 O STORAGE RACKS WOULD BE REQUIRED.

ORBIT CHARACTERISTICS
GEOSYNCHRONOUS ORBIT ( ) YES (X) NO
APOGEE, KM 300 PERIGEE, KM 300 TOLERANCE + 200 - 100
INCLINATION, DEG TOLERANCE + -
NODAL ANGLE, DEG EPHEMERIS ACCURACY, M
ESCAPE DV REQUIRED, M/S

POINTING/ORIENTATION
VIEW DIRECTION ( ) INERTIAL ( ) SOLAR ( ) EARTH (X) ANY
TRUTH SITES (IF KNOWN)
POINTING ACCURACY, ARC-SEC FIELD OF VIEW (DEG)
POINTING STABILITY (JITTER), ARC-SEC/SEC
SPECIAL RESTRICTIONS (AVOIDANCE)

POWER
( ) AC (X) DC

	POWER, W	DURATION, HRS/DAY
OPERATING	10000	24.00
STANDBY	3000	0.00
PEAK	10000	0.00
VOLTAGE, V	2000	

(X) CONTINUOUS
FREQUENCY, HZ 0

```
DATA/COMMUNICATIONS
   MONITORING REQUIREMENTS:
   ( ) NONE        ( ) REALTIME    (X) OFFLINE      ( ) OTHER:
   ( ) ENCRIPTION/DECRIPTION REQUIRED
   ( ) UPLINK REQUIRED:  COMMAND RATE (KBS):                  FREQUENCY (MHZ):
   ( ) ON-BOARD DATA PROCESSING REQUIRED
       DESCRIPTION:
       DATA TYPES:   ( ) ANALOG      ( ) DIGITAL              HOURS/DAY
       FILM (AMOUNT):                                         VOICE (HOURS/DAY):
       LIVE TV (HOURS/DAY):                                   OTHER:
       ON-BOARD STORAGE (MBIT):
       DATA DUMP FREQUENCY (PER ORBIT)                        DOWNLINK COMMAND RATE:
       RECORDING RATE (KBPS)                                  DOWNLINK FREQUENCY (MHZ):
---------------------------------------------------------------------------------------------------------------
THERMAL
   ( ) ACTIVE     (X) PASSIVE
       TEMPERATURE, DEG C   OPERATIONAL MINIMUM        20          MAXIMUM     40
                            NON-OPERATIONAL MINIMUM     4          MAXIMUM     40
       HEAT REJECTION, W    OPERATIONAL MINIMUM      9000          MAXIMUM  11000
                            NON-OPERATIONAL MINIMUM     0          MAXIMUM
---------------------------------------------------------------------------------------------------------------
EQUIPMENT PHYSICAL CHARACTERISTICS
   LOCATION          (X) INTERNAL        ( ) EXTERNAL       ( ) REMOTE
   EQUIPMENT ID/FUNCTION                 (X) PRESSURIZED    ( ) UNPRESSURIZED
                  L, M:    12.00     W, M:     5.00     H, M:     5.00    STOWED
                  L, M:    35.00     W, M:     2.00     H, M:     5.00    DEPLOYED
                  LAUNCH MASS, KG:   30000              RETURN MASS, KG:  15000
                  CONSUMABLE TYPES
                  ACCELERATION SENSITIVITY, (G)     MIN:      E+00     MAX:      E+00
---------------------------------------------------------------------------------------------------------------
CREW REQUIREMENTS
   CREW SIZE          10          TASK ASSIGNMENTS
                                  ---------------------------------------------------------
   SKILLS (SEE TABLE B)           | SKILL     |     |     |     |     |     |     |
                                  ---------------------------------------------------------
                                  | LEVEL     |     |     |     |     |     |     |
                                  ---------------------------------------------------------
                                  | HOURS/DAY |     |     |     |     |     |     |
                                  ---------------------------------------------------------
   EVA  ( ) YES    (X) NO         REASON                     HOURS/EVA
---------------------------------------------------------------------------------------------------------------
SERVICING/MAINTENANCE
   SERVICE:                          INTERVAL,  DAYS                 CONSUMABLES, KG
                                     RETURNABLES, KG                 MAN HOURS
   CONFIGURATION CHANGES:            INTERVAL, DAY                   MAN/HOURS REQUIRED
                                     DELIVERABLES, KG                RETURNABLES, KG
---------------------------------------------------------------------------------------------------------------
SPECIAL CONSIDERATIONS/SEE INSTRUCTIONS



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ORIGINAL PAGE IS
OF POOR QUALITY

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                                        BOEING-SPECIFIC INPUT DATA
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MISSION TYPE                                      OPS CODE
  FREE FLYER
   ( ) NOT SERVICED                                  F
   ( ) REMOTE TMS                                    FT
   ( ) REMOTE MANNED                                 FM
   ( ) SERVICED AT STATION (TMS RETRIEVED)           FST
   ( ) SERVICED AT STATION (SELF-PROPELLED)          FS

  PLATFORM BASED
   ( ) NOT SERVICED                                  P
   ( ) REMOTE TMS                                    PT
   ( ) REMOTE MANNED                                 PM
   ( ) SERVICED AT STATION (TMS RETRIEVED)           PST
   ( ) SERVICED AT STATION (SELF-PROPELLED)          PS

  OTHER
   ( ) SPACE STATION BASED                           SS
   ( ) SORTIE                                        SOR

CONSTRUCTION/SERVICING COMPLEXITY
   ( ) LOW
   ( ) MEDIUM
   ( ) HIGH

OPERATIONS TIMES
   OTV UP/DOWN                           DAYS
   OTV OR TMS ON ORBIT                   DAYS
   MISSION USE                           DAYS/YEAR
   IVA SERVICE                           MAN-DAYS/YEAR
   EVA SERVICE                           MAN-DAYS/YEAR
   EXPERIMENT OPS                        MAN-DAYS/YEAR
   SERVICE FREQUENCY                     TIMES/YEAR

DELTA VELOCITIES
   UP                        0.00
   DOWN                      0.00
   AERO RETURN               0.00

SUPPORT EQUIPMENT
            LENGTH:          0.00 METERS     WIDTH:     0.00 METERS     HEIGHT:     0.00 METERS     (STOWED)
            LENGTH:          0.00 METERS     WIDTH:     0.00 METERS     HEIGHT:     0.00 METERS     (DEPLOYED)

            MASS:              0 KG

MANIFEST RESTRICTIONS
   (X) NO RESTRICTIONS
   ( ) ONLY WITH COMPATIBLE PAYLOADS
   ( ) FLY-ALONE
   ( ) MUST HAVE DOCKING MODULE

LENGTH OF BEAM FAB                                          0.00
NUMBER OF APPENDAGES                                           0
NUMBER OF MODULES REQUIRED TO ASSEMBLE THE PAYLOAD             0
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PAYLOAD ELEMENT NAME
CONTINUOUS FLOW ELECTROPHORESIS

CODE
BACX1038

TYPE
( ) SCIENCE AND APPLICATIONS (NON-COMM.)
(X) COMMERCIAL
( ) TECHNOLOGY DEVELOPMENT
( ) OPERATIONS
( ) OTHER
( ) NATIONAL SECURITY
TYPE NUMBER (SEE TABLE A) 8

CONTACT
NAME DR. HARVEY J. WILLENBERG
ADDRESS BOEING AEROSPACE COMPANY
PO BOX 3999, MS 84-86
SEATTLE, WA 98124

TELEPHONE (206) 773-2020

IMPORTANCE OF THE SPACE STATION TO THIS ELEMENT
1 = LOW VALUE, BUT COULD USE
10 = VITAL
SCALE = 6

STATUS
( ) OPERATIONAL ( ) APPROVED (X) PLANNED ( ) CANDIDATE ( ) OPPORTUNITY

DESIRED FIRST FLIGHT, YEAR: 1999 NUMBER OF FLIGHTS 15 DURATION OF FLIGHT, DAYS 21

OBJECTIVE
PROVIDE BIOCHEMICAL LABORATORY FOR DEVELOPING NEW ELECTROPHORESIS PRODUCTS, TESTING NEW EQUIPMENT AND PROCEDURES, AND PRODUCING RESEARCH QUANTITIES OF BIOLOGICAL MATERIALS.

DESCRIPTION
A BIOCHEMICAL LABORATORY IS NEEDED TO DEVELOP ELECTROPHORESIS TECHNOLOGY BEYOND PROTOTYPE COMMERCIAL PRODUCTION FREE-FLYER. THE LABORATORY WOULD INCLUDE 5-10 ELECTROPHORESIS UNITS FOR SEVERAL RESEARCH AND COMMERCIAL USERS. A CONTROL LABORATORY STORAGE RACKS, AND CREW ACCOMMODATIONS. THESE UNITS WOULD PROVIDE SEPARATIONS FOR A NUMBER OF DIFFERENT PHARMACEUTICALS AND DIFFERENT COMMERCIAL USERS. THE CONTROL LABORATORY WOULD BE FOR PROCESS CONTROL OF THE ELECTROPHORESIS UNITS, QUALITY CONTROL OF THE PRODUCT, AND REPAIR OF THE PROCESS UNITS. IT IS BELIEVED THAT THIS CAN BE A SHARED MULTI-USER FACILITY, OF ROUGHLY 50 M3, WITH FLUID, THERMAL, AND ELECTRICAL CONTROL SYSTEMS AND BIOLOGICAL LABORATORY EQUIPMENT. ABOUT 5 M3 0 STORAGE RACKS WOULD BE REQUIRED.

ORBIT CHARACTERISTICS
GEOSYNCHRONOUS ORBIT ( ) YES (X) NO
APOGEE, KM 300 PERIGEE, KM 300 TOLERANCE + 200 - 100
INCLINATION, DEG TOLERANCE + -
NODAL ANGLE, DEG EPHEMERIS ACCURACY, M
ESCAPE DV REQUIRED, M/S

POINTING/ORIENTATION
VIEW DIRECTION ( ) INERTIAL ( ) SOLAR ( ) EARTH (X) ANY
TRUTH SITES (IF KNOWN)
POINTING ACCURACY, ARC-SEC FIELD OF VIEW (DEG)
POINTING STABILITY (JITTER), ARC-SEC/SEC
SPECIAL RESTRICTIONS (AVOIDANCE)

POWER
( ) AC (X) DC

	POWER, W	DURATION, HRS/DAY	
OPERATING	10000	24.00	
STANDBY	3000	0.00	(X) CONTINUOUS
PEAK	10000	0.00	
VOLTAGE, V	2000	FREQUENCY, HZ	0

DATA/COMMUNICATIONS

MONITORING REQUIREMENTS:
( ) NONE ( ) REALTIME (X) OFFLINE ( ) OTHER:
( ) ENCRIPTION/DECRIPTION REQUIRED
( ) UPLINK REQUIRED: COMMAND RATE (KBS): FREQUENCY (MHZ):
( ) ON-BOARD DATA PROCESSING REQUIRED
DESCRIPTION:
DATA TYPES: ( ) ANALOG ( ) DIGITAL HOURS/DAY
FILM (AMOUNT): VOICE (HOURS/DAY):
LIVE TV (HOURS/DAY): OTHER:
ON-BOARD STORAGE (MBIT):
DATA DUMP FREQUENCY (PER ORBIT) DOWNLINK COMMAND RATE:
RECORDING RATE (KBPS) DOWNLINK FREQUENCY (MHZ):

THERMAL

( ) ACTIVE (X) PASSIVE

TEMPERATURE, DEG C	OPERATIONAL MINIMUM	20	MAXIMUM	40
	NON-OPERATIONAL MINIMUM	4	MAXIMUM	40
HEAT REJECTION, W	OPERATIONAL MINIMUM	9000	MAXIMUM	11000
	NON-OPERATIONAL MINIMUM	0	MAXIMUM	

EQUIPMENT PHYSICAL CHARACTERISTICS

LOCATION (X) INTERNAL ( ) EXTERNAL ( ) REMOTE
EQUIPMENT ID/FUNCTION (X) PRESSURIZED ( ) UNPRESSURIZED
L, M: 12.00 W, M: 5.00 H, M: 5.00 STOWED
L, M: 35.00 W, M: 2.00 H, M: 5.00 DEPLOYED
LAUNCH MASS, KG: 30000 RETURN MASS, KG: 15000
CONSUMABLE TYPES
ACCELERATION SENSITIVITY, (G) MIN: E+00 MAX: E+00

CREW REQUIREMENTS

CREW SIZE 18

SKILLS (SEE TABLE B)

TASK ASSIGNMENTS

SKILL						
LEVEL						
HOURS/DAY						

EVA ( ) YES (X) NO REASON HOURS/EVA

SERVICING/MAINTENANCE

SERVICE: INTERVAL, DAYS CONSUMABLES, KG
RETURNABLES, KG MAN HOURS
CONFIGURATION CHANGES: INTERVAL, DAY MAN/HOURS REQUIRED
DELIVERABLES, KG RETURNABLES, KG

SPECIAL CONSIDERATIONS/SEE INSTRUCTIONS

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                                                    BOEING-SPECIFIC INPUT DATA
----------------------------------------------------------------------------------------------------------------------------
MISSION TYPE                                     OPS CODE
   FREE FLYER
   ( ) NOT SERVICED                                 F
   ( ) REMOTE TMS                                   FT
   ( ) REMOTE MANNED                                FM
   ( ) SERVICED AT STATION (TMS RETRIEVED)          FST
   ( ) SERVICED AT STATION (SELF-PROPELLED)         FS

   PLATFORM BASED
   ( ) NOT SERVICED                                 P
   ( ) REMOTE TMS                                   PT
   ( ) REMOTE MANNED                                PM
   ( ) SERVICED AT STATION (TMS RETRIEVED)          PST
   ( ) SERVICED AT STATION (SELF-PROPELLED)         PS

   OTHER
   ( ) SPACE STATION BASED                          SS
   ( ) SORTIE                                       SOR

CONSTRUCTION/SERVICING COMPLEXITY
   ( ) LOW
   ( ) MEDIUM
   ( ) HIGH

OPERATIONS TIMES
   OTV UP/DOWN                          DAYS
   OTV OR TMS ON ORBIT                  DAYS
   MISSION USE                          DAYS/YEAR
   IVA SERVICE                          MAN-DAYS/YEAR
   EVA SERVICE                          MAN-DAYS/YEAR
   EXPERIMENT OPS                       MAN-DAYS/YEAR
   SERVICE FREQUENCY                    TIMES/YEAR

DELTA VELOCITIES
   UP                          0.00
   DOWN                        0.00
   AERO RETURN                 0.00

SUPPORT EQUIPMENT
            LENGTH:            0.00 METERS       WIDTH:      0.00 METERS        HEIGHT:      0.00 METERS      (STOWED)
            LENGTH:            0.00 METERS       WIDTH:      0.00 METERS        HEIGHT:      0.00 METERS      (DEPLOYED)

            MASS:                 0 KG

MANIFEST RESTRICTIONS
   (X) NO RESTRICTIONS
   ( ) ONLY WITH COMPATIBLE PAYLOADS
   ( ) FLY-ALONE
   ( ) MUST HAVE DOCKING MODULE

LENGTH OF BEAM FAB                                          0.00
NUMBER OF APPENDAGES                                           0
NUMBER OF MODULES REQUIRED TO ASSEMBLE THE PAYLOAD             0
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PAYLOAD ELEMENT NAME
CONTINUOUS FLOW ELECTROPHORESIS

CODE
BACX1039

TYPE
( ) SCIENCE AND APPLICATIONS (NON-COMM.)
(X) COMMERCIAL
( ) TECHNOLOGY DEVELOPMENT
( ) OPERATIONS
( ) OTHER
( ) NATIONAL SECURITY
TYPE NUMBER (SEE TABLE A) 8

CONTACT
NAME DR. HARVEY J. WILLENBERG
ADDRESS BOEING AEROSPACE COMPANY
PO BOX 3999, MS 84-86
SEATTLE, WA 98124

TELEPHONE (206) 773-2020

IMPORTANCE OF THE SPACE STATION TO THIS ELEMENT
1 = LOW VALUE, BUT COULD USE
10 = VITAL
SCALE = 6

STATUS
( ) OPERATIONAL ( ) APPROVED (X) PLANNED ( ) CANDIDATE ( ) OPPORTUNITY

DESIRED FIRST FLIGHT, YEAR: 2000 NUMBER OF FLIGHTS 17 DURATION OF FLIGHT, DAYS 21

OBJECTIVE
PROVIDE BIOCHEMICAL LABORATORY FOR DEVELOPING NEW ELECTROPHORESIS PRODUCTS, TESTING NEW EQUIPMENT AND PROCEDURES, AND PRODUCING RESEARCH QUANTITIES OF BIOLOGICAL MATERIALS.

DESCRIPTION
A BIOCHEMICAL LABORATORY IS NEEDED TO DEVELOP ELECTROPHORESIS TECHNOLOGY BEYOND PROTOTYPE COMMERCIAL PRODUCTION FREE-FLYER. THE LABORATORY WOULD INCLUDE 5-10 ELECTROPHORESIS UNITS FOR SEVERAL RESEARCH AND COMMERCIAL USERS. A CONTROL LABORATORY STORAGE RACKS, AND CREW ACCOMMODATIONS. THESE UNITS WOULD PROVIDE SEPARATIONS FOR A NUMBER OF DIFFERENT PHARMACEUTICALS AND DIFFERENT COMMERCIAL USERS. THE CONTROL LABORATORY WOULD BE FOR PROCESS CONTROL OF THE ELECTROPHORESIS UNITS, QUALITY CONTROL OF THE PRODUCT, AND REPAIR OF THE PROCESS UNITS. IT IS BELIEVED THAT THIS CAN BE A SHARED MULTI-USER FACILITY, OF ROUGHLY 50 M3, WITH FLUID, THERMAL, AND ELECTRICAL CONTROL SYSTEMS AND BIOLOGICAL LABORATORY EQUIPMENT. ABOUT 5 M3 O STORAGE RACKS WOULD BE REQUIRED.

ORBIT CHARACTERISTICS
GEOSYNCHRONOUS ORBIT ( ) YES (X) NO
APOGEE, KM 300 PERIGEE, KM 300 TOLERANCE + 200 - 100
INCLINATION, DEG TOLERANCE + -
NODAL ANGLE, DEG EPHEMERIS ACCURACY, M
ESCAPE DV REQUIRED, M/S .

POINTING/ORIENTATION
VIEW DIRECTION ( ) INERTIAL ( ) SOLAR ( ) EARTH (X) ANY
TRUTH SITES (IF KNOWN)
POINTING ACCURACY, ARC-SEC FIELD OF VIEW (DEG)
POINTING STABILITY (JITTER), ARC-SEC/SEC
SPECIAL RESTRICTIONS (AVOIDANCE)

POWER
( ) AC (X) DC

	POWER, W	DURATION, HRS/DAY	
OPERATING	10000	24.00	
STANDBY	3000	0.00	(X) CONTINUOUS
PEAK	10000	0.00	
VOLTAGE, V	2000	FREQUENCY, HZ	0

DATA/COMMUNICATIONS
MONITORING REQUIREMENTS:
( ) NONE ( ) REALTIME (X) OFFLINE ( ) OTHER:
( ) ENCRIPTION/DECRIPTION REQUIRED
( ) UPLINK REQUIRED: COMMAND RATE (KBS): FREQUENCY (MHZ):
( ) ON-BOARD DATA PROCESSING REQUIRED
DESCRIPTION:
DATA TYPES: ( ) ANALOG ( ) DIGITAL HOURS/DAY
FILM (AMOUNT):
VOICE (HOURS/DAY):
LIVE TV (HOURS/DAY):
OTHER:
ON-BOARD STORAGE (MBIT):
DATA DUMP FREQUENCY (PER ORBIT)
DOWNLINK COMMAND RATE:
RECORDING RATE (KBPS)
DOWNLINK FREQUENCY (MHZ):

THERMAL
( ) ACTIVE (X) PASSIVE

TEMPERATURE, DEG C	OPERATIONAL MINIMUM	20	MAXIMUM	40
	NON-OPERATIONAL MINIMUM	4	MAXIMUM	40
HEAT REJECTION, W	OPERATIONAL MINIMUM	9000	MAXIMUM	11000
	NON-OPERATIONAL MINIMUM	0	MAXIMUM	

EQUIPMENT PHYSICAL CHARACTERISTICS
LOCATION (X) INTERNAL ( ) EXTERNAL ( ) REMOTE
EQUIPMENT ID/FUNCTION (X) PRESSURIZED ( ) UNPRESSURIZED
L, M: 12.00 W, M: 5.00 H, M: 5.00 STOWED
L, M: 35.00 W, M: 2.00 H, M: 5.00 DEPLOYED
LAUNCH MASS, KG: 30000 RETURN MASS, KG: 15000
CONSUMABLE TYPES
ACCELERATION SENSITIVITY, (G) MIN: E+00 MAX: E+00

CREW REQUIREMENTS
CREW SIZE 18

SKILLS (SEE TABLE B)

TASK ASSIGNMENTS

SKILL						
LEVEL						
HOURS/DAY						

EVA ( ) YES (X) NO REASON HOURS/EVA

SERVICING/MAINTENANCE
SERVICE: INTERVAL, DAYS CONSUMABLES, KG
RETURNABLES, KG MAN HOURS
CONFIGURATION CHANGES: INTERVAL, DAY MAN/HOURS REQUIRED
DELIVERABLES, KG RETURNABLES, KG

SPECIAL CONSIDERATIONS/SEE INSTRUCTIONS

ORIGINAL PAGE IS
OF POOR QUALITY

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                                                     BOEING-SPECIFIC INPUT DATA
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MISSION TYPE                                   OPS CODE
   FREE FLYER
   ( ) NOT SERVICED                               F
   ( ) REMOTE TMS                                 FT
   ( ) REMOTE MANNED                              FM
   ( ) SERVICED AT STATION (TMS RETRIEVED)        FST
   ( ) SERVICED AT STATION (SELF-PROPELLED)       FS

   PLATFORM BASED
   ( ) NOT SERVICED                               P
   ( ) REMOTE TMS                                 PT
   ( ) REMOTE MANNED                              PM
   ( ) SERVICED AT STATION (TMS RETRIEVED)        PST
   ( ) SERVICED AT STATION (SELF-PROPELLED)       PS

   OTHER
   ( ) SPACE STATION BASED                        SS
   ( ) SORTIE                                     SOR

CONSTRUCTION/SERVICING COMPLEXITY
   ( ) LOW
   ( ) MEDIUM
   ( ) HIGH

OPERATIONS TIMES
   OTV UP/DOWN                           DAYS
   OTV OR TMS ON ORBIT                   DAYS
   MISSION USE                           DAYS/YEAR
   IVA SERVICE                           MAN-DAYS/YEAR
   EVA SERVICE                           MAN-DAYS/YEAR
   EXPERIMENT OPS                        MAN-DAYS/YEAR
   SERVICE FREQUENCY                     TIMES/YEAR

DELTA VELOCITIES
   UP                    0.00
   DOWN                  0.00
   AERO RETURN           0.00

SUPPORT EQUIPMENT
            LENGTH:      0.00 METERS       WIDTH:      0.00 METERS         HEIGHT:      0.00 METERS     (STOWED)
            LENGTH:      0.00 METERS       WIDTH:      0.00 METERS         HEIGHT:      0.00 METERS     (DEPLOYED)

            MASS:           0 KG

MANIFEST RESTRICTIONS
   (X) NO RESTRICTIONS
   ( ) ONLY WITH COMPATIBLE PAYLOADS
   ( ) FLY-ALONE
   ( ) MUST HAVE DOCKING MODULE

LENGTH OF BEAM FAB                                        0.00
NUMBER OF APPENDAGES                                         0
NUMBER OF MODULES REQUIRED TO ASSEMBLE THE PAYLOAD           0
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ORIGINAL PAGE IS
OF POOR QUALITY

PAYLOAD ELEMENT NAME
GLASS PROCESSING FOR OPTICAL FIB

CODE
BACX1040

TYPE
( ) SCIENCE AND APPLICATIONS (NON-COMM.)
(X) COMMERCIAL
( ) TECHNOLOGY DEVELOPMENT
( ) OPERATIONS
( ) OTHER
( ) NATIONAL SECURITY
TYPE NUMBER (SEE TABLE A)

CONTACT
NAME DR. HARVEY J. WILLENBERG
ADDRESS BOEING AEROSPACE COMPANY
PO BOX 3999 MS 84-06
SEATTLE, WA 98124

TELEPHONE 206/773-2020

IMPORTANCE OF THE SPACE STATION TO THIS ELEMENT
1 = LOW VALUE, BUT COULD USE
10 = VITAL
SCALE = 8

STATUS
( ) OPERATIONAL ( ) APPROVED ( ) PLANNED ( ) CANDIDATE (X) OPPORTUNITY

DESIRED FIRST FLIGHT, YEAR: 1991 NUMBER OF FLIGHTS 30 DURATION OF FLIGHT, DAYS 45

OBJECTIVE
PRODUCE HIGH QUALITY OPTICAL FIBERS BY CONTAINERLESS PROCESSING OF GLASS.

DESCRIPTION
CONTAINERLESS PROCESSING FURNACES HEAT HIGH PURITY GLASS BEYOND MELTING POINT AND PULL 10 UM DIAMETER FIBERS FROM THE MELT, WHICH ARE THEN WRAPPED ON A SPOOL.

ORBIT CHARACTERISTICS
GEOSYNCHRONOUS ORBIT ( ) YES (X) NO
APOGEE, KM PERIGEE, KM TOLERANCE + -
INCLINATION, DEG TOLERANCE + -
NODAL ANGLE, DEG EPHEMERIS ACCURACY, M
ESCAPE DV REQUIRED, M/S

POINTING/ORIENTATION
VIEW DIRECTION ( ) INERTIAL ( ) SOLAR ( ) EARTH ( ) ANY
TRUTH SITES (IF KNOWN):
POINTING ACCURACY, ARC-SEC FIELD OF VIEW (DEG)
POINTING STABILITY (JITTER), ARC-SEC/SEC
SPECIAL RESTRICTIONS (AVOIDANCE)

POWER
( ) AC (X) DC

	POWER, W	DURATION, HRS/DAY
OPERATING	10600	24.00
STANDBY		
PEAK	10600	24.00
VOLTAGE, V	50	FREQUENCY, HZ

(X) CONTINUOUS

DATA/COMMUN TIONS

MONITORING REQUIREMENTS:

( ) NONE ( ) REALTIME ( ) OFFLINE ( ) OTHER:

( ) ENCRIPTION/DECRIPTION REQUIRED

( ) UPLINK REQUIRED: COMMAND RATE (KBS): FREQUENCY (MHZ):

( ) ON-BOARD DATA PROCESSING REQUIRED

DESCRIPTION:

DATA TYPES: ( ) ANALOG ( ) DIGITAL HOURS/DAY

FILM (AMOUNT): VOICE (HOURS/DAY):

LIVE TV (HOURS/DAY): OTHER:

ON-BOARD STORAGE (MBIT):

DATA DUMP FREQUENCY (PER ORBIT) DOWNLINK COMMAND RATE:

RECORDING RATE (KBPS) DOWNLINK FREQUENCY (MHZ):

THERMAL

(X) ACTIVE ( ) PASSIVE

TEMPERATURE, DEG C OPERATIONAL MINIMUM 800 MAXIMUM 2000

NON-OPERATIONAL MINIMUM MAXIMUM 100

HEAT REJECTION, W OPERATIONAL MINIMUM 10000 MAXIMUM 20000

NON-OPERATIONAL MINIMUM MAXIMUM 20000

EQUIPMENT PHYSICAL CHARACTERISTICS

LOCATION (X) INTERNAL ( ) EXTERNAL ( ) REMOTE

EQUIPMENT ID/FUNCTION ( ) PRESSURIZED ( ) UNPRESSURIZED

LENGTH: 20.00 METERS WIDTH: 5.00 METERS HEIGHT: METERS (STOWED)

LENGTH: 20.00 METERS WIDTH: 5.00 METERS HEIGHT: METERS (DEPLOYED)

LAUNCH MASS, KG: 29500 RETURN MASS, KG: 29500

CONSUMABLE TYPES

ACCELERATION SENSITIVITY, (G) MIN: MAX:

CREW REQUIREMENTS

CREW SIZE TASK ASSIGNMENTS

SKILLS (SEE TABLE B)

SKILL										
LEVEL										
HOURS/DAY										

EVA ( ) YES ( ) NO REASON HOURS/EVA

SERVICING/MAINTENANCE

SERVICE: INTERVAL DAYS CONSUMABLES KG

RETURNABLES KG MAN HOURS REQUIRED

CONFIGURATION CHANGES: INTERVAL DAYS MAN-HOURS REQUIRED

DELIVERABLES KG RETURNABLES KG

SPECIAL CONSIDERATIONS/SEE INSTRUCTIONS

BOEING-SPECIFIC INPUT DATA

MISSION TYPE	OPS CODE
FREE FLYER	
( ) NOT SERVICED	F
( ) REMOTE TMS	FT
( ) REMOTE MANNED	FM
( ) SERVICED AT STATION (TMS RETRIEVED)	FST
( ) SERVICED AT STATION (SELF-PROPELLED)	FS
PLATFORM BASED	
( ) NOT SERVICED	P
( ) REMOTE TMS	PT
( ) REMOTE MANNED	PM
( ) SERVICED AT STATION (TMS RETRIEVED)	PST
( ) SERVICED AT STATION (SELF-PROPELLED)	PS
OTHER	
( ) SPACE STATION BASED	SS
( ) SORTIE	SOR

CONSTRUCTION/SERVICING COMPLEXITY
- ( ) LOW
- ( ) MEDIUM
- ( ) HIGH

OPERATIONS TIMES	
OTV UP/DOWN	DAYS
OTV OR TMS ON ORBIT	DAYS
MISSION USE	DAYS/YEAR
IVA SERVICE	MAN-DAYS/YEAR
EVA SERVICE	MAN-DAYS/YEAR
EXPERIMENT OPS	MAN-DAYS/YEAR
SERVICE FREQUENCY	TIMES/YEAR

DELTA VELOCITIES
UP
DOWN
AERO RETURN

SUPPORT EQUIPMENT
LENGTH: METERS WIDTH: METERS HEIGHT: METERS (STOWED)
LENGTH: METERS WIDTH: METERS HEIGHT: METERS (DEPLOYED)

MASS: KG

MANIFEST RESTRICTIONS
- ( ) NO RESTRICTIONS
- ( ) ONLY WITH COMPATIBLE PAYLOADS
- ( ) FLY-ALONE
- ( ) MUST HAVE DOCKING MODULE

LENGTH OF BEAM FAB
NUMBER OF APPENDAGES
NUMBER OF MODULES REQUIRED TO ASSEMBLE THE PAYLOAD

COST DATA

NAME AND PHONE NUMBER:

DESCRIPTION

CONTAINERLESS PROCESSING FURNACES HEAT HIGH PURITY GLASS BEYOND MELTING POINT AND PULL 10 UM DIAMETER FIBERS FROM THE MELT, WHICH ARE THEN WRAPPED ON A SPOOL.

ITEM DRY WEIGHT: POUNDS VOLUME: CUBIC FEET

STRUCTURAL WEIGHT (INCLUDES TYPICAL "MECHANICAL" ITEMS LISTED BELOW): POUNDS

DESIGN COMPLEXITY:

MANUFACTURING COMPLEXITY FOR STRUCTURAL/MECHANICAL ITEMS:

TYPICAL "MECHANICAL" ITEMS INCLUDE ENCLOSURES, OPTICS, MOTORS, BLOWERS, GYROS, BATTERIES, CABLES, CONNECTORS, SWITCHES, INDICATORS, CATHODE RAY TUBES, ANTENNAS WITHOUT ELECTRONICS, MECHANISMS, WAVEGUIDES, ETC.

ELECTRONIC EQUIPMENT DESCRIPTION:
ANALOG %
DIGITAL %
POWER SUPPLIES %
OTHER %

MANUFACTURING COMPLEXITY FOR ELECTRONIC ITEMS:

WEIGHT OF THE CIRCUIT BOARD AND ELECTRONICS MOUNTED ON IT: POUNDS

MATERIAL USED FOR THE ENCLOSURE: MACHINE CASTING?

OF THE ELECTRONICS WEIGHT, WHAT % IS OFF-THE-SHELF?

OF THE STURCTURAL WEIGHT, WHAT % IS OFF-THE-SHELF?

MANUFACTURING DEGREE OF AUTOMATION
ELECTRONICS ( ) LOW ( ) MEDIUM ( ) HIGH
MECHANICAL ( ) LOW ( ) MEDIUM ( ) HIGH

IS THE ITEM HARDENED?

APPENDIX I

SUMMARY OF STUDY TASKS AND FINAL REPORT TOPICAL CROSS REFERENCE

SUMMARY OF STUDY TASKS

The study accomplished 3 major objectives:

1. Identified, collected, and analyzed science, applications, commercial, national security, technology development and space operations missions that require or benefit by the availability of a permanently manned space station. The space station attributes and characteristics that will be necessary to satisfy these requirements were identified.
2. Identified alternative space station architectural concepts that would satisfy the user mission requirements.
3. Performed programmatic analyses to define cost and schedule implications of the various architectural options.

Figure A-1 shows the summary task flow that was used to accomplish these objectives.

In Tasks 1.1 thru 1.5, missions were identified, screened, and their needs and benefits analyzed. Mission investigators were assigned to each of the mission classes (science and applications, commercial, technology development, space operations, and national security). In general, these investigators (and their supporting subcontractors) contacted potential users and analyzed available data to characterize potential mission needs. They worked in conjunction with designers and operations analysts to characterize the potential payloads and operational interfaces. In Task 1.6, the missions were allocated to orbits, and were assigned to platforms, free-flyers, or space stations, as appropriate. During Task 1.7, the various missions were integrated into time-phased mission models. The time-phasing took into account available budgetary constraints, prioritization, time sequencing constraints, and transportation availability. A computer program was used to process the integrated time-phased mission model to derive a year-by-year shuttle manifest schedule. The computer program was also used for Task 1.8 to derive the integrated time-phased space station accommodation requirements, i.e., power and thermal demands, berthing requirements, and crew skills. These mission analyses have been reported in Volume 2 of the final report.

Also included in Volume 2 are the results from Task 1.10. In this task, some of the primary commerical opportunities were examined to define the economics of the use of a space station and to define the benefits of doing business on a space station relative to doing it using the shuttle.

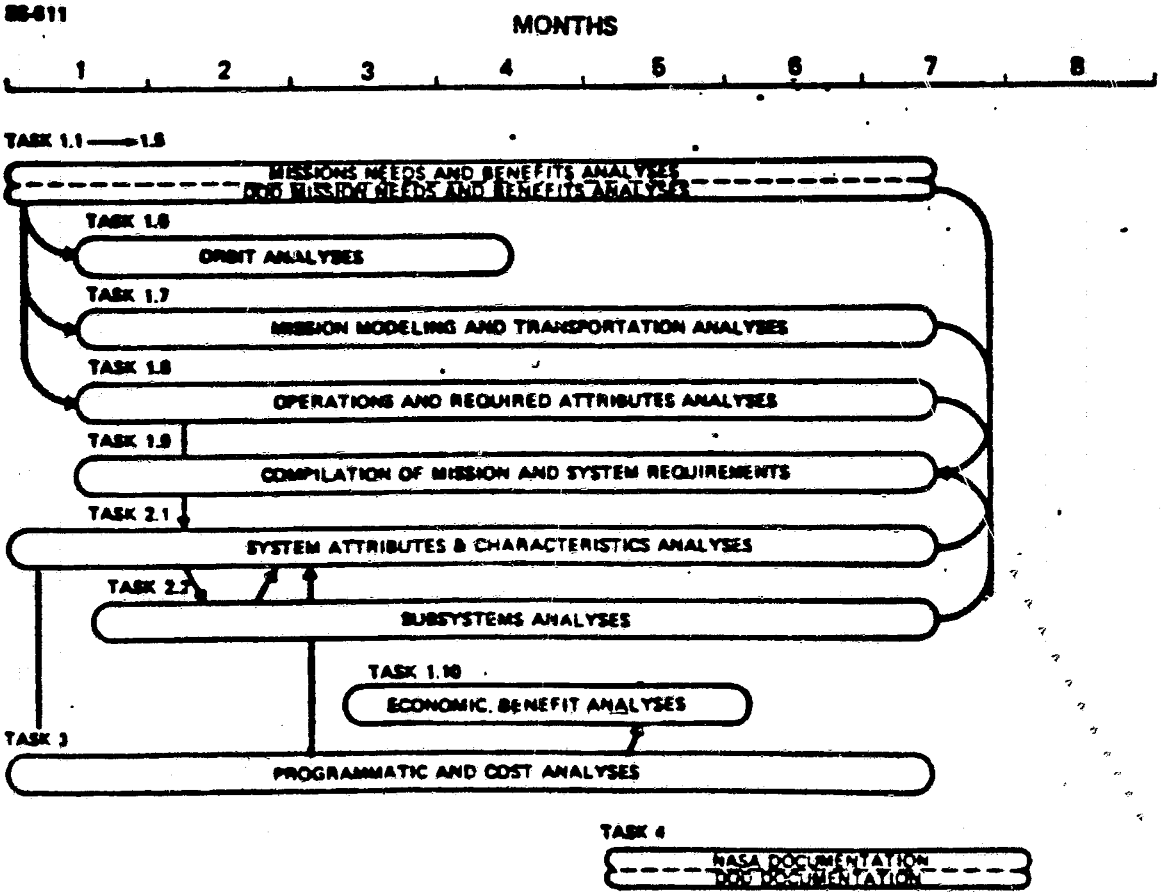

Figure A-1. Summary Diagram Outlines Major Task Traffic

In Task 1.9, mission requirements and space station design requirements were identified. An aggregate of these requirements are reported in Volume 3.

Volume 4 of the final report contains the results from Tasks 2.1, 2.2 and 3. Specifically in Task 2.1, a methodology for defining realistic architectural options was established. This methodology was applied using the requirements defined in the previous tasks. From this, we have created 3 architectural options and have shown some reference space station configuration concepts for each architectural option. Task 2.2 was performed to obtain analysis and trades of some of the principle subsystems, i.e., data management, environmental control and life support, and habitability. Task 3 provides the analyses of programmatics and cost options associated with the concepts derived during the study.

A cross reference guide to enable locating study topics within the volumes and volume sections of the final report is presented in Table A-1.

TABLE A-1

Final Report Topical Cross Reference Guide

Topic	Vol. 1 Exec Summ	Vol. 2 Mission Anal	Vol. 3 Rqm'ts	Vol. 4 Archit	Vol. 5 DoD	Vol. 6 Final Brief	Vol. 7-1 Sci/App Data Book	Vol. 7-2 Commer Data Book	Vol. 7-3 Tech Demo Data Book	Vol. 7-4 Archit Data Book	Vol. 7-5 Mission Data Book
Commercial Missions											
o Communication Satellites	o	3.2.1				o		o			
o Reconfigurable o Multibeam											
o Materials Proc.	o	3.2.2		I-1.3.2.3, 1.2.2.1		o		o			
o Semiconductors o Biological o Glass Fibers											
o Earth Observation		3.2.3									
Industrial Services		3.2.4						o			
o Crew Selection & Training o In-Space OPS											
Technology Demo's	o	3.3				o			o		
Space Operation	o	3.4				o					
o Construction o Flight Support o Servicing											

TABLE A-1

Final Report Topical Cross Reference Guide

Topic	Vol. 1 Exec Summ	Vol. 2 Mission Anal	Vol. 3 Rqm'ts	Vol. 4 Archit	Vol. 5 DoD	Vol. 6 Final Brief	Vol. 7-1 Sci/App Data Book	Vol. 7-2 Commer Data Book	Vol. 7-3 Tech Demo Data Book	Vol. 7-4 Archit Data Book	Vol. 7-5 Mission Data Book
Science & Applications Missions											
o Space Environment Missions	o	3.1.2				o	o				
o Astrophysics Missions	o	3.1.3				o	o				
o Earth Environment Missions	o	3.1.4				o	o				
o Life Sciences Missions	o	3.1.5				o	o				
o Materials Science Missions	o	3.1.6					o				
Scenarios of Operational Capabilities	o	4.0, 5.0				o					
o Mission Constrained											
o Station Constrained											
o No Space Station											

TABLE A-1

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Topic	Vol. 1 Exec Summ	Vol. 2 Mission Anal	Vol. 3 Rqm'ts	Vol. 4 Archit	Vol. 5 DoD	Vol. 6 Final Brief	Vol. 7-1 Sci/App Data Book	Vol. 7-2 Commer Data Book	Vol. 7-3 Tech Demo Data Book	Vol. 7-4 Archit Data Book	Vol. 7-5 Mission Data Book
Mission Requirements Summary		5.0									o
o Low Inclination Space Station	o	5.2,5.3	3.2.1	I-1.2.2.4		o					o
o High Inclination Space Station	o	5.2,5.3		I-1.2.2.4		o					o
o Platform only	o	5.4				o					o
o Manifesting o Shuttle o OTV o TMS	o	5.2, 5.3, 5.4				o					o
o Crew Size	o	5.2,5.3 5.4	3.2.1			o					o
o Crew Skills		5.2.5.3 3.1.2.5, 3.1.3.5, 3.1.4.5, 3.1.5.5, 3.2.1.5, 3.2.2.6, 3.2.3 3.3		II-2.2.3							o

TABLE A-1

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Topic	Vol. 1 Exec Summ	Vol. 2 Mission Anal	Vol. 3 Rqm'ts	Vol. 4 Archit	Vol. 5 DoD	Vol. 6 Final Brief	Vol. 7-1 Sci/App Data Book	Vol. 7-2 Commer Data Book	Vol. 7-3 Tech Demo Data Book	Vol. 7-4 Archit Data Book	Vol. 7-5 Mission Data Book
Mission Requirements Summary (Continued)											
o Accommodations Reqm'ts	o	2.2 5.2,5.3	3.2.1			o					o
o Power		5.4	I-1.2.1.2, 1.2.2.4 1.2.3.3 1.2.3.4								
o Internal Vol											
o Berthing Ports											
Benefits		6.0									
o Semiconductor Manufacturing	o	6.2				o					o
o Glass Fiber Manufacturing	o	6.3				o					o
o Communications Satellite Assembly	o	6.4				o					o
o Biological Materials Manufacturing	o	6.5				o					o

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Mission Analysis											
o Manifesting Analysis Software	o	2.2				o					o
o Accommodations & Crew Activity Analysis Software	o	2.2				o					o
o Crew Skills											
o Crew Size											
o Berthing Ports											
o Electrical power											
o Internal volume											
Design Requirements											
o Mission Accommodation Reqm'ts		5.0	3.2								
o Interfaces				II-10.0						o	
o Berthing/Docking Port				I-1.3.2.1							
o Hangar		3.3		I-1.3.2.2							

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Architectural Options											
o Architecture Development Methodology	o			I-1.1		o				o	
o Space Station Architectural Options	o			I-1.2		o				o	
Build-up and Growth	o	5.0		I-1.2.3.4, 1.3.1.3, 1.3.2.3, 1.3.3.3							
Data Management											
o Architecture				II-3.2						o	
o In-Flt Checkout				II-3.3						o	
o Space-Ground Integration				II-3.4						o	
o Ground Lab				II-3.5						o	
o Software Devel.				II-3.6						o	
o Hardware Stds				II-3.7						o	
o Software Stds				II-3.8						o	
o Verif/Valid.				II-3.9						o	

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Logistics/Resupply											
o Logistics Module				II-7.1, 7.3,7.4							
o Resupply Reqm'ts				II-7.2							
Environmental Control and Life Support Subsystem				II-5.0						o	
o ECLS Evolution				II-5.2.1, 5.3.2						o	
o Safe Haven Logistics Module				II-5.2.1						o	
o Air Revitalization System				II-5.0,5.3.2						o	
o Water Revitalization System				II-5.0,5.3.2						o	
o Performance and Loads Specification										o	
o Overboard Venting				II-5.2.1,5.2.2						o	
o Architecture				II-5.2.1						o	
o Water Recovery System				II-5.0,5.3.2						o	
o CO_2 Concentration				II-5.0,5.3.2						o	
o Regenerative-Fuel-Cell-Based ECLS				II-5.0,5.2.1, 5.3.2						o	
o Recommendations				II-5.0, 5.3.2						o	
EVA/EMU				II-5.0, 5.2.2						o	

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Communications & Tracking Subsystem			3.2.2.1.11	II-4.0						o	
Manipulator System				II-6.0						o	
Pointing Systems				II-8.0						o	
Thermal Management				II-9.0						o	
Crew				II-2.0							
o Tasks				II-2.2						o	
o Skills		5.2.5.3 3.1.2.5, 3.1.3.5, 3.1.4.5, 3.1.5.5, 3.2.1.5 3.2.2.6, 3.2.3 3.3		II-2.2.3							
o Capabilities				II-2.2.2						o	
o Role Relationships				II-2.3.2						o	
o Accommodations			3.2.2.1.11	II-2.4						o	

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Crew (Continued)											
o Habitability	o		3.2.2.1.11	II-2.0,2.4						o	
o IVA Work Stations				II-2.5.2						o	
o EVA Work Stations				II-2.5.3 II-5.2.2						o	
o Maintenance				II-2.5.4						o	
o Stowage			3.2.2.1.11							o	
o Windows			3.2.2.1.11	II-2.4.1						o	
o Hygiene			3.2.2.1.11	II-2.4.2.4						o	
o Scheduling			3.2.2.1.11	II-2.3.1						o	

APPENDIX 2

KEY TEAM MEMBERS

KEY TEAM MEMBERS

Subject	**Boeing Team**	**Subcontractor Team**	
Study Manager	Gordon Woodcock	ADL:	Dr. Peter Glaser
		Battelle:	Kenneth E. Hughes
		ECON:	John Skratt
		ERIM:	Albert Sellman
		Hamilton Standard:	Harlan Brose
		Intermetrics:	John Hanaway
		Life Systems:	Franz Shubert
		MRA:	Col. Richard Randolph (Ret.)
		NBS:	Dr. B. J. Bluth
		RCA:	Dr. Herbert Gurk
		SAI:	Dr. Hugh R. Anderson
Technology Manager	Dr. Richard L. Olson		
Mission Analysis			
Science & Applications	Dr. Harold Liemohn David Tingey (Earth Obs.) Dr. Derek Mahaffey (Mission Integration) Melvin W. Oleson (Life Sciences) Dr. Robert Spiger (Plasma physics, astrophysics, solar physics)	SAI:	Dr. Hugh R. Anderson (Environmental Science) Dr. Peter Hendricks (Meterology/ Oceanography) Dr. Gil Stegen Dr. John Wilson (Life Sciences) Dr. Robert Loveless (Integration) Dr. Robin Muench Dr. Stuart Gorney (Life Sciences) Ms. Monica Dussman (Life Sciences)
		ERIM:	Albert Sellman (Earth Obs.) Dr. Irvin Sattinger (Earth Obs.)
Commercial	Dr. Harvey Willenberg	RCA:	Dr. Herbert Gurk Thaddeus (Ted) Hawkes
		ADL:	Dr. Peter Glaser
		Battelle:	Dr. Kenneth E. Hughes
		MRA:	Col. Richard Randolph (Ret.) Robert Pace

KEY TEAM MEMBERS (Cont'd)

Subject	**Boeing Team**	**Subcontractor Team**	
Mission Analysis (Cont'd)			
Technology Demonstrations	George Reid Dr. Alan G. Osgood David S. Parkman Steve Robinson Richard Gates Tim Vinopal		
National Defense	Robert S.Y. Yoseph	ERIM:	Mirko Najman
Space Operations	Keith H. Miller		
Architecture and Subsystems			
Architecture & Configurations	John J. Olson Brand Griffin Tim Vinopal David S. Parkman Steve Robinson		
Communications		RCA:	Donald McGiffney
Crew Systems	Keith H. Miller George Reid Dr. Alan G. Osgood	NBS:	Dr. B. J. Bluth
Data Management and Software	Les Holgerson	Intermetrics:	John Hanaway
ECLSS	Keith H. Miller	Ham Std:	Harlan Brose Ross Cushman Al Boehm Ken King Todd Lewis
		Life Systems:	Dr. R. A. Winveen Franz Schubert Dr. Dennis B. Heppner
Operations Analysis	Keith H. Miller George Reid Dr. Alan G. Osgood		
Orbit Analysis	Dani Eder		

KEY TEAM MEMBERS (Cont'd)

Subject	Boeing Team	Subcontractor Team
Architecture and Subsystems (Cont'd)		
Orbit/Survivability Analysis	Stephen W. Paris Merri Anne Stowe	
C^3I	H. Paul Janes	
Radiation Effects	Dr. William C. Bowman	
Requirements Analysis	Lowell Wiley	
Programmatics & Cost		
Cost Analysis	Ken verGowe	ECON: Ed Dupnick
Programmatics	Gordon Woodcock	

APPENDIX 3

ACRONYMS AND ABBREVIATIONS

LIST OF ACRONYMS AND ABBREVIATIONS

AAP	Airlock Adapter Plate
AC	Alternating Current
ADM	Adaptive Delta Modulation
AM	Airlock Module
APC	Adaptive Predictive Coders
APSM	Automated Power Systems Management
ACS	Attitude Control System
ARS	Air Revitalization System
ASE	Airborn Support Equipment
BIT	Built in Test
BITE	Built in Test Equipment
CAMS	Continuous Atmosphere Monitoring System
C&D	Controls and Displays
C&W	Caution and Warning
CCA	Communications Carrier Assembly
CCC	Contaminant Control Cartridge
CCTV	Closed Circuit Television
CEI	Critical End Item
CER	Cost Estimating Relationship
CF	Construction Facility
CMG	Control Moment Gyro
CMD	Command
CMDS	Commands
CO_2	Carbon Dioxide
CPU	Computer Processor Units
CRT	Cathode Ray Tube
dB	Decibels
DC	Direct Current
DCM	Display and Control Module
DDT&E	Design, Development, Test, and Evaluation
DOD, DoD	Department of Defense
DT	Docking Tunnel
DM	Docking Module
DMS	Data Management System
DSCS	Defense Satellite Communications System
ECLSS	Environmental Control/Life Support System
EDC	Electrochemical Depolarized CO_2 Concentrator
EEH	EMU Electrical Harness
EIRP	Effective Isotropic Radiated Power
EMI	Electromagnetic Interference
EMU	Extravehicular Mobility Unit
EPS	Electrical Power System
ET	External Tank
EVA	Extravehicular Activity
EVC	EVA Communications System
EVVA	EVA Visor Assembly
FM	Flow Meter
FMEA	Failure Mode and Effects Analysis
ftc	Foot candles
FSF	Flight Support Facility
FSS	Fluid Storage System
GaAs	Gallium Acsenide

LIST OF ACRONYMS AND ABBREVIATIONS (Continued)

GN&C	Guidance, Navigation and Control
GEO	Geosynchronous Earth Orbit
GHZ	Gigahertz
GPC	General Payload Computer
GPS	Global Positioning System
GSE	Ground Support Equipment
GSTDN	Ground Satellite Tracking and Data Network
GFE	Government Furnished Equipment
GTV	Ground Test Vehicle
HLL	High Level Language
HLLV	Heavy Lift Launch Vehicle
HM	Habitat Module
HMF	Health Maintenance Facility
HPA	Handling and Positioning Aide
HUT	Hard Upper Torso
Hz	Hertz (cycles per second)
ICD	Interface Control Document
IDB	Insert Drink Bag
IOC	Initial Operating Capability
IR	Infrared
IVA	Intravehicular Activity
JSC	Johnson Space Center
KBPS	Kilo Bits Per Second
KM, Km	Kilometers
KSC	Kennedy Space Center
lbm	Pounds Mass
LCD	Liquid Crystal Display
LCVG	Liquid Cooling and Ventilation Garment
LED	Light Emitting Diode
LEO	Low Earth Orbit
LiOH	Lithium Hydroxide
LM	Logistics Module
LPC	Linear Predictive Coders
LRU	Lowest Replaceable Unit
LSS	Life Support System
LTA	Lower Torso Assembly
LV	Launch Vehicle
lx	Lumens
MBA	Multibeam Antenna
mbps	Megabits per second
MHz	Megahertz
MMU	Manned Maneuvering Unit
MM-Wave	Millimeter wave
MOTV	Manned Orbit Transfer Vehicle
MRWS	Manned Remote Work Station
MSFN	Manned Space Flight Network
N/A	Not Applicable
NBS	National Bureau of Standards
NSA	National Security Agency
N	Newton
NiCd	Nickel Cadmium
NiH_2	Nickle Hydrogen

LIST OF ACRONYMS AND ABBREVIATIONS (Continued)

Nm,nm	Nautical miles
N/m^2	Newtons per meter squared
OBS	Operational Bioinstrumentation System
OCS	Onboard Checkout System
OCP	Open Cherrypicker
OMS	Orbital Manuevering System
OTV	Orbital Transfer Vehicle
PCM	Pulse Code Modulation
PCM	Parametric Cost Model
PEP	Power Extension Package
PIDA	Payload Installation and Deployment Apparatus
P/L	Payload
PLSS	Portable Life Support System
PM	Power Module
POM	Proximity Operations Module
ppm	Parts per Million
PRS	Personnel Rescue System
PSID	Pounds per Square Inch Differential
RCS	Reaction Control System
REM	Roentgen Equivalent Man
RF	Radio Frequency
RFI	Radio Frequency Interference
RMS	Remote Manipulator System
RPM	Revolutions Per Minute
RPS	Real-time Photogrammetric System
SAF	Systems Assembly Facility
SAWD	Solid Amine Water Desorbed
SPGaAs	Space Produced Gallium Arsenide
scfm	Standard Cubic Feet per Minute
SCS	Stability and Control System
SCU	Service and Cooling Umbilical
SDV	Shuttle - Derived Vehicle
SDHLV	Shuttle - Derived Heavy Lift Vehicle
SEPS	Solar Electric Propulsion System
SF	Storage Facility
SM	Service Module
SOC	Space Operations Center
SOP	Secondary Oxygen Pack
SRB	Solid Rocket Booster
SRMS	Shuttle Remote Manipulative System
SRU	Shop Replacable Units
SSA	Space Suite Assembly
SSME	Space Shuttle Main Engine
STS	Space Transportation System
SSP	Space Station Prototype
STAR	Shuttle Turnaround Analysis Report
STDN	Spaceflight Tracking and Data Network
STE	Standard Test Equipment
TBD	To Be Determined
TDRSS	Tracing and Data Relay Satellite System
TFU	Theoretical First Unit
TGA	Trace Gas Analyzer

LIST OF ACRONYMS AND ABBREVIATIONS (Continued)

Nm,nm	Nautical miles
N/m^2	Newtons per meter squared
OBS	Operational Bioinstrumentation System
OCS	Onboard Checkout System
OCP	Open Cherrypicker
OMS	Orbital Manuevering System
OTV	Orbital Transfer Vehicle
PCM	Pulse Code Modulation
PCM	Parametric Cost Model
PEP	Power Extension Package
PIDA	Payload Installation and Deployment Apparatus
P/L	Payload
PLSS	Portable Life Support System
PM	Power Module
POM	Proximity Operations Module
ppm	Parts per Million
PRS	Personnel Rescue System
PSID	Pounds per Square Inch Differential
RCS	Reaction Control System
REM	Roentgen Equivalent Man
RF	Radio Frequency
RFI	Radio Frequency Interference
RMS	Remote Manipulator System
RPM	Revolutions Per Minute
RPS	Real-time Photogrammetric System
SAF	Systems Assembly Facility
SAWD	Solid Amine Water Desorbed
SPGaAs	Space Produced Gallium Arsenide
scfm	Standard Cubic Feet per Minute
SCS	Stability and Control System
SCU	Service and Cooling Umbilical
SDV	Shuttle - Derived Vehicle
SDHLV	Shuttle - Derived Heavy Lift Vehicle
SEPS	Solar Electric Propulsion System
SF	Storage Facility
SM	Service Module
SOC	Space Operations Center
SOP	Secondary Oxygen Pack
SRB	Solid Rocket Booster
SRMS	Shuttle Remote Manipulative System
SRU	Shop Replacable Units
SSA	Space Suite Assembly
SSME	Space Shuttle Main Engine
STS	Space Transportation System
SSP	Space Station Prototype
STAR	Shuttle Turnaround Analysis Report
STDN	Spaceflight Tracking and Data Network
STE	Standard Test Equipment
TBD	To Be Determined
TDRSS	Tracing and Data Relay Satellite System
TFU	Theoretical First Unit
TGA	Trace Gas Analyzer

LIST OF ACRONYMS AND ABBREVIATIONS (Continued)

TIMES	Thermoelectric Integrated Membrane Evaporation System
TLM	Telemetry
TM	Telemetry
TMS	Teleoperator Maneuvering System
TT	Turntable/Tilttable
TV	Television
UCD	Urine Collection Device
VCD	Vapor Compression Distillation
VDC	Volts Direct Current
VLSI	Very Large Sacle Integrated Circuits
VSS	Versatile Servicing Stage
WBS	Work Breakdown Structure
WMS	Waste Management System