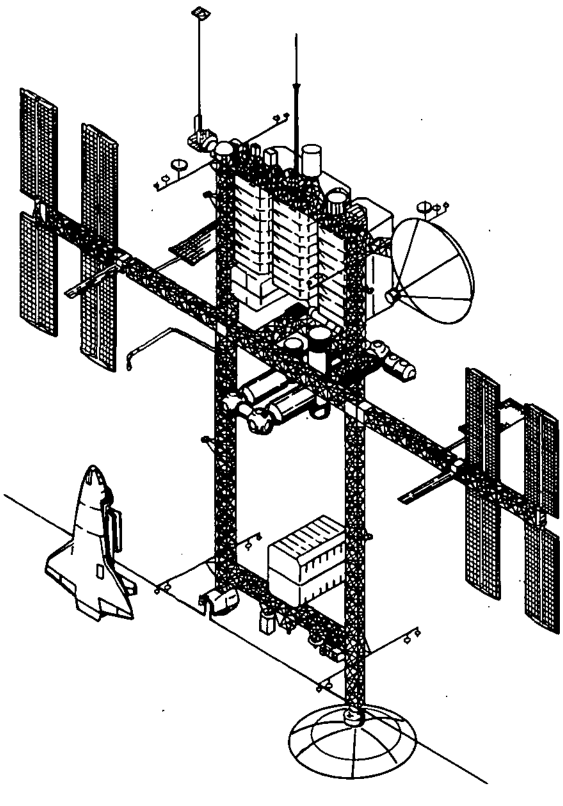
CR 175038

ACCOMMODATION REQUIREMENTS for MICROGRAVITY SCIENCE AND APPLICATIONS RESEARCH on SPACE STATION

December 1985



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Task 1
Contract No. NAS3-24654
NASA/Lewis Research Center

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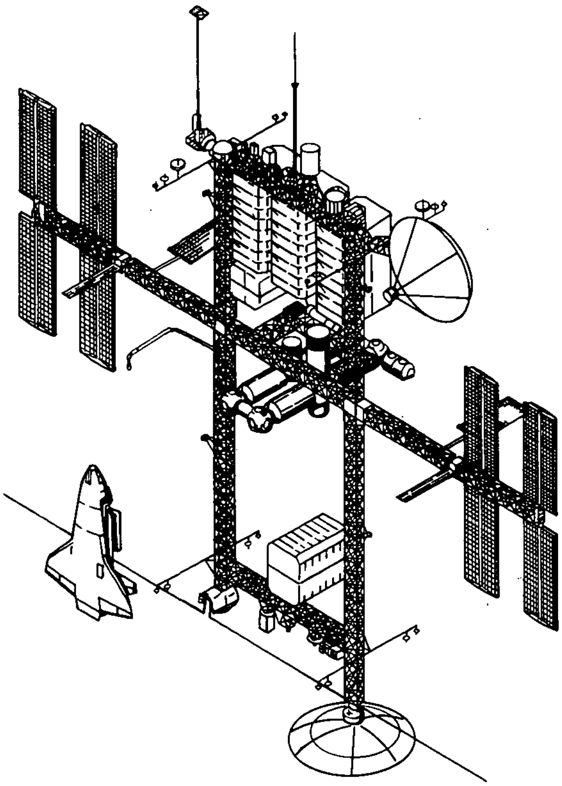

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Lewis Research Center

16. Abstract Scientific research conducted in the microgravity environment of space represents a unique opportunity to explore and exploit the benefits of materials processing in the virtual abscence of gravity induced forces. In accordance with this opportunity, NASA has initiated the preliminary design of a permanently manned Space Station that will support technological advances in process science and stimulate the development of new and improved materials having applications across the commercial spectrum.

A study was performed to define from the researchers' perspective, the requirements for laboratory equipment to accommodate microgravity experiments on the Space Station. The accommodation requirements focus on the microgravity science disciplines including combustion science, electronic materials, metals and alloys, fluids and transport phenomena, glasses and ceramics, and polymer science.

User requirements have been identified in eleven research classes, each of which contain an envelope of functional requirements for related experiments having similar characteristics, objectives, and equipment needs. Based on these functional requirements seventeen items of experiment apparatus and twenty items of core supporting equipment have been defined which represent currently identified equipment requirements for a pressurized laboratory module at the initial operating capability of the NASA Space Station.

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WYLE LABORATORIES - SPACE PROGRAMS

ACCOMMODATION REQUIREMENTS

for

MICROGRAVITY SCIENCE AND APPLICATIONS RESEARCH

on

SPACE STATION

December 1985

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Interim Report
of
Work Performed Under Contract No. NAS3-24654 (Task 1)
for
NASA/Lewis Research Center

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INTRODUCTION

Contract No. NAS3-24654, "Space Station Microgravity Science Accommodation Requirements Study," was initiated by Wyle Laboratories in May 1985 under the direction of the NASA Lewis Research Center - Space Experiments Office. The NASA technical monitor for the effort is Mr. Richard J. Parker.

The study effort includes two primary tasks:

- Task 1: Identification of the General Requirements for Performing Microgravity Science and Commercial Process Experiments on the Space Station.
- Task 2: Preparation of Conceptual Designs and Development Plans for Experiment Apparatus and Laboratory Support Equipment.

Task 1 has been completed and the study results are reported herein. Task 2 is underway and scheduled for completion in May 1986.

The objective of Task 1 was to define facility requirements and development needs from the **User Perspective.** As such, this study builds upon the efforts initiated at the December 1984 Space Station Users Workshop. During this preliminary effort "Top-Level Requirements"[1] were assembled utilizing a **Functional Approach** to requirements definition. The earlier results indicated a very broad range of potential research involving more than one hundred candidate apparatus and support systems.

The current effort represents **Focused Requirements** for a limited complement of experiment apparatus and core equipment to meet near-term needs at the Space Station Initial Operating Capability (IOC) configuration. These requirements have been assembled through direct interaction with the research community and in accordance with the perceived priorities of future Space Station users.

The publication of this interim report on Task 1 is made to provide timely accommodation requirements input to the Microgravity and Materials Processing Facility (MMPF) Study (NAS8-36122) managed by the Marshall Space Flight Center. These user requirements focus on the microgravity science and applications discipline areas of Lewis Research Center (LeRC) interest and expertise including combustion science, electronic materials, metals and alloys, fluids and transport phenomena, glasses and ceramics, and polymer science. As such, they include the LeRC input to the MMPF study.

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[1]"Top-Level Requirements for Microgravity Science and Applications Research on Space Station - Proceedings of the First Users Workshop," Wyle Laboratories report No. WR 85-03, final report on NASA Contract NAS8-36117, March 1985.

1.0 SUMMARY OF FINDINGS

Scientific research conducted in the microgravity environment of space represents a unique opportunity to explore and exploit the benefits of materials processing in the virtual absence of gravity-induced forces. In accordance with this opportunity, NASA has initiated the preliminary design of a permanently manned Space Station that will support technological advances in process science and stimulate the development of new and improved materials having applications across the commercial spectrum.

The planned Space Station will serve as an on-orbit base of operations for continuous basic and applied research in the material sciences. A dedicated pressurized laboratory module is envisioned as the focal point for the contemplated research activities. The laboratory must be developed and managed in such a manner as to be conducive to sustained research productivity and supportive of commercial process development. As a result, laboratory accommodations require careful evaluation with particular emphasis on the evolutionary nature of technology development. Facility flexibility is considered essential due to the range of research activities currently under consideration and the growth associated with an expanding science base. For this reason a **Functional Approach** to facility design has been encouraged by the research community. The benefits of the "functional approach," in contrast with the traditional "strawman approach," are reviewed in Figure 1.

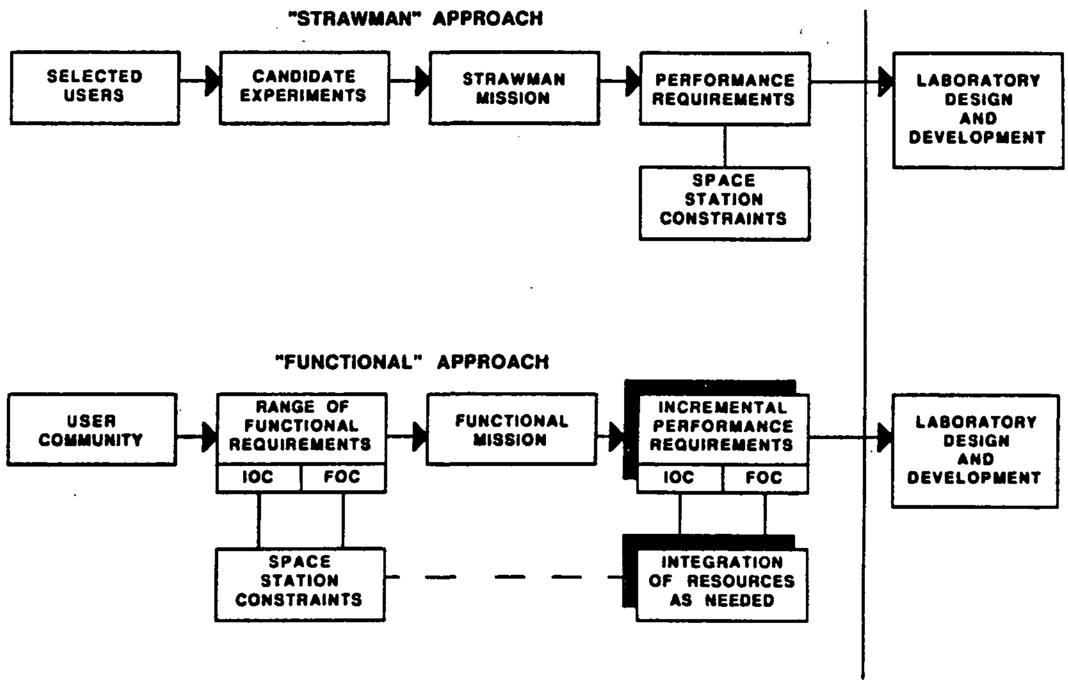


Figure 1. Comparison of the "Functional" vs. "Strawman" Approach

1.1 Microgravity Science Research Classes

The identification of potential experiments to be performed in the planned Space Station laboratory involves a comprehensive assessment of the range and depth of both basic and applied investigations for greater than one hundred suggested research topics. In order to assist in this task, the following sources of information were reviewed:

- Technical Papers presented at the December 1984 Microgravity Science and Applications (MSA) Workshop - Jet Propulsion Laboratory.
- Candidate Research Topics developed at the December 1984 Space Station MSA Users Workshop - Wyle Laboratories.
- Recommended Research Topics developed at the May 1985 Microgravity Polymer Workshop - NASA/Lewis Research Center.
- Candidate Experiments for Commerce Lab developed during Spring 1985 - Wyle Laboratories.
- Paylist for the Microgravity and Materials Processing Facility (MMPF) developed during 1985 - Teledyne Brown/Boeing.
- Preliminary Science Goals developed by MSA Discipline Working Groups during 1985 - USRA.
- Interviews and/or Telephone Conversations with selected government, industry, and university investigators.

Through this review it was determined that the definition of explicit requirements for a very large number of specific experiments was impractical. In addition, it has been previously noted that,

> "...before a commercial product can be identified, many years of basic research must occur and the predictability of the exact experiments that will be needed is nearly impossible."[2]

---

[2] Report of the Task Force for the Commercial Use of Space, NASA Advisory Council, August 1985.

In accordance with the functional approach to laboratory design, a taxonomy of Research Classes was developed. The accommodation requirements for each research class were derived as an envelope of the functional requirements for related experiments having similar characteristics, objectives, and equipment needs. Each research class represents the potential to perform numerous individual experiments involving a range of materials, phenomena, and/or processes.

Eleven research classes[3] have been identified based on the benefit factors and suitability factors presented in Figure 2. It is anticipated that new research classes may emerge and emphasis on current research classes may shift as experimentation proceeds and the science base expands. The relatively recent interest in Polymer Science and Protein Crystal Growth supports this premise.

RESEARCH CLASS	1. BENEFIT FACTORS			2. SUITABILITY FACTORS			
	SM	TAG	TAS	SNO	SSC	TM	SC
FLUID, GAS AND INTERFACE DYNAMICS	●	●	●	●	●	●	●
COMBUSTION SCIENCE	●	●	⊖	●	●	⊖	○
POLYMER SCIENCE	●	●	●	●	●	⊖	⊖
DIRECTIONAL SOLIDIFICATION	●	⊖	●	●	●	⊖	⊖
FLOAT ZONE SOLIDIFICATION	●	⊖	●	●	●	⊖	⊖
ISOTHERMAL SOLIDIFICATION	●	●	⊖	●	●	⊖	⊖
SOLUTION CRYSTAL GROWTH	●	⊖	●	●	●	●	⊖
VAPOR CRYSTAL GROWTH	●	⊖	●	●	●	●	⊖
LIQUID PHASE ELECTROEPITAXY	●	⊖	●	●	●	○	○
CONTAINERLESS PROCESSING (CONDUCTIVE MELTS)	●	⊖	●	●	●	⊖	⊖
CONTAINERLESS PROCESSING (NON-CONDUCTIVE MELTS)	●	⊖	●	●	●	⊖	⊖

● HIGH ⊖ MEDIUM ○ LOW

1. BENEFIT FACTORS		2. SUITABILITY FACTORS	
SM	SCIENTIFIC MERIT	SNO	SUPPORTIVE OF NASA OBJECTIVES
TAG	TECHNICAL APPLICATION TO GROUND PROCESSES	SSC	SPACE STATION COMPATIBLE
TAS	TECHNICAL APPLICATION TO SPACE PROCESSES	TM	TECHNOLOGICAL MATURITY IN SPACE
		SC	SCIENTIFIC COMMONALITY

Figure 2. Microgravity Science Research Classes

[3] The area of Biotechnology has been specifically excluded from this study effort. The exclusion does not suggest any lack of suitability.

Following research class identification, background information and accommodation requirements were assembled for each of the following areas:

BACKGROUND DATA

- Research Objectives
- Potential Applications
- Phenomena of Interest
- Processes of Interest
- Products of Interest
- Properties of Interest
- History of Investigation
- Key Individuals
- Flight Requirement
- Primary Equipment Requirements
- Support Equipment Requirements
- Sample Characteristics
- Security Considerations

SAFETY REQUIREMENTS

- Hazards Assessment

ENVIRONMENTAL REQUIREMENTS

- Microgravity Environment
- Ambient Environment
- Acoustic Environment
- Radiation Environment
- Isolation Requirements

UTILITY REQUIREMENTS

- Power
- Heat Rejection
- Data Management
- Waste Management
- Vacuum
- Crew Support

LOGISTIC REQUIREMENTS

- Supply Schedule
- Consummables

The data and information obtained is provided in detail in Appendix A: Research Class Accommodation Requirements, and is summarized in Figure 3: Accommodations Composite.

AREA OF STUDY	FINDING	
BACKGROUND		
Research Range and Objectives	**RANGE** ● Fluid, Gas, and Interface Dynamics ● Combustion Science ● Polymer Science ● Directional Solidification ● Float Zone Solidification ● Isothermal Solidification ● Solution Crystal Growth ● Vapor Crystal Growth ● Liquid Phase Electroepitaxy ● Containerless Processing (Conductive Melts) ● Containerless Processing (Non-Conductive Melts)	**OBJECTIVES** ● Expansion of the science base in materials research ● Refinement and validation of theoretical models. ● Quantification of mass transport dynamics ● Optimization of processing parameters ● Identification of processes with commercial potential. ● Prototype production processing
Applications	**SCIENTIFIC APPLICATIONS** ● Increased understanding of morphological phenomena. ● High temperature thermophysical properties measurement. ● Quantification of normally weak forces: - interfacial tension - capillary flow - coupled flux phenomena **REPRESENTATIVE COMMERCIAL APPLICATIONS** ● Increased fuel combustion efficiency ● Pyroelectric detectors ● Laser Q-switches ● Infrared windows ● Imaging systems ● X-ray targets ● Corrosion resistant materials ● High efficiency mirrors ● Engineered polymers ● Catalysts ● Gas turbine components ● Ultrapure materials ● Metallic glasses	 ● Large diameter single crystals ● Defect free semiconductor alloys ● High purity fiber optics ● Tailored laser hosts ● Aerospace structural materials ● Super conductors/super insulators ● Super magnets ● Polarization lenses ● Light filters ● Striking glasses ● Viscoelastic fluids ● Ultrahard materials ● Degradation resistant materials
	● CONTROLLED MATERIALS MORPHOLOGY	
Phenomena	● Solutal diffusion ● Thermal/structural gradients ● Phase transition dynamics ● Coalescence, nucleation & crystallization	● Constitutional supercooling ● Capillarity ● Surface & interfacial tension ● Electromigration
	● MASS TRANSPORT DYNAMICS	
Processes	● Melting ● Purifying ● Positioning ● Stirring ● Solidifying ● Dispersing ● Adsorbing ● Shaping	● Supercooling ● Polymerizing ● Fining ● Homogenizing
	● MATERIALS REFINING	
Properties	● Flammability ● Viscosity ● Defect density ● Corrosivity ● Reactivity ● Stability ● Conductivity ● Resistivity	● Emissivity ● Transmissivity ● Uniformity ● Purity
	● MATERIALS QUALITY	
History & Key Individuals	Cumulative No. of Investigations : ~ 330 ● Ground-based (theoretical) : 49% ● Ground-based (empirical) : 36% ● Space-based (empirical) : 15%	Distribution of principal investigators ● Academic 42% ● Government 34% ● Commercial 24%

FIGURE 3a. ACCOMMODATIONS COMPOSITE

AREA OF STUDY	FINDING
BACKGROUND	
Flight Requirements	Space Station Initial Operating Capability (IOC) - 1993 360 Days
Security Requirements	• Encryption of downlinked data. • Sample, payload, data security during transport and on ground. • Crew function security. • Government confidentiality regarding experimental techniques.
Sample Characteristics	<u>FORMS</u> — <u>DIMENSIONAL RANGES (IOC)</u> • Solutions .... 100 ml - 10 liters • Polycrystalline Rods .... 150 mm wide X 1 meter long • Sealed Growth Cells .... up to 250,000 cc • Sealed Ampoules .... 5-50 mm diameter X 50-250 mm long • Solid Sphere & Rod .... 5-20 mm diameter ; up to 100 mm long • Pressed Powders .... 1-50 grams
EQUIPMENT	
Required Experiment Apparatus	<u>APPARATUS</u> — <u>CURRENT STATUS</u> • Acoustic levitation system — Existing (DDM) • Combustion calorimeter — Required • Combustion furnace — Required • Combustion tunnel — Requried • Droplet/spray combustion facility — Requried • Electroepitaxial crystal growth system — Required • Electromagnetic levitator furnace — Required • Float zone solidification furnace — Required • High temperature isothermal furnace — Required • High temperature levitating furnace — Required • Modular crystal growth facility — Required • Directional solidification furnaces — Planned (AADSF/MEPF) • Slow solute diffusion system — Required • Solution chemical reactor system — Required • Solution crystal growth system — Existing (FES) • Ultrahigh temperature levitating furnace — Required • Vapor crystal growth system — Existing (VCGS)
Required Support Equipment (core items only)	<u>EQUIPMENT ITEM</u> — <u>AUTOMATION LEVEL</u> • High resolution video system — Semi • Mass measurement system — Full • Integrated optical microscopy lab — Manual • Integrated electronics lab — Manual • Sample cutting, polishing, & etching system — Manual • Standard modular lockers — N/A • Reconfigurable workbench — Manual • Tool/supplies locker — N/A • Tri-axis accelerometer system — Full • Attached external pallet — N/A • Automated gas distribution system — Full • Fluids dispensing system — Semi • Emergency provisions locker — N/A • Science airlock — N/A • Waste management system — Full • Central data storage/transceiver system — Full • Heat rejection system — Full • Power conditioning/distribution system — Full • Lighting system — Full

FIGURE 3b. ACCOMMODATIONS COMPOSITE (continued)

AREA OF STUDY	FINDING
ENVIRONMENT	
Microgravity	• Constant unidirectional: 1E-6g • Impulsive: Unknown • Additional flight experience is required to determine the sensitivity of individual processes. • Periodic dynamic: 1E-1g @ 10.0000 Hz 1E-3g @ 01.0000 Hz 1E-5g @ 00.1000 Hz 1E-6g @ 00.0100 Hz 1E-6g @ 00.0010 Hz 1E-6g @ 00.0001 Hz
Ambient	• Temperature: 21.0°C ± 2°C • Humidity: 50-60% relative humidity • Pressure: 14.7 psi ± 0.2 psi • Particulates: Class 10,000 clean room std. • Continuous Monitoring of Environmental Parameters
UTILITIES	

Power	DEMAND	IOC	FOC	SERVICE
	• Maximum power demand.....	40	100 kw.	• 115/230 vac (60/400 Hz)
	• Demand period..................	24	24 hrs.	
	• Demand frequency.............	30	30 days/mo	• Process power: ± 5% voltage
	• Average power demand......	40	100 kw.	(80% of load)
	• Demand period.................	24	24 hrs.	• Precision power: ± 0.1% freq.
	• Demand frequency............	30	30 days/mo.	± 4.0% volt.
	• Energy budget.................	28,800	72,000 kwh/mo.	• 24 - 36 vdc: ± 2.0 volts

Heat Rejection	THERMAL BUSSES	IOC	FOC	SERVICE
	• Maximum heat rejection rate	40	100 kw.	
	• Duration............................	24	24 hrs.	• High temp. liquid bus capable
	• Rejection temperature(s)....	90	90 °C nom.	of 100 kw load.
		4	4 °C nom.	• Low temp. liquid bus capable
	FORCED AIR LOOP			of 35 kw load.
	• Maximum heat rejection rate	10	20 kw.	• Forced air loop capable of 20
	• Duration...........................	24	24 hrs.	kw load.
	• Rejection temperature.......	46	46 °C	

Data Management	DIGITAL DATA	IOC	FOC	SERVICE
	• Maximum rate....................	50	200 kbps	
	• Generation period............	24	24 hrs.	• Central data storage/
	• Frequency.......................	30	30 days/mo.	transceiver system.
				• Distributed processing
	Interactive Audio..............	24	24 hrs/day	local area network
				• Dual audio links
	Live Video.......................	24	24 hrs/day	• High resolution/rate color video system

Waste Management		SERVICE
	GASES • A wide variety of gaseous elements and compound should be anticipated.	• Waste gas adsorption and venting system. • Gaseous hydrogen recovery system.
	LIQUIDS • A wide variety of liquid elements and compounds should be anticipated.	• Waste liquids filtration/ recovery and disposal system.
	SOLIDS • A wide variety of solid elements and compounds should be anticipated.	• Waste solids compaction and containment system

FIGURE 3c. ACCOMMODATIONS COMPOSITE (continued)

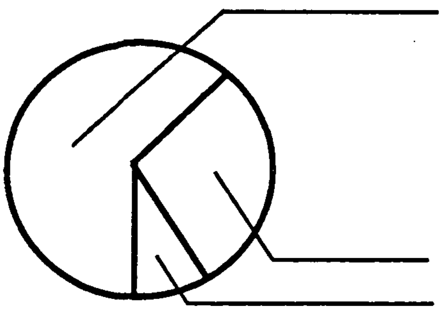
AREA OF STUDY	FINDING
Vacuum	| | IOC | FOC | | • Vacuum pressure: IOC 1E-3, FOC 1E-6 pa • Evacuation volume: IOC 2.00, FOC 2.00 cu m • Pumping rate: IOC 1,000, FOC 2,000 ℓ/sec **SERVICE** • Lab-internal vacuum pumping utility. • High vacuum wake shield facility.
Crew Support	**IOC:** • Sample preparation/loading • Experiment initiation • Process monitoring • Real-time experiment interaction • Post-experiment sample analysis • Interactive communications **FOC:** • Sample loading/unloading • Process monitoring/adjustment • Interactive communications
LOGISTICS	
Primary Payloads	• Payload mass (range):............200-2500 kg • Payload volume (range):.........0.5-3.0 cu m
Supplies & Support Equipment	• GTS stowage mass (range):.....25-2500 kg • GTS stowage volume (range):..0.5-3.0 cu m • STG stowage mass (range):.....25-2500 kg • STG stowage volume (range):..0.5-3.0 cu m
Primary Payloads / Supplies & Support Equipment: RESUPPLY INTERVAL	• 90 days @ IOC • Provisos: 1. Minimal on-orbit characterization capability. 2. Frequent interactive audio/video communications.
Consummables	**LOW VOLUME** • Transport in standardized modular lockers and on-orbit transfer via standard containers to fluids dispensing system or payload subsystem. **HIGH VOLUME** • Transport in standardized vessels with storage on external attached pallet and on-orbit transfer via automated distribution systems.
Ground-Based Support Facilities	• High fidelity mockup for compatibility testing, training, and ground checkout activities. • Wide area networking to allow users to perform payload operations and control (POCC) functions at their laboratory.
SAFETY	
Hazards Assessment	**PARAMETRIC HAZARDS** • Temperature extreme:......3500. deg C • Pressure extreme:............3E+5 pa • Vacuum extreme:..............1E-6 pa • Current extreme:............... 80 amps **MATERIAL HAZARDS** • Toxicity..............................Assumed • Corrosivity..........................Assumed • Flammability........................Assumed **PROCESS HAZARDS** • Explosion: Potential for volatile process gases (hydrogen). • Radiation: Potential for electron beam, x-ray, and RF radiation.
SOURCES CONSULTED	 USERS[1].....................................60% • Scientific/Commercial........32% • Hardware Development..... 7% • Hardware Integration......... 6% • Mission Management........ 5% • Operations..................... .. 6% • Flight Crew...................... 4% OPEN LITERATURE......................30% SYMPOSIA/CONFERENCES........10% 1 Includes "Design Requirements to make the Space Station user friendly", Pace & Waite, Inc. (1985)

FIGURE 3d. ACCOMMODATIONS COMPOSITE (concluded)

1.2 Core Equipment

Support equipment for microgravity science research encompasses the full complement of typical equipment found in ground-based materials science laboratories. Apparatus and instrumentation for (1) sample transport and storage, (2) experiment control and monitoring, (3) process data acquisition, (4) sample characterization, (5) materials handling, and (6) safety assurance may each be required to support specific experiments. These equipment items cannot be comprehensively defined at this time due to the nature of basic research and the breadth of potential experimentation over the next several decades.

A limited complement of **core equipment** has been suggested by various representatives of the research community. These items represent the minimum functions required in a wide-spectrum materials science laboratory. Twenty core equipment items have been identified and the general performance requirements defined. Figure 4 lists each item and indicates the broad base of utilization.

	CORE EQUIPMENT	USER GROUPS [1]						MASS (Kg)	VOL (m^3)	AUTOMATION LEVEL	TRL [2]
		E	M	G	F	C	P				
01	HIGH RESOLUTION VIDEO SYSTEM	●	●	●	●	●	●	20	0.2	SEMI	1
02	MASS MEASUREMENT SYSTEM	●	●	●	●	●	●	50	0.3	FULL	8
03	INTEGRATED OPTICAL MICROSCOPY LAB	●	●	●	●	●	●	100	1.0	MANUAL	2
04	INTEGRATED ELECTRONICS LAB	●	●	●	●	●	●	100	1.0	MANUAL	2
05	SAMPLE CUTTING, POLISHING AND ETCHING SYSTEM	●	●	●	●		●	100	0.3	MANUAL	2
06	STANDARD MODULAR LOCKERS	●	●	●	●	●	●	120	0.2	N/A	2
07	RECONFIGURABLE WORKBENCH	●	●	●	●	●	●	30	0.1	MANUAL	2
08	TOOL/SUPPLIES LOCKER	●	●	●	●	●	●	100	0.5	N/A	8
09	ACCELEROMETER SYSTEM	●	●	●	●	●	●	200	0.2	FULL	2
10	ATTACHED EXTERNAL PALLET	●	●	●	●	●	●	5000	N/A	N/A	8
11	AUTOMATED GAS DISTRIBUTION SYSTEM	●	●	●	●	●	●	1000	0.5	SEMI	8
12	FLUIDS DISPENSING SYSTEM	●	●	●	●	●	●	200	0.6	N/A	2
13	EMERGENCY PROVISIONS LOCKER	●	●	●	●	●	●	50	0.5	N/A	8
14	SCIENCE AIRLOCK	●	●	●	●	●	●	1000	4.5	FULL	8
15	WASTE MANAGEMENT SYSTEM	●	●	●	●	●	●	1000	1.0	FULL	1
16	CENTRAL DATA STORAGE/TRANSCEIVER SYSTEM	●	●	●	●	●	●	100	0.5	FULL	1
17	HEAT REJECTION SYSTEM	●	●	●	●	●	●	1000	1.0	FULL	8
18	POWER CONDITIONING/DISTRIBUTION SYSTEM	●	●	●	●	●	●	2000	1.0	FULL	8
19	LIGHTING SYSTEM	●	●	●	●	●	●	750	0.5	FULL	8
20	ENVIRONMENTAL CONTROL/LIFE SUPPORT SYSTEM	●	●	●	●	●	●	2000	2.0	FULL	8

1. USER GROUPS
E Electronic Materials, M Metals and Alloys, G Glasses and Ceramics, F Fluids and Transport Phenomena, C Combustion Science, P Polymer Science

2. TECHNOLOGY READINESS LEVEL : See Figure 5.

$\overline{\text{TRL}}$ 4.8

Figure 4. Core Equipment Requirements

A wide variety of additional support equipment can be anticipated; however, these items are experiment-specific and may be accommodated via Standard Modular Lockers (Core Equipment Item No. 06) as the need arises. The high interest expressed by users for this item is associated with the demonstrated versatility of the current shuttle middeck locker.

The **technology readiness level** (TRL) has been determined for each core equipment item. These levels are defined in Figure 5 and range from Full Operational Capability (level 8) to Technology Assessment Required (level 1). The average TRL is shown to be 4.8, indicating that significant equipment development efforts will be necessary in order to meet Initial Operating Capability (IOC) requirements.

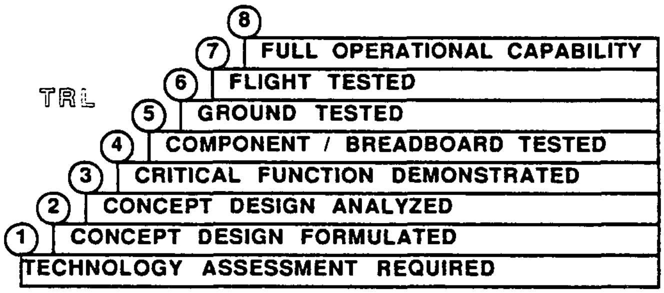


Figure 5. Technology Readiness Levels

Following core equipment identification, supporting data and information were assembled in each of the following areas:

PURPOSE

- Functional Description
- Rationale for Inclusion
- Impact of Exclusion
- Equipment User Groups

TECHNOLOGY STATUS

- Technology Readiness Level
- Equipment Availability
- Development Needs

PERFORMANCE ENVELOPE

- Capabilities Range
- Interface Provisions
- Automation Level
- Observation Requirements
- Data Recording/Transmission
- Maintenance
- Safety/Hazards Assessment
- Physical Parameters

RECOMMENDATIONS

The data and information obtained is provided in detail in Appendix B: Core Equipment Requirements.

1.3 Experiment Apparatus

Unique experiment apparatus are required for each stage of the technology development cycle. The transition from basic research to applied research and process development may involve as many as three generations of experimental hardware. These stages can be defined as follows.

Stage 1 - Basic Phenomenological Research: During this period, fundamental properties of the microgravity environment are explored. Such topics as fluid, gas, and interface dynamics are investigated, and empirical data is collected to support theoretical models. Phenomenological research of this nature is performed in support of concurrent program objectives and contributes valuable data applicable to a variety of applied investigations. In doing so the science base is expanded and overall laboratory productivity is enhanced.

Stage 2 - Applied Process Research: As sufficient basic data is obtained and theoretical models validated, applied investigations involving the refinement of specific processes are initiated. Such "Demonstration of Principle" experiments provide confirmation of the benefits of microgravity materials processing and serve as precursors to commercial process development.

Stage 3 - Prototype Production Research: Having established the technical feasibilty of a given process, investigations are directed toward scale-up factors and automation. Resource requirements such as space and power may increase by an order of magnitude, and crew requirements may decrease by a similar proportion. Following successful demonstration, the mature technology enters a commercialization phase, and the technology development cycle, as it relates to the Space Station laboratory, is completed. Further process refinements, advances in automation, and operational logistics are implemented by the developer.

Excluding start-up costs, the technology development cycle for space-based processes is identical to that of ground-based processes. In reviewing the cycle with potential Space Station users, two points were consistently encountered.

- The availability of basic equipment is critical to stage 1.
- Adequate resources are critical to stage 3.

The current microgravity science research classes are, in general, process oriented. The basic experiment apparatus necessary to expand the science base are listed in Figure 6. Among the seventeen apparatus identified, three are currently available and one category is presently planned. The remaining thirteen apparatus represent fundamental requirements to support basic research. Existing apparatus developed under the Space Processing Applications Rocket (SPAR 1974-79) program do not meet requirements for advanced research on Space Station.

	NO. OF RESEARCH CLASSES SUPPORTED (1 2 3 4 5)	MASS (Kg)	VOL (m^3)	EA[1]	TRL[2]
ACOUSTIC LEVITATION SYSTEM (DDM)	5	500	1.7	●	8
COMBUSTION CALORIMETER	2	100	2.2	○	2
COMBUSTION FURNACE	2	200	2.4	○	2
COMBUSTION TUNNEL	2	200	0.6	○	2
DROPLET/SPRAY COMBUSTION FACILITY	2	100	1.3	○	2
ELECTROEPITAXIAL CRYSTAL GROWTH SYSTEM	1	250	1.1	○	2
ELECTROMAGNETIC LEVITATOR FURNACE	4	350	1.1	○	5
FLOAT ZONE SOLIDIFICATION FURNACE	4	750	1.7	○	5
HIGH TEMPERATURE ISOTHERMAL FURNACE	4	200	0.7	○	2
HIGH TEMPERATURE LEVITATING FURNACE	4	250	1.1	○	2
MODULAR CRYSTAL GROWTH FACILITY	3	500	1.7	○	2
DIRECTIONAL SOLIDIFICATION FURNACES	3	250	1.1	⊖	5
SLOW SOLUTE DIFFUSION SYSTEM	3	50	0.2	○	2
SOLUTION CHEMICAL REACTOR SYSTEM	3	350	1.1	○	2
SOLUTION CRYSTAL GROWTH SYSTEM (FES)	3	625	1.7	●	8
ULTRAHIGH TEMPERATURE LEVITATING FURNACE	3	350	1.1	○	1
VAPOR CRYSTAL GROWTH SYSTEM (VCGS)	3	76	0.8	●	8

1. EQUIPMENT AVAILABILITY: ● EXISTING ⊖ PLANNED ○ REQUIRED

2. TECHNOLOGY READINESS LEVEL : See Figure 5.

$\overline{TRL}$ 3.5

Figure 6. Experiment Apparatus Requirements

The **technology readiness level** has been identified for each item of experiment apparatus. The average TRL is shown to be 3.5, indicating that significant equipment development efforts will be necessary in order to meet IOC requirements.

Supporting data and information on experiment apparatus were assembled in each of the following areas:

- Required Capability
- Current Capability
- Development Needs
- Commonality Assessment
- Risk Assessment
- Recommendation

This information is provided in detail in Appendix C: Experiment Apparatus Requirements. Information on existing apparatus and capabilities have been previously prepared and are available under separate cover.[4]

1.4 Conclusion

Materials processing research in the microgravity environment of space has been limited primarily by equipment availability and flight opportunities. In those cases where limitations have been overcome, significant and highly encouraging flight results have been achieved. Notable among these is the Spacelab-3 mission during which Mercuric Iodide and Triglycine Sulfate crystals were successfully grown by vapor and solution growth techniques respectively.

The prospect of a dedicated and permanently manned on-orbit materials science laboratory represents an opportunity for the United States' public and private research communities to accelerate successful demonstrations and lead in the development of space resources. Discussions with a broad base of potential users indicate that *judicious selection of core equipment and basic experiment apparatus, coupled with* adequate resource accommodations during the growth stage, are key factors to the achievement of this objective.

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[4] "Microgravity Science and Applications: Experiment Apparatus and Facilities," Wyle Laboratories interim report, NASA Contract NAS8-35615, 1984.

APPENDIX A

RESEARCH CLASS ACCOMMODATION REQUIREMENTS

The following classes of research are each recommended as suitable for inclusion in a Microgravity Science and Applications laboratory module at the initial operating capability (IOC) of the planned NASA Space Station.

The accommodation requirements for each research class have been derived as an envelope of the functional requirements for related experiments having similar characteristics, objectives, and equipment needs. Each research class represents the potential to perform numerous individual experiments involving a range of materials, phenomena, and/or processes.

Page

The area of BIOTECHNOLOGY has been specifically excluded from this study effort. The exclusion does not suggest any lack of suitability.

1.0 BACKGROUND

1.1 RESEARCH OBJECTIVES

Primary objective is to develop a fundamental understanding of the dynamics of single and multi-phase material systems undergoing transitions in the microgravity environment of space. Such phenomena are significantly simplified under microgravity conditions due to the virtual abscence of gravity induced convection and buoyancy which complicates the understanding of mass transport dynamics under one-g conditions. The space environment allows investigations in subtle transport processes, thermophysical properties measurement, and normally "weak" forces such as interfacial tension, capillary flow, and coupled flux phenomena. The development of theoretical models, followed by validation through empirical research, provides a basis from which to quantify fluid flow and concentration fields. This important step, in turn, allows applied research on specific materials systems and accelerates the progress of commercial endeavors. A secondary objective is therefore to expand upon the fundamental knowledge gained and apply it to both ground-based and on-orbit materials processing programs. In doing so the science base grows and a foundation is created upon which to build future efforts in microgravity research having potential across the commercial spectrum.

1.2 POTENTIAL APPLICATIONS

Fundamental quantitative descriptions of fluid, gas and interfacial dynamics under microgravity conditions will permit advances in both ground-based and on-orbit research programs. The potential applications are diverse and apply equally to investigations in electronic materials, glasses and ceramics, combustion processes, metals and alloys, polymers, and biomaterials. In each case the potential to develop unique and/or improved materials and processes will be enhanced.

1.3 PHENOMENA OF INTEREST

Phase Transitions, Mass Transport, Solutal Diffusion, Capillarity, Surface Tension, Nucleation

1.4 PROCESSES OF INTEREST

Changes of State

1.5 PRODUCTS OF INTEREST

Validated Theoretical Models, Supporting Empirical Data

1.6 PROPERTIES OF INTEREST

Stability, Rates of Change, Thermophysical and Electrokinetic Characteristics, Critical Points

1.7 HISTORY OF INVESTIGATION

Virtually all on-orbit research projects performed to date have focused on the acquisition of basic data in fluid, gas, and interface dynamics as a precursor to applied product/process research. Considerable ground-based efforts have been performed in the development of theoretical models supporting each of the flight programs. Approximately 150 investigations can be identified.

1.8 KEY INDIVIDUALS

Coriell, S. / Fowlis, W. / Hanratty, T. / Hart, J. / Langlois, W. / Lipa, J. / Rosenberger, F. / Saville, D. / Szekely, J. / Labus, T. / Lal, R. / Wilcox, W. / Subramanian, S.

1.9 FLIGHT REQUIREMENT

1993 Space Station Initial Operating Configuration (IOC)
360 Days

Status: Conceptual (> 5 Year Horizon)

1.10 SECURITY CONSIDERATIONS

Proprietary research can be anticipated. Provisions arerequired for:
(1) encryptionof downlinked data,
(2) crew function security,
(3) sample, payload, and video tape security during transport, and
(4) government confidentiality regarding specific experimental techniques. On-orbit PI accommodations are highly desirable.

1.11 PRIMARY EQUIPMENT

Primary equipment requirement is for mission-specific experiment apparatus designed to perform unique phenomenological research as required to develop and/or validate theoretical concepts. Due to the nature of basic research specific apparatus cannot be well defined at this time. As problems are encountered or identified, a specific apparatus may be conceived that will allow investigation and quantification of the inadequately understood phenomena. In addition, considerable research can be anticipated to occur with the experiment apparatus used for other flight projects. Accommodation requirements for apparatus in the Fluid, Gas, and Interface Dynamics research class must therefore be represented as an envelope of all potential functional requirements.

Descriptions located in "Experiment Apparatus" files.

1.12 SUPPORT EQUIPMENT

The following **Core Equipment Items** are required:

- High Resolution Video System
- Mass Measurement System
- Integrated Optical Microscopy Lab
- Integrated Electronics Lab
- Sample Cutting, Polishing, & Etching System
- Standardized Modular Lockers
- Reconfigurable Workbench
- Tool/Supplies Locker
- Tri-Axis Accelerometer System
- Attached External Pallet
- Automated Gas Distribution System
- Fluids Dispensing System
- Emergency Provisions Locker
- Science Airlock
- Waste Management System
- Central Data Storage/Transceiver System
- Heat Rejection System
- Power Conditioning/Distribution System
- Lighting System
- Environmental Control & Life Support System

Numerous additional support equipment items can be anticipated. These items are mission-specific and cannot be comprehensively defined at this time due to the nature of basic research. It is expected that mission-specific items can be accommodated via standardized storage lockers as the need arises.

Descriptions located in "Core Equipment" files

1.13 SAMPLE CHARACTERISTICS

Samples cannot be comprehensively defined. A complete range of solids, liquids, and gases must be assumed.

2.0 ENVIRONMENTAL REQUIREMENTS

2.1 MICROGRAVITY ENVIRONMENT

Microgravity environment sensitivities are anticipated to be the subject of many research efforts. Identification and quantification of constant unidirectional, periodic dynamic, and impulsive forces typical of the laboratory environment is a singular research objective.

2.2 AMBIENT ENVIRONMENT

Temperature: 21.0 deg C +/- 2.0 deg C
(constant record required)
Pressure: 14.7 psi +/- 0.2 psi
(constant record required)
Humidity: 70% relative humidity +/- 10%
(constant record required)

2.3 ACOUSTIC ENVIRONMENT

No acoustic output or susceptibility identified at this time. Evaluation will have to be performed for each unique experiment as it is conceived.

2.4 RADIATION ENVIRONMENT

No radiation output or susceptibility identified.

2.5 ISOLATION REQUIREMENT

All research activities are anticipated to be performed in mission-specific experiment apparatus isolated from the pressurized laboratory environment. Required experiment environments (temperature, pressure, composition) are to be accommodated in the design of the specific apparatus during the payload planning phase. The lab environment should minimize large magnitude swings in environmental parameters that have the potential to affect operation of the experiment apparatus subsystems. Continuous monitoring is required.

3.0 UTILITY REQUIREMENTS

3.1 POWER

Provisions for up to 15 kW of instantaneous power may be required during the life of the laboratory. At IOC a reduced power resource is anticipated, however accommodations for the growth phase must be included in the baseline configuration. Experiment durations may be on the order of 0.5 - 4.0 hours at average power draws of up to 4.0 kW. Values provided below represent an extreme requirement intended to envelope all potential experimentation.

Operating Power:..................15.00 kw
Typical Operating Cycle:..........4.00 hrs
Energy per Cycle:................60.00 kwh
Electric Service:......115/230 vac (60 Hz)
............28 vdc +/- 4%

3.2 HEAT REJECTION

Heat rejection requirements reflect the peak power loads anticipated. A liquid cooling loop capable of providing a sink to 20 deg C will accommodate most currently envisioned research. Experiments requiring cryogenic cooling can incorporate the necessary mission-specific apparatus via Standardized Storage Lockers (Core Equipment Item).

Peak Heat Rejection:.............15.00 kw
Sink Temperature:................20.00 deg C

3.3 DATA MANAGEMENT

Data acquisition, reduction, and display to be performed at the payload via integral microcomputer. A Central Data Storage/Transceiver and High Resolution Video System (Core Equipment Items) are required to establish principal investigator telepresence and accelerate research productivity. Parameters for data quality and quantity are provided as extremes in order to accommodate currently undefined experiments that are anticipated to occur over the life of the laboratory.

Digital Data Rate:...............16.00 kbps
Generation Period:...............20.00 hrs
Interactive Audio:...............20.00 hrs/day
Live Video:......................20.00 hrs/day

3.4 WASTE MANAGEMENT

The following are considered essential Core Equipment Items: (1) Gas Evacuation/Adsorption/Venting System, (2) Solids Compaction/Containment System, (3) Liquids Filtration/Purification System. All waste materials should be assumed toxic.

Solids:

Liquids:

Representative solid, liquid, and gaseous waste materials are listed for the remaining ten research classes.

Gases:

3.5 VACUUM

Vacuum requirements cannot be fully defined, however, it is anticipated that extreme conditions may be required to support as yet undefined research during the life of the lab. Provisions should therefore be made to accommodate a nominal requirement during the Space Station growth stage. The value provided below applies an internal lab utility. The availability of a wake shield facility capable to 10 EE-14 torr is also highly desirable.

Vacuum Pressure:..................0.000001 pa
Evacuation Volume:................0.085000 cu m

3.6 CREW SUPPORT

Crew support will be required for experiment initiation, monitoring, and in some cases real-time interaction. The nature of basic research precludes the ability to fully automate experiments. The capability to rerun experiments with modified experimental design can greatly enhance research productivity. A scientist skill level is desirable.

4.0 LOGISTIC REQUIREMENTS

4.1 SUPPLY SCHEDULE

Resupply at 90 day intervals is considered adequate provided accommodations are available for the downlinking of video/digital data, followed by interactive audio sessions.

Typical Payload Mass:...........300.00 kg
Typical Payload Volume:...........0.84 cu m
GTS Stowage Mass:................60.00 kg
GTS Stowage Volume:...............0.25 cu m
STG Stowage Mass:................60.00 kg
STG Stowage Volume:...............0.25 cu m

GTS: Ground to Station
STG: Station to Ground

4.2 CONSUMMABLES

Small volume mission-specific consummable materials require transport in Standardized Modular Lockers (Core Equipment Item) and on-obit transfer via standard containers to the Fluids Dispensing System (Core Equipment Item), or an integral payload subsystem. Large volume consummables (gases) require storage on an Attached External Pallet (Core Equipment Item) and transfer via automated distribution system for end-use.

5.0 SAFETY

5.1 HAZARDS ASSESSMENT

Hazardous chemicals can be anticipated, including radioactive elements used as tracers. Cryogenic temperatures and extreme vacuums may also be required for currently unplanned experiments. All experiments should be assumed hazardous.

ADDENDUM

1.0 BACKGROUND

1.1 RESEARCH OBJECTIVES

Primary objective is the examination of analytical models for numerous combustion phenomena including: (1) gas mixture flammability, (2) particle cloud combustion, (3) liquid pool burning, (4) droplet burning, (5) single solid particle combustion, and (6) smoldering. Determination of base mechanisms will allow model validation and/or refinement and serve as a foundation on which to build an understanding of more complex combustion processes. Secondary objective is to establish research capability at micro-g, allowing investigators (1) to use suitably contained liquid/gaseous/solid fuels, (2) to specify/establish composition and pressure level of combustion atmosphere, (3) to characterize experiment with common instruments and specialized diagnostic equipment, and (4) to study combustion processses visually by direct observation and video coverage and to obtain time histories of pertinent parameters.

1.2 POTENTIAL APPLICATIONS

Spacecraft fire safety is near term application. Techniques for fire extinguishment in space are required, current design is to oversafe potentially hazardous situations at high cost and inefficiency. Historically, combustion science has shown relatively short incubation periods for scientific concept translation into practical applications. Increased fuel combustion efficiency has significant technological impact on broad range of ground based processes and represents an achievable goal.

1.3 PHENOMENA OF INTEREST

Combustion of: Gas Mixture/Particle Cloud/ Liquid Pool/Droplet/Particle/Porous Solid

COMBUSTION SCIENCE

1.4 PROCESSES OF INTEREST

Combustion Kinetics for Liquid, Solid, and Gaseous Materials

1.5 PRODUCTS OF INTEREST

Validated Analytical Models for Combustion Phenomena / Realistic Space Vehicle Safety Criteria

1.6 PROPERTIES OF INTEREST

Flammability and Extinction Limits, Propagation Rates, Flame Structure and Stability

1.7 HISTORY OF INVESTIGATION

Extensive ground-based research performed in LeRC drop towers & labs. Scientific advance is now dependent on extended periods of micro-g available only on orbit. Planned shuttle investigations include (1) solid surface combustion 1985-86, (2) particle cloud combustion 1987, & (3) droplet burning 1987. ESA announcement of opportunity issued Feb.1985; 5 experiments to be selected for Spacelab. American progress limited by flight opportunities and schedule slippage.

1.8 KEY INDIVIDUALS

Berlad,A. / Sacksteder,K. / Bartok,W. / Levine, S. / Myers,P. / Palmer,H. / Penner,S. / Strehlow, R. / Williams,F. / Peters,B. / Altenkirch,R. / Edelman,R. / Pagni,P. / Sirignano,W.

1.9 FLIGHT REQUIREMENT

1993 Space Station Initial Operating Configuration (IOC)
360 Days

Status: Conceptual (> 5 Year Horizon)

1.10 SECURITY CONSIDERATIONS

Proprietary research can be anticipated. Provisions arerequired for:
(1) encryptionof downlinked data,
(2) crew function security,
(3) sample, payload, and video tape security during transport, and
(4) government confidentiality regarding specific experimental techniques. On-orbit PI accommodations are highly desirable.

1.11 PRIMARY EQUIPMENT

Primary equipment includes mission-specific experiment apparatus designed to perform phenomenological research as required to develop and/or validate theoretical concepts. Four equipment items have been identified including: (1) Combustion Tunnel, (2) Combustion Calorimeter, (3) Droplet/Spray Combustion Facility, and (4) Combustion Furnace. A wide variety of supporting diagnostic hardware are also required. These items may be accommodated in a mission-specific mode via Standardized Storage Lockers (Core Equipment Item).

Descriptions located in "Experiment Apparatus" files.

1.12 SUPPORT EQUIPMENT

The following **Core Equipment Items** are required:

- ● High Resolution Video System
- ● Mass Measurement System
- ● Integrated Optical Microscopy Lab
- ● Integrated Electronics Lab
- O Sample Cutting, Polishing, & Etching System
- ● Standardized Modular Lockers
- ● Reconfigurable Workbench
- ● Tool/Supplies Locker
- ● Tri-Axis Accelerometer System
- ● Attached External Pallet
- ● Automated Gas Distribution System
- ● Fluids Dispensing System
- ● Emergency Provisions Locker
- ● Science Airlock
- ● Waste Management System
- ● Central Data Storage/Transceiver System
- ● Heat Rejection System
- ● Power Conditioning/Distribution System
- ● Lighting System
- ● Environmental Control & Life Support System

Numerous additional support equipment items can be anticipated. These items are mission-specific and cannot be comprehensively defined at this time due to the nature of basic research. It is expected that mission-specific items can be accommodated via standardized storage lockers as the need arises.

Descriptions located in "Core Equipment" files

1.13 SAMPLE CHARACTERISTICS

Samples include full range of liquids, solids, and gases as required to meet specific research objectives. Toxic/corrosive fuels are anticipated in small quantities. 1.0 liter of each fuel to be tested is considered adequate for a 90 day series of experiments. Samples have an indefinite shelf life.

2.0 ENVIRONMENTAL REQUIREMENTS

2.1 MICROGRAVITY ENVIRONMENT

Constant Unidirectional:....................1E-5g
Periodic Dynamic:.........................Unknown
Impulsive:................................Unknown

Additional flight experience is required to further define g-level sensitivity of specific combustion phenomena.

2.2 AMBIENT ENVIRONMENT

Temperature: 21.0 deg C +/- 2.0 deg C
(constant record required)
Pressure: 14.7 psi +/- 0.2 psi
(constant record required)
Humidity: 70% relative humidity +/- 10%
(constant record required)

2.3 ACOUSTIC ENVIRONMENT

No acoustic output or susceptibility identified.

2.4 RADIATION ENVIRONMENT

No radiation output or susceptibility identified.

2.5 ISOLATION REQUIREMENT

All research activities are anticipated to be performed in mission-specific experiment apparatus isolated from the pressurized laboratory environment. Required experiment environments (temperature, pressure, composition) are to be accommodated in the design of the specific apparatus during the payload planning phase. The lab environment should minimize large magnitude swings in environmental parameters that have the potential to affect operation of the experiment apparatus subsystems. Continuous monitoring is required.

3.0 UTILITY REQUIREMENTS

3.1 POWER

Operating power for combustion experiments is typically < 1.0 kw over brief intervals (< 30 minutes). Laser diagnostic equipment is anticipated at higher levels up to 20.0 kw. Experimentation performed in the combustion furnace may require up to 10.0 kw over a one hour period. Values provided below represent the peak requirement.

Operating Power:.................20.00 kW
Typical Operating Cycle:..........1.00 hrs
Energy per Cycle:................20.00 kWh
Electric Service:......115/230 vac (60 Hz)
....................28 vdc

3.2 HEAT REJECTION

Heat rejection values reflect peak power requirements of potential laser diagnostic equipment. Actual experiment heat rejection requirement is anticipated to be less than 10.0 kw.

Peak Heat Rejection:.............20.00 kw
Sink Temperature:................80.00 deg C

3.3 DATA MANAGEMENT

Data acquisition, reduction (where required), and display (where required) to be performed at the payload via integral microcomputer subsystems having high data rate capability. Central Data Storage/Transceiver System (Core Equipment Item) required to accommodate temporary (90 minute) data storage and to serve as interface for downlink. High Resolution Video System (Core Equipment Item) required to achieve high research productivity. Best available technology at IOC perceived critical.

Digital Data Rate:................1.60 kbps
Generation Period:...............20.00 hrs
Interactive Audio:...............20.00 hrs/day
Live Video:......................20.00 hrs/day

3.4 WASTE MANAGEMENT

A Gas Evacuation, Adsorption, & Purge System is required to remove waste products and purge the experiment environment prior to next experiment run. Quantities cannot be accurately estimated without further flight experience.

Solids: Oxidized particulates in trace quantities and partially oxidized small (< 0.5 kg) solids of variable composition.

Liquids: Cleaning solvents and hydrocarbon fuel pools.

Gases: Noxious hydrocarbon vapors, oxidizers, and inert gases.

3.5 VACUUM

Access to Gas Evacuation/Adsorption/Venting System (Core Equipment Item) is considered essential to accommodate apparatus purge and waste product removal prior to rerun of experiment and /or initiation of next experiment.

Vacuum Pressure:..................0.20 pa
Evacuation Volume:................2.00 cu m

3.6 CREW SUPPORT

Nature of basic research precludes ability to fully automate experiment apparatus. Process monitoring and real-time modification is essential to experiment design and research productivity. Crew support will be required for experiment setup, initiation, process monitoring and evaluation, parameter adjustment, experiment rerun, and post-experiment diagnostics. Combustion scientist skill level will yield highest research productivity; technologist acceptable at the expense of research timeline.

4.0 LOGISTIC REQUIREMENTS

4.1 SUPPLY SCHEDULE

Resupply at 90 day interval is adequate at IOC phase. Rapid sample return is not required provided that video, and digital data can be transmitted for ground-based evaluation and followed by interactive audio sessions. 90 day interval is required to changeout experiment apparatus/support systems.

Typical Payload Mass:...........250.00 kg
Typical Payload Volume:...........2.50 cu m
GTS Stowage Mass:................50.00 kg
GTS Stowage Volume:...............0.25 cu m
STG Stowage Mass:................50.00 kg
STG Stowage Volume:...............0.25 cu m

GTS: Ground to Station
STG: Station to Ground

4.2 CONSUMMABLES

Small volume mission-specific consummable materials require transport in Standardized Modular Lockers (Core Equipment Item) and on-obit transfer via standard containers to the Fluids Dispensing System (Core Equipment Item), or an integral payload subsystem. Large volume consummables (gases) require storage on an Attached External Pallet (Core Equipment Item) and transfer via automated distribution system for end-use.

5.0 SAFETY

5.1 HAZARDS ASSESSMENT

Provisions for handling toxic/corrosive materials and noxious gases are required. Experiment apparatus require design for failsafe operation via mechanical/electrical interlocks. Deluge type fire suppresion subsystem employing Halon 1301 at 6% distribution concentration over 4.0 seconds has been recommended as backup. Safety relief in excess of 30.0 psia to be provided via burst disc design on all pressurized vessels. All safety requirements can be accommodated during payload design phase.

ADDENDUM

POLYMER SCIENCE

1.0 BACKGROUND

Polymer Science is the study of order within long-chain molecules composed of repeated units covalently bound. Structurally, polymers include a backbone forming the basic chain structure and side groups of varying atomic structure having a complex arrangement in space (bent, folded, coiled) termed conformation. Properties of these complex macromolecules depend on nature of the backbone, size/constitution of side groups, chain length/conformation, and temperature. Synthesis techniques encompass: (1) suspension polymerization, including formation of catalyst substrates via precipitation, (2) gas phase polymerization via physical vapor transport catalyzed by heterogeneous surfaces, and (3) crytallization from melts forming polymeric materials. The microgravity environment permits virtual elimination of buoyancy driven convection/sedimentation and consequent thermal/structural gradients, currently governing ground-based polymerization processes. The implications are extensive, compelling systematic investigation of basic polymer physics/chemistry with the objective of elucidating fundamental process kinetics as a precursor to the engineering of advanced polymer materials having very high molecular order, controlled structure, chemical purity, and myriad applications as both catalysts and end-products. The processes of polymer formation and the consequences of physical and chemical properties represent potentially high payoff technologies for both space and ground utilization.

1.1 RESEARCH OBJECTIVES

1.2 POTENTIAL APPLICATIONS

Diverse applications have been identified including: fibers, catalysts, composites, films, substrates, interpenetrating networks (IPN), thermoplastics, ultrapure materials, uniform vesicles, initiators, viscoelastic fluids, degradation resistant materials, electrically conductive/semiconductive polymers and light conductive polymers. In each case, the structural/chemical purity may significantly extend the performance capabilities of existing materials and/or permit bulk production of new forms.

1.3 PHENOMENA OF INTEREST

Structural/Thermal Gradients, Coalescence, Phase Transition, Nucleation, Crystallization, Adsorption

1.4 PROCESSES OF INTEREST

Solution Polymerization, Gas Phase Polymerization, Melt Crystallization

1.5 PRODUCTS OF INTEREST

Catalysts, Composites, Thin Films, Thermoplastics, Microencapsulants, Fibers, Unique Macromolecules

1.6 PROPERTIES OF INTEREST

Degradation Resistance, Structural/Chemical Purity, Chemical Reactivity, Stability, Conductivity

1.7 HISTORY OF INVESTIGATION

Flight research limited to successful production of monodisperse latex spheres currently used as NBS reference standard (Vanderhoff et al), physical vapor transport of organic solids (3M-proprietary), and biological two-phase acqueous polymer phase partitioning (Brooks and Harris). Research progress limited by available experiment apparatus and flight opportunities. Numerous ground studies underway as potential flight precursors. Industrial research expansive in support of ground processes since 1940's.

1.8 KEY INDIVIDUALS

Vanderhoff, J. / Egbert, W. / Caruthers, J. / Connor, W. / El-Aasser, M. / Gardland, Z. / Harris, M. / Brooks, D. / Koenig, J. / Pearce, E. / Chan, J. / Porter, R. / Runge, M. / White, J. / Mark, H.

1.9 FLIGHT REQUIREMENT

1993 Space Station Initial Operating Configuration (IOC)
360 Days

Status: Conceptual (> 5 Year Horizon)

1.10 SECURITY CONSIDERATIONS

Proprietary research can be anticipated. Provisions arerequired for:
(1) encryptionof downlinked data,
(2) crew function security,
(3) sample, payload, and video tape security during transport, and
(4) government confidentiality regarding specific experimental techniques. On-orbit PI accommodations are highly desirable.

1.11 PRIMARY EQUIPMENT

Primary equipment requirement is for solution chemical reactors to support fundamental studies in the kinetics of polymer formation. Investigators have cited the continuing need to perform basic research prior to the planning of advanced experimental apparatus for applied product research. Following the establishment of theoretical models for fluid dynamics under microgravity conditions, and the performance of validating empirical research, requirements are anticipated to escalate to prototype production systems during the space station growth phase. Such systems may include catalyst production systems, thin film deposition systems, melt crystallization systems, and a broad variety of hardware for advanced applied research. This equipment cannot be accurately projected at this time due to the nature of basic research. Primary concern of the scientific community is to establish fundamental research capability in space, prior to planning applied investigations.

Descriptions located in "Experiment Apparatus" files.

1.12 SUPPORT EQUIPMENT

The following **Core Equipment Items** are required:

- High Resolution Video System
- Mass Measurement System
- Integrated Optical Microscopy Lab
- Integrated Electronics Lab
- Sample Cutting, Polishing, & Etching System
- Standardized Modular Lockers
- Reconfigurable Workbench
- Tool/Supplies Locker
- Tri-Axis Accelerometer System
- Attached External Pallet
- Automated Gas Distribution System
- Fluids Dispensing System
- Emergency Provisions Locker
- Science Airlock
- Waste Management System
- Central Data Storage/Transceiver System
- Heat Rejection System
- Power Conditioning/Distribution System
- Lighting System
- Environmental Control & Life Support System

Numerous additional support equipment items can be anticipated. These items are mission-specific and cannot be comprehensively defined at this time due to the nature of basic research. It is expected that mission-specific items can be accommodated via standardized storage lockers as the need arises.

Descriptions located in "Core Equipment" files

1.13 SAMPLE CHARACTERISTICS

Samples are expected to consist primarily of encapsulated seed materials and suspension solutions prepared in ground-based labs in batch modes. Quantities may range from 100 ml/batch during initial stages up to several l/batch during prototype production test stages. Solid catalyst substrates can also be anticipated for gas phase polymerization processes.

2.0 ENVIRONMENTAL REQUIREMENTS

2.1 MICROGRAVITY ENVIRONMENT

Constant Unidirectional:....................1E-5g
Periodic Dynamic:..................1E-3g @ 0.1 Hz
Impulsive:...............................Unknown

Additional flight experience and improved instrumentation required.

2.2 AMBIENT ENVIRONMENT

Temperature:	21.0 deg C +/- 2.0 deg C (constant record required)
Pressure:	14.7 psi +/- 0.2 psi (constant record required)
Humidity:	70% relative humidity +/- 10% (constant record required)

2.3 ACOUSTIC ENVIRONMENT

No acoustic output or susceptibility identified.

2.4 RADIATION ENVIRONMENT

No radiation output or susceptibility identified.

2.5 ISOLATION REQUIREMENT

All research activities are anticipated to be performed in mission-specific experiment apparatus isolated from the pressurized laboratory environment. Required experiment environments (temperature, pressure, composition) are to be accommodated in the design of the specific apparatus during the payload planning phase. The lab environment should minimize large magnitude swings in environmental parameters that have the potential to affect operation of the experiment apparatus subsystems. Continuous monitoring is required.

3.0 UTILITY REQUIREMENTS

3.1 POWER

Power requirements are less than 2.0 kW primarily to provide low level heating (e.g., < 200 deg C) of batch solutions in prototype production quantities. During initial stages 0.5 kW will accommodate basic research, however, provisions must be included for the growth requirement as research progresses. Values provided below represent the growth requirement.

Operating Power:..................2.00 kw
Typical Operating Cycle:.........20.00 hrs
Energy per Cycle:................40.00 kwh
Electric Service...........115 vac (60 Hz)

3.2 HEAT REJECTION

Heat rejection requirements reflect the peak power consumption anticipated during the growth stage. A low temperature cooling loop will be required to maintain proces temperatures in the 50-100 deg C. range. High temperature loop is also desirable for 100-200 deg C processes.

Peak Heat Rejection:.............2.00 kw
Sink Temperature(s):.............4.00 deg C
.............80.00 deg C

3.3 DATA MANAGEMENT

Data acquisition, control and display is to be performed at the payload via integral microcomputer. A Central Data Storage/Transceiver System (Core Equipment Item) will be required to accommodate temporary data storage (90 minute) and to serve as interface for downlink. A High Resolution Video System (Core Equipment Item) is required to achieve high research productivity.

Digital Data Rate:................0.64 kbps
Generation Period:...............20.00 hrs
Interactive Audio:...............20.00 hrs/day
Live Video:......................20.00 hrs/day

3.4 WASTE MANAGEMENT

Wastes are anticipated to be used solutions, process gases and solid/semisolid materials. Recyclable solutions require Liquids Filtration/ Purification System (Core Equipment Item). Waste gases require Gas Evacuation/Adsorption/Venting System (Core Equipment Item). Most solids return to ground.

Solids: Solid substrate materials and semisolid coagulants, foams, and/or thickened mixtures.

Liquids: Used solutions.

Gases: Process gases are anticipated but not yet identified.

3.5 VACUUM

Minimal vacuum is required for evacuation and purge of experiment apparatus between process runs. High vacuum may be required for control of contaminant species during gas phase polymerization studies. Access to a vacuum wake shield facility is highly desirable. Values provided below represent the maximum requirement identified to date.

Vacuum Pressure:..................0.000001 pa
Evacuation Volume:................0.085000 cu m

3.6 CREW SUPPORT

Process experiments may run for hours to days unattended with the exception of periodic crew monitoring. Crew support will be required to prepare samples, initiate process, and perform post-process analysis. Basic phenomenological experiments will require continuous interaction and experiment modification in real-time in order to achieve high research productivity. Scientist skill level is highly desirable. Technologist is adequate at the expense of research timelines.

4.0 LOGISTIC REQUIREMENTS

4.1 SUPPLY SCHEDULE

Resupply at 90 day intervals is adequate at IOC phase provided: (1) video/digital data can be transmitted to ground for analysis and followed by interactive audio session, and (2) minimal characterization is available (e.g., microscopy, chemical analysis) on-orbit.

Typical Payload Mass:...........350.00 kg
Typical Payload Volume:...........1.00 cu m
GTS Stowage Mass:................50.00 kg
GTS Stowage Volume:...............0.25 cu m
STG Stowage Mass:................50.00 kg
STG Stowage Volume:...............0.25 cu m

GTS: Ground to Station
STG: Station to Ground

4.2 CONSUMMABLES

Small volume mission-specific consummable materials require transport in Standardized Modular Lockers (Core Equipment Item) and on-obit transfer via standard containers to the Fluids Dispensing System (Core Equipment Item), or an integral payload subsystem. Large volume consummables (gases) require storage on an Attached External Pallet (Core Equipment Item) and transfer via automated distribution system for end-use.

5.0 SAFETY

5.1 HAZARDS ASSESSMENT

No hazardous temperatures or pressures have been identified. Processes are generally run at < 200 deg. C and 1.0 atm. Some materials may have high flammability level and/or toxicity. Standard spaceflight provisions for control of electric shock hazard are required at all electrical interfaces.

ADDENDUM

1.0 BACKGROUND

1.1 RESEARCH OBJECTIVES

Horizontal temperature and concentration gradients promote fluid flow during directional solidification, affecting both the shape of the solid-liquid interface as well as solute segregation. When such flows are present, they can significantly affect the homogeneity of the solidified material and for critical electronic, electromagnetic, or optical applications a material's performance may be degraded. Experiments performed on transparant, well characterized, eutectic, off-eutectic, and monotectic systems in a microgravity environment can reveal the interaction between convective flow, solute effects, and interface effects. The presence of gravity induced thermal convection and buoyancy prevents quantitative description of such interactions in ground based investigations. Research objectives are therefore to take advantage of the microgravity environment to perform experiments dealing with: (1) the influence of diffusive transport on phase spacing and morphology in eutectics, (2) the contact angle of the liquid phase(s) in the phase separation mechanism of monotectics, and (3) macrosegregation in directionally solidified polyphase alloys. These investigations will provide knowledge from which to advance theoretical models, and quantitatively describe directional solidification processes both at one-g and micro-g. Following empirical validation, the opportunity exists to engineer advanced material systems having application across the industrial spectrum.

1.2 POTENTIAL APPLICATIONS

Primary application is control of growth morphology during materials solidification, resulting in engineered microstructures having tailored properties unachievable on earth. Such properties include: increased strength and corrosion resistance, thermal resistance, hardness, enhanced electronic, magnetic, and optical properties. Products include: single crystal, low defect density, inorganic boules, and directionally aligned microstructures capable of taking a variety of final forms.

1.3 PHENOMENA OF INTEREST

Segregation (axial and radial), Constitutional Supercooling, Composition Profile Transients

DIRECTIONAL SOLIDIFICATION

1.4 PROCESSES OF INTEREST	Plane front directional solidification by moving a thermal gradient along a stationary sample
1.5 PRODUCTS OF INTEREST	Single-crystal electronic materials (III-V and II-VI alloys), microstructurally aligned composites
1.6 PROPERTIES OF INTEREST	Crystal Uniformity, Band Structure, Carrier Density and Type, Mechanical/Magnetic Properties.
1.7 HISTORY OF INVESTIGATION	Ground-based research on theoretical models for growth morpholgy are ongoing at various laboratories. Primary flight experiments have been on aligned magnetic composites (Larson et al), miscibility gap alloys (Potard et al), semiconductor alloys (Witt, Gatos, et al), and interfacial destabilization (Favier et al). American progress has been limited by flight opportunities and availability of adequate experiment apparatus. European program is accelerating during 1985-86 under German D1 mission.
1.8 KEY INDIVIDUALS	Aldrich, B. / Chandra, D. / Crouch, R. / Fripp, A. / Gatos, H. / Holland, L. / Lehoczky, S. / Naumann, R. / Szofran, F. / Witt, A. / Bachmann, K. / Larson, D. / Potard, C. / Favier, J. / Coriell, S. / Glicksman, M. / Wilcox, W. / Brown, R. / Gray, H. /
1.9 FLIGHT REQUIREMENT	1993 Space Station Initial Operating Configuration (IOC) 360 Days Status: Conceptual (> 5 Year Horizon)
1.10 SECURITY CONSIDERATIONS	Proprietary research can be anticipated. Provisions arerequired for: (1) encryptionof downlinked data, (2) crew function security, (3) sample, payload, and video tape security during transport, and (4) government confidentiality regarding specific experimental techniques. On-orbit PI accommodations are highly desirable.

DIRECTIONAL SOLIDIFICATION

1.11 PRIMARY EQUIPMENT

Primary equipment requirements are for a class of directional solidification furnaces incorporating both high and low thermal gradient capabilities, and both high and low maximum temperature capabilities. A series of four apparatus have been suggested as necessary to meet the range of requirements. These apparatus may be developed in response to specificly defined experimental programs that arise over the life of the laboratory. The near term requirement is for an advanced version of the currently used Automated Directional Solidification Furnace (ADSF). Requirements have also been identified for a Modular Crystal Growth Facility (MCGF) comprising (1) a power control unit, (2) a charge placement/translation unit, (3) a thermal insulation and heat extraction unit, and (4) a compatible general purpose hot zone capable of accommodating growth cartridges with diameters up to ~4.0 cm.

Descriptions located in "Experiment Apparatus" files.

1.12 SUPPORT EQUIPMENT

The following **Core Equipment Items** are required:

- High Resolution Video System
- Mass Measurement System
- Integrated Optical Microscopy Lab
- Integrated Electronics Lab
- Sample Cutting, Polishing, & Etching System
- Standardized Modular Lockers
- Reconfigurable Workbench
- Tool/Supplies Locker
- Tri-Axis Accelerometer System
- Attached External Pallet
- Automated Gas Distribution System
- Fluids Dispensing System
- Emergency Provisions Locker
- Science Airlock
- Waste Management System
- Central Data Storage/Transceiver System
- Heat Rejection System
- Power Conditioning/Distribution System
- Lighting System
- Environmental Control & Life Support System

Numerous additional support equipment items can be anticipated. These items are mission-specific and cannot be comprehensively defined at this time due to the nature of basic research. It is expected that mission-specific items can be accommodated via standardized storage lockers as the need arises.

Descriptions located in "Core Equipment" files

1.13 SAMPLE CHARACTERISTICS

Samples are anticipated to consist largely of inorganic materials prepared on the ground for loading into experiment apparatus. Dependent on apparatus design, samples may be contained in sealed cartridges, crucibles, or ampoules. No limit to shelf life has been identified. Samples will require transport in Standardized Modular Lockers (Core Equipment Item) and storage on-orbit.

2.0 ENVIRONMENTAL REQUIREMENTS

2.1 MICROGRAVITY ENVIRONMENT

Constant Unidirectional:....................1E-6g
Periodic Dynamic:..................1E-4g @ 0.01 Hz
..................1E-2g @ 0.10 Hz
..................1E 0g @ 1.00 Hz
Impulsive:..................................Unknown

Additional flight experience and improved instrumentation required.

2.2 AMBIENT ENVIRONMENT

Temperature: 21.0 deg C +/- 2.0 deg C
(constant record required)
Pressure: 14.7 psi +/- 0.2 psi
(constant record required)
Humidity: 70% relative humidity +/- 10%
(constant record required)

2.3 ACOUSTIC ENVIRONMENT

No acoustic output or susceptibility identified.

2.4 RADIATION ENVIRONMENT

No radiation output or susceptibility identified.

2.5 ISOLATION REQUIREMENT

All research activities are anticipated to be performed in mission-specific experiment apparatus isolated from the pressurized laboratory environment. Required experiment environments (temperature, pressure, composition) are to be accommodated in the design of the specific apparatus during the payload planning phase. The lab environment should minimize large magnitude swings in environmental parameters that have the potential to affect operation of the experiment apparatus subsystems. Continuous monitoring is required.

3.0 UTILITY REQUIREMENTS

3.1 POWER

Peak power requirements may range as high as 10 kW during the Space Station growth phase in order to accommodate large diameter, high density specimens. Prototype production process research can be anticipated. At IOC a reduced power level will allow basic research with small specimens, however, the growth requirement must be provided for in the baseline laboratory configuration. Values provided below reflect the peak requirement.

Operating Power:.................10.00 kw
Typical Operating Cycle:........140.00 hrs
Energy per Cycle:..............1400.00 kwh
Electric Service:......115/230 vac (60 Hz)

3.2 HEAT REJECTION

A liquid cooling loop will be required for heat dissipation in furnace apparatus. Additional convective cooling is required for support electronics. The values provided below reflect the peak requirement for the liquid loop.

Peak Heat Rejection:.............10.00 kw
Sink Temperature:................90.00 deg C

3.3 DATA MANAGEMENT

Data acquisition, reduction, and display to be performed at the payload via integral microcomputer. Central Data Storage/Transceiver System (Core Equipment Item) required to provide temporary data storage and to serve as interface for digital downlink. High Resolution Video System (Core Equipment Item) required to establish principal investigator telepresence and increase research productivity.

Digital Data Rate:................1.60 kbps
Generation Period:...............20.00 hrs
Interactive Audio:...............20.00 hrs/day
Live Video:......................20.00 hrs/day

3.4 WASTE MANAGEMENT

Wastes include a broad range of potentially toxic solids, liquids, and process gases. Quantities cannot be accurately estimated at this time. A Gas Evacuation/Adsorption/Venting System (Core Equipment Item) is considered essential to remove waste products and purge the experiment environment.

Solids: Trace quantities of sample material from grinding and polishing activities; balance of solids returned to ground for analysis.

Liquids: Etchants (acids, bromides, hydroxides, peroxides) and wash slurries (solvents) in quantities < 1.0 liter/30 days.

Gases: Inert gases.

3.5 VACUUM

A minimum evacuation level will be required for purge of experiment apparatus and removal of waste products between experiment runs. Access to a Gas Evacuation/Adsorption/Venting System (Core Equipment Item) is considered essential.

Vacuum Pressure:..................0.0010 pa
Evacuation Volume:................0.1000 cu m

3.6 CREW SUPPORT

Nature of basic research precludes the ability to fully automate experiment apparatus. Process monitoring and capability for real-time modification are essential to experiment design and research productivity. Crew support will be required for process initiation, parameter adjustment, and post-experiment diagnostics. Scientist skill level is desirable.

4.0 LOGISTIC REQUIREMENTS

4.1 SUPPLY SCHEDULE

Resupply at 90 day interval is considered adequate provided: (1) video and digital data can be transmitted to ground for evaluation and followed by interactive audio, and (2) minimal characterization (sample preparation/microscopy) is available on orbit.

Typical Payload Mass:...........200.00 kg
Typical Payload Volume:...........0.75 cu m
GTS Stowage Mass:................25.00 kg
GTS Stowage Volume:...............0.15 cu m
STG Stowage Mass:................25.00 kg
STG Stowage Volume:...............0.15 cu m

GTS: Ground to Station
STG: Station to Ground

4.2 CONSUMMABLES

Small volume mission-specific consummable materials require transport in Standardized Modular Lockers (Core Equipment Item) and on-obit transfer via standard containers to the Fluids Dispensing System (Core Equipment Item), or an integral payload subsystem. Large volume consummables (gases) require storage on an Attached External Pallet (Core Equipment Item) and transfer via automated distribution system for end-use.

5.0 SAFETY

5.1 HAZARDS ASSESSMENT

Temperature extremes up to 2800 deg C may be anticipated over the life of the lab. Provisions are required for the handling of toxic and corrosive substances used as etchants and solvents. Standard spaceflight provisions for the control of shock hazard at all electrical interfaces are required.

ADDENDUM

FLOAT ZONE SOLIDIFICATION

1.0 BACKGROUND

1.1 RESEARCH OBJECTIVES

In the float zone process a rod of sample material is suspended at both ends and the middle region is melted. The molten zone is supported by the surface tension of the liquid. By moving either the rod or the heater the zone can be made to traverse the rod. The region behind the traveling zone is purified and, through repeated passes, the purity can be increased. Thus the floating zone is an excellent technique for the preparation of high purity materials. The height of the vertical zone is presently limited (< 15 mm.) due to the influence of gravity. The microgravity environment can permit significant extension beyond the current limit. As a result investigations are underway having the following objectives: (1) modeling and analysis of the thermophysical nature of the floating zone, including buoyancy driven melt convection, surface tension driven surface convection, and heat flow; (2) prediction of improvements in growth characteristics and physical properties, including ways to better control growth conditions; (3) investigation of the optimum heating methods in terms of thermal profile, power efficiency/control, and practicality; (4) analytical measurement of the zoning system and grown crystals; and (5) development of prototype hardware to demonstrate reliability of the technique for microgravity application. Following demonstration, objective is to produce large diameter (> 150 mm), high purity crystalline materials in high demand for advanced semiconductor devices.

1.2 POTENTIAL APPLICATIONS

Primary application is the growth of large diameter single crystals having specialized properties needed for advanced devices. Crystals include silicon for infrared detectors, high density integrated circuits, and solar cells; semiconductor alloys (SiGe, InP, As and Hg, CdTe) for designators, imaging systems, and fiber optic telecommunications applications in the high bandwidth, low-loss wavelength range; and reference measurement standards for resistivity, and oxygen /carbon composition.

1.3 PHENOMENA OF INTEREST

Surface Tension, Marangoni Flow, Thermal Convection, Radial/Axial Segregation, Melt/Solid Interface

FLOAT ZONE SOLIDIFICATION

1.4 PROCESSES OF INTEREST

Melting, Purifying, Directionally Solidifying via Traveling Zone

1.5 PRODUCTS OF INTEREST

High purity, large diameter crystals for integrated circuits, detectors, solar cells, & adv. devices

1.6 PROPERTIES OF INTEREST

Crystal size and quality, Growth rates, Optical/Electrical characteristics

1.7 HISTORY OF INVESTIGATION

Ground-based program well advanced by Kern, Gill et al in prototype float zoner. Flight system has been proposed. Theoretical studies on surface tension/Marangoni flow effects, process modeling, control surfaces, and the influence of thermal convection completed. German efforts advanced to empirical research stage under actual microgravity conditions on Spacelab 1. American program is currently limited by insufficient funds for flight hardware and limited flight opportunities.

1.8 KEY INDIVIDUALS

Kern, E. / Gill, G. / Bachmann, K. / Brown, R. / Kramer, H. / Stafsudd, O. / Verhoeven, J. / Wilcox, W. / Jastrzebski, L. / Benson, K. / Foster, L. /

1.9 FLIGHT REQUIREMENT

1993 Space Station Initial Operating Configuration (IOC)
360 Days

Status: Conceptual (> 5 Year Horizon)

1.10 SECURITY CONSIDERATIONS

Proprietary research can be anticipated. Provisions arerequired for:
(1) encryptionof downlinked data,
(2) crew function security,
(3) sample, payload, and video tape security during transport, and
(4) government confidentiality regarding specific experimental techniques. On-orbit PI accommodations are highly desirable.

FLOAT ZONE SOLIDIFICATION

1.11 PRIMARY EQUIPMENT

Primary equipment requirement is for flight version of silicon float zone apparatus capable of zoning temperatures up to 1500 deg C. Process has been proposed in inert gas (argon) environment at 0.1 torr, achieved by venting to space. The entire sequence of experiments are to be programmed into the integral microcomputer, including all zoner movements, heat cycles, atmosphere changes, data collection/storage, sample changeout, time-lining, and fault/error detection. The proposed "Microgravity Thin Rod Zoner" has been designed for crystals of silicon up to 7.0 mm in diameter and represents a precursor demonstration system that is required prior to initiation of advanced concept design for a prototype production system to be operated during the Space Station growth phase.

Descriptions located in "Experiment Apparatus" files.

1.12 SUPPORT EQUIPMENT

The following **Core Equipment Items** are required:

- High Resolution Video System
- Mass Measurement System
- Integrated Optical Microscopy Lab
- Integrated Electronics Lab
- Sample Cutting, Polishing, & Etching System
- Standardized Modular Lockers
- Reconfigurable Workbench
- Tool/Supplies Locker
- Tri-Axis Accelerometer System
- Attached External Pallet
- Automated Gas Distribution System
- Fluids Dispensing System
- Emergency Provisions Locker
- Science Airlock
- Waste Management System
- Central Data Storage/Transceiver System
- Heat Rejection System
- Power Conditioning/Distribution System
- Lighting System
- Environmental Control & Life Support System

Numerous additional support equipment items can be anticipated. These items are mission-specific and cannot be comprehensively defined at this time due to the nature of basic research. It is expected that mission-specific items can be accommodated via standardized storage lockers as the need arises.

Descriptions located in "Core Equipment" files

1.13 SAMPLE CHARACTERISTICS

Input samples are projected to be silicon polycrystalline rods up to 150 mm in diameter and 1.0 meter long. Additional elemental semiconductors can be anticipated during the growth stage, as well as metallic oxides such as used for laser crystals.

2.0 ENVIRONMENTAL REQUIREMENTS

2.1 MICROGRAVITY ENVIRONMENT

Constant Unidirectional:....................1E-6g
Periodic Dynamic:..................1E-6 @ 00.01 Hz
..................1E-5 @ 00.10 Hz
..................1E-3 @ 01.00 Hz
..................1E-1 @ 10.00 Hz
Impulsive:................................Unknown

Additional flight experience and improved instrumentation required.

2.2 AMBIENT ENVIRONMENT

Temperature: 21.0 deg C +/- 2.0 deg C (constant record required)
Pressure: 14.7 psi +/- 0.2 psi (constant record required)
Humidity: 70% relative humidity +/- 10% (constant record required)

2.3 ACOUSTIC ENVIRONMENT

No acoustic output or susceptibility identified.

2.4 RADIATION ENVIRONMENT

If radio frequency heating is employed, ~ 1.0 watt @ 500 kHz or 50 mHz may be output.

2.5 ISOLATION REQUIREMENT

All research activities are anticipated to be performed in mission-specific experiment apparatus isolated from the pressurized laboratory environment. Required experiment environments (temperature, pressure, composition) are to be accommodated in the design of the specific apparatus during the payload planning phase. The lab environment should minimize large magnitude swings in environmental parameters that have the potential to affect operation of the experiment apparatus subsystems. Continuous monitoring is required.

3.0 UTILITY REQUIREMENTS

3.1 POWER

Power estimates have ranged as high as 60.0 kW continuous to produce large diameter (150 mm) single crystal rod during growth stage. Similar estimates have been provided for processing of oxides. Current proposed effort is to produce 7.5 mm diameter rod at 0.5 kW level. Heater power is dependent on atmosphere; the lower the pressure, the lower the required power. Use of argon increases power. Continued research is necessary to establish appropriate power for desired atmosphere and material. Values which follow represent the peak requirement.

Operating Power:......................60.00 kw
Typical Operating Cycle:..............30.00 hrs
Energy per Cycle:...................1800.00 kwh
Electric Service:..................8 vdc +/- 4%

3.2 HEAT REJECTION

Heat rejection requirements are based on the highest power input values estimated for the growth of large diameter silicon and oxide materials. Actual power/heat rejection levels may be lower dependent on improvements in energy conversion efficiency for the process. Values provided below represent the growth requirement.

Peak Heat Rejection:.............60.00 kw
Sink Temperature:................95.00 deg C

3.3 DATA MANAGEMENT

Data acquisition, reduction (as required), and display (as required) is to be performed at the payload via an integral microcomputer subsystem. Central Data Storage/Transceiver System (Core Equipment Item) required to accommodate temporary data storage (90 minute) and to serve as downlink interface. High Resolution Video System (Core Equipment Item) required to achieve high research productivity by establishing principal investigator telepresence.

Digital Data Rate:................1.60 kbps
Generation Period:...............30.00 hrs
Interactive Audio:...............20.00 hrs/day
Live Video:......................20.00 hrs/day

3.4 WASTE MANAGEMENT

Waste materials will be limited to containers and purging gases. All solid sample material is expected to be returned to ground for analysis. A Solids Compaction/Containment System (Core Equipment Item) is required.

Solids: Trace quantities of sample material from grinding and polishing activities; balance of solids returned to ground for analysis.

Liquids: Etchants (acids, bromides, hydroxides, peroxides) and wash slurries (solvents) in quantities < 1.0 liter/30 days.

Gases: Inert gases.

3.5 VACUUM

Preliminary experiments are anticipated to be performed in an inert gas (argon) environment at ~10 pa. Advanced research during the growth stage may increase vacuum requirements to as low as 0.0001 pa. Values below reflect the growth requirement.

Vacuum Pressure:..................0.0001 pa
Evacuation Volume:................0.8500 cu m

3.6 CREW SUPPORT

The nature of basic research precludes the ability to fully automate float zone experiments. Process monitoring and real-time modification is essential to experimental design and research productivity. Crew support will be required for experiment initiation, parameter adjustment, and post-experiment diagnostics. Scientist skill level will yield highest productivity.

4.0 LOGISTIC REQUIREMENTS

4.1 SUPPLY SCHEDULE

Resupply at 90 day intervals is considered adequate provided (1) video and digital data can be downlinked for evaluation and followed by interactive audio sessions, and (2) minimal characterization (sample preparation and microscopy) is available on-orbit.

Typical Payload Mass:...........200.00 kg
Typical Payload Volume:...........1.10 cu m
GTS Stowage Mass:................25.00 kg
GTS Stowage Volume:...............0.15 cu m
STG Stowage Mass:................25.00 kg
STG Stowage Volume:...............0.15 cu m

GTS: Ground to Station
STG: Station to Ground

4.2 CONSUMMABLES

Small volume mission-specific consummable materials require transport in Standardized Modular Lockers (Core Equipment Item) and on-obit transfer via standard containers to the Fluids Dispensing System (Core Equipment Item), or an integral payload subsystem. Large volume consummables (gases) require storage on an Attached External Pallet (Core Equipment Item) and transfer via automated distribution system for end-use.

5.0 SAFETY

5.1 HAZARDS ASSESSMENT

Temperature extremes up to 1600 deg C are anticipated. Provisions are required for the safe handling of toxic and corrosive substances used as solvents and etchants. Standard spaceflight provisions are required for control of shock hazard at electrical interfaces.

ADDENDUM

ISOTHERMAL SOLIDIFICATION

1.0 BACKGROUND

1.1 RESEARCH OBJECTIVES

The solidification of alloy and composite systems is a complex process influenced largely by the density differences of the materials and the forces of thermal convection. Constituents which are thoroughly mixed in the melt segregate as they begin to solidify due the difference in solubility between the liquid and solid phases. This results in enrichment of one of the constituents near the interface, changing the composition and density, and giving rise to solutal convection. Thermal gradients are also of influence in any solidification process, giving rise to thermal convection. The change in composition often results in a lowering of the solidification temperature of the melt ahead of the interface, producing constitutional supercooling and causing interfacial breakdown and dendritic growth. The associated flows cause dendrite arms to melt or break off, resulting in particles available for new nucleation sites. Microstructural formation is therefore difficult to control under one-g conditions. The microgravity environment allows virtual elimination of thermal convection and buoyancy effects during materials solidification. Microstructural control has been successfully demonstrated. Objectives of current research are to take advantage of this capability and to develop new and improved material systems, under diffusion controlled conditions achievable only in microgravity. Improved understanding of ground-based processes and unique new materials represent achievable goals.

1.2 POTENTIAL APPLICATIONS

Primary application is control of growth morphology during materials solidification, resulting in engineered microstructures having tailored properties unachievable on earth. Such properties include: strength and corrosion resistance, thermal resistance, hardness, electrical conductivity/resistivity, and magnetic and optic qualities. Products include: wires, plates, rod, films, spheres, and similar forms having applications across the industrial spectrum.

1.3 PHENOMENA OF INTEREST

Segregation, Coalescence, Growth Morphology, Diffusion Mass Transport, Coursening, Nucleation

ISOTHERMAL SOLIDIFICATION

1.4 PROCESSES OF INTEREST

Solidification via Isothermal Heat Removal / Quenching

1.5 PRODUCTS OF INTEREST

Cast, Drawn, Plated, and Sintered Materials, Binary/Ternary Alloys, Composites, Fibers

1.6 PROPERTIES OF INTEREST

Strength, Degradation Resistance, Electrical /Magnetic/Optical Characteristics, Thermophysical Values

1.7 HISTORY OF INVESTIGATION

Ground-based research on theoretical models for growth morpholgy are ongoing at various laboratories. Primary flight experiments have been on alloying of immiscible materials (Gelles et al), microstructure control in castings (Stefanescu et al), and metallic foams (Pond). Extensive work on deep undercooling effects performed in NASA drop tubes (Bayuzick, Perepezko, et al). Progress limited by flight hardware availability and flight opportunities. European program is accelerating during 1985-86.

1.8 KEY INDIVIDUALS

Stefanescu, D. / Malmejac, L. / Laxmanen, V. / Gelles, S. / Wilcox, W. / Frazier, D. / Curreri, P. / Pond, R. / Potard, C. / Johnston, M. / Gray, H. / Perepezko, J. / Bayuzick, R. / Chu, C. / Kelley, M. / Hellawell, A. / Graham, J. / Glicksman, M. / Flemings, M. /

1.9 FLIGHT REQUIREMENT

1993 Space Station Initial Operating Configuration (IOC)
360 Days

Status: Conceptual (> 5 Year Horizon)

1.10 SECURITY CONSIDERATIONS

Proprietary research can be anticipated. Provisions arerequired for:
(1) encryptionof downlinked data,
(2) crew function security,
(3) sample, payload, and video tape security during transport, and
(4) government confidentiality regarding specific experimental techniques. On-orbit PI accommodations are highly desirable.

ISOTHERMAL SOLIDIFICATION

1.11 PRIMARY EQUIPMENT

Primary equipment requirement is for a high temperature isothermal furnace to establish the fundamental capability for processing multiple samples sequentially. Such an apparatus is perceived necessary as a precursor to advanced systems designed to meet specific requirements which arise as a result of the basic research activity. Advanced systems cannot be comprehensively defined at this time due to the nature of basic research.

Descriptions located in "Experiment Apparatus" files.

1.12 SUPPORT EQUIPMENT

The following **Core Equipment Items** are required:

- High Resolution Video System
- Mass Measurement System
- Integrated Optical Microscopy Lab
- Integrated Electronics Lab
- Sample Cutting, Polishing, & Etching System
- Standardized Modular Lockers
- Reconfigurable Workbench
- Tool/Supplies Locker
- Tri-Axis Accelerometer System
- Attached External Pallet
- Automated Gas Distribution System
- Fluids Dispensing System
- Emergency Provisions Locker
- Science Airlock
- Waste Management System
- Central Data Storage/Transceiver System
- Heat Rejection System
- Power Conditioning/Distribution System
- Lighting System
- Environmental Control & Life Support System

Numerous additional support equipment items can be anticipated. These items are mission-specific and cannot be comprehensively defined at this time due to the nature of basic research. It is expected that mission-specific items can be accommodated via standardized storage lockers as the need arises.

Descriptions located in "Core Equipment" files

1.13 SAMPLE CHARACTERISTICS

Input materials are anticipated to include commercial grade stock, powders, and/or pellets that have been sintered, cut, and/or pressed into experiment-ready specimens. Output products may include spheroids, ingots, and rods. Shelf life is indefinite for all materials currently under consideration. No special handling provisions are foreseen beyond the storage of samples in a non-contaminating environment.

2.0 ENVIRONMENTAL REQUIREMENTS

2.1 MICROGRAVITY ENVIRONMENT

Constant Unidirectional:............1E-3g to 1E-5g
Periodic Dynamic:.........................Unknown
Impulsive:.................................Unknown

Additional flight experience and improved instrumentation required.

2.2 AMBIENT ENVIRONMENT

Temperature: 21.0 deg C +/- 2.0 deg C (constant record required)
Pressure: 14.7 psi +/- 0.2 psi (constant record required)
Humidity: 70% relative humidity +/- 10% (constant record required)

2.3 ACOUSTIC ENVIRONMENT

No acoustic output or susceptibility identified.

2.4 RADIATION ENVIRONMENT

No radiation output or susceptibility identified.

2.5 ISOLATION REQUIREMENT

All research activities are anticipated to be performed in mission-specific experiment apparatus isolated from the pressurized laboratory environment. Required experiment environments (temperature, pressure, composition) are to be accommodated in the design of the specific apparatus during the payload planning phase. The lab environment should minimize large magnitude swings in environmental parameters that have the potential to affect operation of the experiment apparatus subsystems. Continuous monitoring is required.

3.0 UTILITY REQUIREMENTS

3.1 POWER

Peak power requirements may range as high as 10 kW during the Space Station growth phase in order to accommodate large diameter, high density specimens. Prototype production process research can be anticipated. At IOC, a 4 kW accommodation will allow basic research with small specimens, however, the growth requirements must be provided for in the baseline configuration. Values provided below represent the growth requirement.

Operating Power:..................10.00 kw
Typical Operating Cycle:..........1.00 hr
Energy per Cycle:.................10.00 kwh
Electric Service:......115/230 vac (60 Hz)

3.2 HEAT REJECTION

A liquid cooling loop will be required for heat dissipation in furnace apparatus. Additional convective cooling is required for support electronics. The values provided below reflect the peak requirement for the liquid loop during the Space Station growth phase.

Peak Heat Rejection:.............10.00 kw
Sink Temperature:................90.00 deg C

3.3 DATA MANAGEMENT

Data acquisition, reduction and display to be performed at the payload via integral microcomputer. Central Data Storage/Transceiver System (Core Equipment Item) required to provide temporary data storage and to serve as interface for digital downlink. High Resolution Video System (Core Equipment Item) required to establish principal investigator telepresence and increase research productivity.

Digital Data Rate:................1.60 kbps
Generation Period:...............20.00 hrs
Interactive Audio:...............20.00 hrs/day
Live Video:......................20.00 hrs/day

3.4 WASTE MANAGEMENT

A Gas Evacuation/Adsorption/Venting System (Core Equipment Item) is required to control waste gases and noxious fumes.

Solids: Trace quantities of sample material from grinding and polishing activities; balance of solids returned to ground for analysis.

Liquids: Etchants (acids, bromides, hydroxides, peroxides) and wash slurries (solvents) in quantities < 1.0 liter/30 days.

Gases: Inert gases.

3.5 VACUUM

Access to Gas Evacuation/Adsorption/Venting System (Core Equipment Item) is essential to apparatus purge and waste product removal between process runs.

Vacuum Pressure:..................0.0200 pa
Evacuation Volume:................0.0850 cu m

3.6 CREW SUPPORT

Nature of basic research precludes ability to fully automate experiment apparatus. Process monitoring and real-time modification is essential to experiment design and research productivity. Crew support will be required for experiment set-up, initiation, process monitoring and evaluation, parameter adjustment, and post experiment characterization. Scientist skill level will yield highest productivity.

4.0 LOGISTIC REQUIREMENTS

4.1 SUPPLY SCHEDULE

Resupply at 90 day interval is adequate at IOC phase. Rapid sample return is not required provided: (1) video and digital data can be transmitted for ground-based evaluation and followed by interactive audio session, and (2) minimal characterization (crystal etching/optical microscopy) is available.

Typical Payload Mass:...........500.00 kg
Typical Payload Volume:...........1.75 cu m
GTS Stowage Mass:................50.00 kg
GTS Stowage Volume:...............0.25 cu m
STG Stowage Mass:................50.00 kg
STG Stowage Volume:...............0.25 cu m

GTS: Ground to Station
STG: Station to Ground

4.2 CONSUMMABLES

Small volume mission-specific consummable materials require transport in Standardized Modular Lockers (Core Equipment Item) and on-obit transfer via standard containers to the Fluids Dispensing System (Core Equipment Item), or an integral payload subsystem. Large volume consummables (gases) require storage on an Attached External Pallet (Core Equipment Item) and transfer via automated distribution system for end-use.

5.0 SAFETY

5.1 HAZARDS ASSESSMENT

Temperature extremes to 2500 deg C and pressure to 5.0 atm can be anticipated. These hazards can be accommodated during payload design phase via failsafe systems. Electric shock hazard requires standard spaceflight provision at all electrical interfaces. Provisions for handling and disposal of noxious waste and volatile gases, and corrosive/toxic liquids are required. Quantities involved cannot be accurately predicted at this time due to the nature of basic research.

ADDENDUM

SOLUTION CRYSTAL GROWTH

1.0 BACKGROUND

1.1 RESEARCH OBJECTIVES

Crystal growth from aqueous solution is a classic technique exemplified by the growth of copper sulfate or alum crystals in an evaporating dish where supersaturation is achieved by loss of solvent. In most well-controlled experiments supersaturation is achieved by change of temperature and solute transport to the crystal is by gravity driven convection. In microgravity this transport is suppressed and diffusion dominates. The large concentration gradient necessary for good diffusion rates is such as to reduce supersaturation at the growing crystal. To overcome this the crystal itself is cooled (or if solubility decreases with temperature, heated) by mounting on a cold (warm) "sting". Heat and mass diffusion thus have the same direction at all points. Greater crystal perfection is expected to result from this true diffusion controlled growth. Primary research objectives are therefore to achieve diffusion controlled growth of crystals by utilizing the advantageous characteristics of the microgravity environment. Once achieved, secondary objective is to define required growth parameters for a variety of technologically important materials that cannot be produced at the required levels of perfection in the one-g environment of earth and to initiate development of prototype production facilities for space-based manufacturing.

1.2 POTENTIAL APPLICATIONS

A wide variety of crystals having highly perfect structure and low dislocation density are needed, particularly for optical and electro-optical applications. Several of these include: (1) pyroelectric detectors such as triglycine sulfate, (2) Laser Q-switches such as KDP, and (3) infrared windows such as alkali halides. Additional materials are anticipated as the science base expands and diffusion controlled growth is achieved.

1.3 PHENOMENA OF INTEREST

Crystal Defect Density, Crystal Morphology, Diffusion Mass Transport, Thermal Gradients.

SOLUTION CRYSTAL GROWTH

1.4 PROCESSES OF INTEREST	Growth from supersaturated solution by diffusion mass transport in abscence of gravity convection
1.5 PRODUCTS OF INTEREST	Very high quality crystals for IR & UV windows, IR detectors, Laser switches, polarizers, etc.
1.6 PROPERTIES OF INTEREST	Crystal size and quality, Growth rates, Optical/Electrical characteristics
1.7 HISTORY OF INVESTIGATION	Successful experiment using the NASA Fluids Experiment System (FES) on Spacelab-3 demonstrated growth of an epitaxial layer of triglycine sulfate on the order of 2.0 mm thick, from a water solution. Preliminary indications are that true diffusion controlled growth was achieved. Research activity centered at Alabama A&M Univ. under direction of R. B. Lal. Slow solute diffusion experiment initiated on LDEF by M. Lind/Rockwell Int'l.; progress limited by schedule slippage on LDEF retrieval mission.
1.8 KEY INDIVIDUALS	Lal,R. / Kroes,R, / Lind,M. / Egbert,W.
1.9 FLIGHT REQUIREMENT	1993 Space Station Initial Operating Configuration (IOC) 360 Days Status: Conceptual (> 5 Year Horizon)
1.10 SECURITY CONSIDERATIONS	Proprietary research can be anticipated. Provisions arerequired for: (1) encryptionof downlinked data, (2) crew function security, (3) sample, payload, and video tape security during transport, and (4) government confidentiality regarding specific experimental techniques. On-orbit PI accommodations are highly desirable.

SOLUTION CRYSTAL GROWTH

1.11 PRIMARY EQUIPMENT

Primary equipment requirement is for multipurpose solution growth experiment apparatus consisting of growth chamber, microcomputer control system, and monitors. Currently available apparatus (NASA Fluids Experiment System-FES), although designed for integration with Spacelab, meets most research requirements and may be modified structurally for Space Station utilization. Additional small passive apparatus, capable of accommodation in Standardized Modular Lockers (Core Equipment Item), are required for performance of experiments involving slow diffusion of solutes.

Descriptions located in "Experiment Apparatus" files.

1.12 SUPPORT EQUIPMENT

The following **Core Equipment Items** are required:

- High Resolution Video System
- Mass Measurement System
- Integrated Optical Microscopy Lab
- Integrated Electronics Lab
- Sample Cutting, Polishing, & Etching System
- Standardized Modular Lockers
- Reconfigurable Workbench
- Tool/Supplies Locker
- Tri-Axis Accelerometer System
- Attached External Pallet
- Automated Gas Distribution System
- Fluids Dispensing System
- Emergency Provisions Locker
- Science Airlock
- Waste Management System
- Central Data Storage/Transceiver System
- Heat Rejection System
- Power Conditioning/Distribution System
- Lighting System
- Environmental Control & Life Support System

Numerous additional support equipment items can be anticipated. These items are mission-specific and cannot be comprehensively defined at this time due to the nature of basic research. It is expected that mission-specific items can be accommodated via standardized storage lockers as the need arises.

Descriptions located in "Core Equipment" files

1.13 SAMPLE CHARACTERISTICS

Seed crystals and growth solutions are supplied separately. Seed is mounted on cold finger attachment fixtures and solutions are stored in controlled temperature containers. Seeds may be encapsulated in solution filled containers. Dry seeds must be protected from shock and humid environments.

2.0 ENVIRONMENTAL REQUIREMENTS

2.1 MICROGRAVITY ENVIRONMENT

Constant Unidirectional:...........1E-5g to 1E-12g
Periodic Dynamic:.................1E-6g @ 0.001 Hz
.................1E-1g @ 0.100 Hz
.................1E+1g @ 1.000 Hz
Impulsive:................................Unknown

Additional flight experience and improved instrumentation required.

2.2 AMBIENT ENVIRONMENT

Temperature: 21.0 deg C +/- 2.0 deg C
(constant record required)
Pressure: 14.7 psi +/- 0.2 psi
(constant record required)
Humidity: 70% relative humidity +/- 10%
(constant record required)

2.3 ACOUSTIC ENVIRONMENT

No acoustic output or susceptibility identified.

2.4 RADIATION ENVIRONMENT

No radiation output or susceptibility identified.

2.5 ISOLATION REQUIREMENT

All research activities are anticipated to be performed in mission-specific experiment apparatus isolated from the pressurized laboratory environment. Required experiment environments (temperature, pressure, composition) are to be accommodated in the design of the specific apparatus during the payload planning phase. The lab environment should minimize large magnitude swings in environmental parameters that have the potential to affect operation of the experiment apparatus subsystems. Continuous monitoring is required.

3.0 UTILITY REQUIREMENTS

3.1 POWER

Previous research in solution crystal growth has required continuous power at 1.0 kw. This requirement has been increased for research to be performed in the pressurized lab in order to accelerate progress and accommodate a wider range of potential materials. The 1.0 kw level may be adequate at IOC; however provisions must be made for higher power availablity during the growth stage to allow full research productivity. Values which follow represent requirements for the growth stage.

Operating Power:..................2.00 kw
Typical Operating Cycle:........700.00 hrs
Energy per Cycle:..............1400.00 kwh
Electric Service:..........115 vac (60 Hz)

3.2 HEAT REJECTION

Heat is extracted at the seed crystal support at 0 deg C (minimum). The heat sink temperature is dependent on the material being studied and the associated solvent, and could potentially range as high as 90 deg C. Access to both high (90 deg C) and low (4 deg C) cooling will therefore be required. Values provided below represent the growth requirements.

Peak Heat Rejection:..............2.00 kw
Sink Temperature(s):..............4.00 deg C
..............90.00 deg C

3.3 DATA MANAGEMENT

Data acquisition, reduction (as required), and display (as required) to be performed at the payload via integral microcomputer subsystem. Central Data Storage/Transceiver System (Core Equipment Item) required to accommodate temporary data storage (90 minutes) and to serve as interface for downlink. High Resolution Video System (Core Equipment Item) required to achieve high research productivity. Best available technology at IOC is perceived as critical.

Digital Data Rate:................1.60 kbps
Generation Period:..............700.00 hrs
Interactive Audio:...............20.00 hrs/day
Live Video:......................20.00 hrs/day

3.4 WASTE MANAGEMENT

Process waste consists primarily of used growth solutions which can be returned to original containers for transport to ground. Recyclable solutions require a Liquids Filtration/Purification System (Core Equipment Item). All wastes should be assumed toxic.

Solids: All process solids are expected to be returned to ground for post-experiment analysis. Small quantities of packaging may require disposal.

Liquids: Cleaning solvents, used growth solutions, and slurry water.

Gases: Inert gases.

3.5 VACUUM

No vacuum requirements have been identified for solution crystal growth.

Vacuum Pressure:..No Requirement Identified
Evacuation Volume:................0.00 cu m

3.6 CREW SUPPORT

During growth process the system may be capable of complete automation. Crew will be required to load and replenish the growth chamber at the end of each experiment run, and to monitor temperature at periodic intervals. Post-experiment characterization by crew will accelerate research progress by allowing modifications to experiment design based on previous results. Scientist skill level will yield highest productivity, technologist is acceptable at the expense of research timelines.

4.0 LOGISTIC REQUIREMENTS

4.1 SUPPLY SCHEDULE

Resupply at 90 day interval is adequate at IOC phase. Rapid sample return not required provided: (1) video/digital data can be transmitted for ground-based evaluation and followed by interactive audio session, and (2) minimal characterization is available (e.g., crystal cut/etch & microscopy).

Typical Payload Mass:............400.00 kg
Typical Payload Volume:............1.75 cu m
GTS Stowage Mass:.................50.00 kg
GTS Stowage Volume:................0.25 cu m
STG Stowage Mass:.................50.00 kg
STG Stowage Volume:................0.25 cu m

GTS: Ground to Station
STG: Station to Ground

4.2 CONSUMMABLES

Small volume mission-specific consummable materials require transport in Standardized Modular Lockers (Core Equipment Item) and on-obit transfer via standard containers to the Fluids Dispensing System (Core Equipment Item), or an integral payload subsystem. Large volume consummables (gases) require storage on an Attached External Pallet (Core Equipment Item) and transfer via automated distribution system for end-use.

5.0 SAFETY

5.1 HAZARDS ASSESSMENT

No hazardous temperatures or pressures identified. Solvents may be flammable or toxic and require special handling provisions. A Fluids Dispensing System (Core Equipment Item) is required. Standard spaceflight provisions for control of electric shock hazard at all electrical interfaces are required.

ADDENDUM

1.0 BACKGROUND

1.1 RESEARCH OBJECTIVES

Crystallization from vapors has gained ever increasing importance in the preparation of semiconductors, insulators, and metals. Vapor-to-solid processes are employed for the growth of bulk samples and, on a particularly large scale, for the production of epitaxial films. Bulk materials are typically grown in closed systems. If the vapor pressure of a material exceeds ~1 EE-2 torr it may be efficiently grown by Physical Vapor Transport (PVT). If the vapor pressure is too low for practical PVT rates one may use a `reversible' chemical reaction for Chemical Vapor Transport (CVT) in closed ampoules. Open flow systems have also been used for bulk growth by Physical Vapor Deposition (PVD) and Chemical Vapor Deposition (CVD). The domain of open flow CVD is in the production of thin films for electronic and optical devices. (F. Rosenberger, 1980) Research in the microgravity environment has focused on the PVT and CVT techniques, to date, with the primary objective being to produce crystalline materials having very high structural quality and low defect-dislocation density. These investigations may determine that the optimum growth technique is material-specific and thereby warrant the continued pursuit of several techniques. Continued support of studies in a variety of areas can therefore be anticipated.

1.2 POTENTIAL APPLICATIONS

A wide variety of crystals having highly perfect structure and low dislocation density are needed, particularly for optical and electro-optical applications. Current research is concentrated on HgCdTe for use as an infrared detector material and HgI for use as a nuclear radiation detector capable of room temperature operation. As the science base expands additional materials, having a variety of applications as sensor materials, can be anticipated.

1.3 PHENOMENA OF INTEREST

Mass Transport Dynamics, Morphology, Structural Defect Formation

VAPOR CRYSTAL GROWTH

1.4 PROCESSES OF INTEREST	Chemical Vapor Transport, Physical Vapor Transport
1.5 PRODUCTS OF INTEREST	Electronic and Electro-optic Materials for Infrared and Nuclear Radiation Detection
1.6 PROPERTIES OF INTEREST	Growth Habit, Structural Quality, Slip Resistance, Electrical Characteristics
1.7 HISTORY OF INVESTIGATION	Considerable empirical research has been performed on PVT by Van Den Berg et al, and on CVT by Wiedemeier et al. Theoretical studies on mass transport rates and vapor growth kinetics have been pursued by Rosenberger et al. Microgravity experimentation has been performed on Skylab, the Apollo-Soyuz Test project, the Shuttle, and Spacelab. Most recent results include successfull PVT experiment by Van Den Berg using the NASA Vapor Crystal Growth System developed for Spacelab.
1.8 KEY INDIVIDUALS	Van den Berg, L. / Schnepple, W. / Wiedemeier, H. / Rosenberger, F.
1.9 FLIGHT REQUIREMENT	1993 Space Station Initial Operating Configuration (IOC) 360 Days Status: Conceptual (> 5 Year Horizon)
1.10 SECURITY CONSIDERATIONS	Proprietary research can be anticipated. Provisions arerequired for: (1) encryptionof downlinked data, (2) crew function security, (3) sample, payload, and video tape security during transport, and (4) government confidentiality regarding specific experimental techniques. On-orbit PI accommodations are highly desirable.

1.11 PRIMARY EQUIPMENT

Primary equipment requirement is for mission-specific experiment apparatus to support studies in chemical and physical vapor transport. Currently available apparatus (NASA Vapor Crystal Growth System-VCGS) meets requirements for PVT and, although designed for integration on Spacelab, may be modified structurally to accommodate PVT research activities on Space Station. CVT research requires a gradient furnace that is optimized for CVT requirements. As the science base expands additional requirements for thin film deposition units, and automated production prototype systems having a one order of magnitude increase in resource and space requirements must be accommodated.

Descriptions located in "Experiment Apparatus" files.

1.12 SUPPORT EQUIPMENT

The following **Core Equipment Items** are required:

- High Resolution Video System
- Mass Measurement System
- Integrated Optical Microscopy Lab
- Integrated Electronics Lab
- Sample Cutting, Polishing, & Etching System
- Standardized Modular Lockers
- Reconfigurable Workbench
- Tool/Supplies Locker
- Tri-Axis Accelerometer System
- Attached External Pallet
- Automated Gas Distribution System
- Fluids Dispensing System
- Emergency Provisions Locker
- Science Airlock
- Waste Management System
- Central Data Storage/Transceiver System
- Heat Rejection System
- Power Conditioning/Distribution System
- Lighting System
- Environmental Control & Life Support System

Numerous additional support equipment items can be anticipated. These items are mission-specific and cannot be comprehensively defined at this time due to the nature of basic research. It is expected that mission-specific items can be accommodated via standardized storage lockers as the need arises.

Descriptions located in "Core Equipment" files

1.13 SAMPLE CHARACTERISTICS

Both seed and source materials are enclosed in sealed cylindrical ampoules and must not be exposed to excessive shock impulse. Samples have approximately one year shelf life.

2.0 ENVIRONMENTAL REQUIREMENTS

2.1 MICROGRAVITY ENVIRONMENT

Constant Unidirectional:....................1E-5g
Periodic Dynamic:..........................Unknown
Impulsive:.................................Unknown

Additional flight experience and improved instrumentation required.

2.2 AMBIENT ENVIRONMENT

Temperature: 21.0 deg C +/- 2.0 deg C
(constant record required)
Pressure: 14.7 psi +/- 0.2 psi
(constant record required)
Humidity: 70% relative humidity +/- 10%
(constant record required)

2.3 ACOUSTIC ENVIRONMENT

No acoustic output or susceptibility identified.

2.4 RADIATION ENVIRONMENT

No radiation output or susceptibility identified.

2.5 ISOLATION REQUIREMENT

All research activities are anticipated to be performed in mission-specific experiment apparatus isolated from the pressurized laboratory environment. Required experiment environments (temperature, pressure, composition) are to be accommodated in the design of the specific apparatus during the payload planning phase. The lab environment should minimize large magnitude swings in environmental parameters that have the potential to affect operation of the experiment apparatus subsystems. Continuous monitoring is required.

3.0 UTILITY REQUIREMENTS

3.1 POWER

Power requirements are dependent on the technique used. Chemical vapor transport represents higher demand due the need for a gradient furnace. Physical vapor transport requires approximately 0.5 kW continuous for up to 100 hours.Values below represent the greater requirement.

Operating Power:.........................2.00 kw
Typical Operating Cycle:.............100.00 hrs
Energy per Cycle:....................200.00 kwh
Electric Service:...............115 vac (60 Hz)

3.2 HEAT REJECTION

Both high and low temperature cooling loops will be required dependent on the vapor growth technique employed. Values below represent the growth requirement.

Peak Heat Rejection...............2.00 kw
Sink Temperature(s):..............4.00 deg C
..............80.00 deg C

3.3 DATA MANAGEMENT

Data acquisition, reduction (as required) and display (as required) is to be performed at the payload via integral microcomputer subsytem. Central Data Storage/Transceiver System (Core Equipment Item) is required to accommodate temporay (90 minute) data storage and to serve as downlink interface. High Resolution Video System (Core Equipment Item) required to achieve high research productivity and establish principal investigator telepresence.

Digital Data Rate:.................1.60 kbps
Generation Period:..............100.00 hrs
Interactive Audio:................20.00 hrs/day
Live Video:.......................20.00 hrs/day

3.4 WASTE MANAGEMENT

Wastes may include a broad range of liquids, solids, and gases employed in experiments which are currently undefined. Quantities and characteristics cannot be accurately predicted. All wastes should be assumed toxic. Core Equipment Items for disposal of all states are required.

Solids: All process solids are expected to be returned to ground for post-experiment analysis. Small quantities of packaging may require disposal.

Liquids: Cleaning solvents, etchants, and slurry water.

Gases: Inert gases and toxic vapors.

3.5 VACUUM

A Gas Evacuation/Adsorption/Venting System (Core Equipment Item) is considered essential to establish required process vacuum and to purge apparatus prior to initiation of next experiment series. Vacuum levels down to 1E-6 pa may be required.

Vacuum Pressure:..................0.000001 pa
Evacuation Volume:................0.015000 cu m

3.6 CREW SUPPORT

Crew support will be required to initiate experiment sequence and perform periodic monitoring of process parameters. Process is capable of continuing unattended for extended periods. Post-process sample characterization (sample preparation and optical microscopic examination) will accelerate research productivity by allowing previous results to be incorporated into the design of the next experiment. Scientist skill level would assure optimum productivity. Technologist acceptable.

4.0 LOGISTIC REQUIREMENTS

4.1 SUPPLY SCHEDULE

Resupply at 90 day intervals is adequate at IOC provided: (1) digital and video data can be transmitted to ground for analysis and followed by interactive audio session, and (2) minimal characterization (sample preparation and microscopic examination) is available on-orbit.

Typical Payload Mass:...........200.00 kg
Typical Payload Volume:...........1.10 cu m
GTS Stowage Mass:................25.00 kg
GTS Stowage Volume:...............0.15 cu m
STG Stowage Mass:................25.00 kg
STG Stowage Volume:...............0.15 cu m

GTS: Ground to Station
STG: Station to Ground

4.2 CONSUMMABLES

Small volume mission-specific consummable materials require transport in Standardized Modular Lockers (Core Equipment Item) and on-obit transfer via standard containers to the Fluids Dispensing System (Core Equipment Item), or an integral payload subsystem. Large volume consummables (gases) require storage on an Attached External Pallet (Core Equipment Item) and transfer via automated distribution system for end-use.

5.0 SAFETY

5.1 HAZARDS ASSESSMENT

Temperatures in excess of 500 deg C are expected in chemical vapor transport and pressure extremes down to 1 EE-8 torr may be required for physical vapor transport. The presence of toxic gases and solvents is anticipated. Standard spaceflight provisions for control of shock hazard at all electrical interfaces are required.

ADDENDUM

1.0 BACKGROUND

1.1 RESEARCH OBJECTIVES

The electronic device structures of III-V compounds are based totally on epitaxial layers grown on bulk single-crystal substrates. For most devices, epitaxial layers are presently grown from liquid solutions. In Liquid Phase Epitaxy (LPE) the substrate is thermally equilibriated with the solution and growth takes place upon supersaturation of the solution brought about by a temperature decrease. Precise control of the growth velocity and of segregation can be achieved through passage of electric current across the growth interface, however, due to convective instabilities in the melt and other complexities introduced by Joule heating, bulk single-crystal growth has not yet been achieved. Current controlled growth has been successfully achieved in a Liquid Phase Electroepitaxy (LPEE) configuration where Joule heating presents no significant difficulties because the dimensions of the substrate and the solution are relatively small (Gatos et al, 1978-80). The microgravity environment offers the opportunity to pursue development of LPEE in the abscence of gravity-induced thermal convection and thereby work in dimensions which are relatively large. Research objectives are therefore to further define the theoretical models for LPEE and to conduct applied research in the microgravity environment as a precursor to development of prototype production scale apparatus. Such apparatus would be designed for the bulk production of single-crystal, device quality semiconductor materials.

1.2 POTENTIAL APPLICATIONS

The LPEE process, using relatively thin substrates in the abscence of appreciable convective flow, takes place under essentially isothermal conditions. As a result, epitaxial layers exhibit improved surface morphology and decreased defect density required for improved device structures. To date, LPEE has been used to successfully grow GaAs, InP, GaAlAs, and garnet layers. Bulk production of such materials represents potentially high payoff technology having significant electronic applications.

1.3 PHENOMENA OF INTEREST

Diffusion Mass Transport, Segregation, Electromigration, Peltier Effect, Combined Effects

LIQUID PHASE ELECTROEPITAXY

1.4 PROCESSES OF INTEREST

Solution crystal growth via current-controlled Liquid Phase ElectroEpitaxy (LPEE)

1.5 PRODUCTS OF INTEREST

III-V Semiconductors (e.g., GaAs, InSb, InP, GaAlAs) produced as large diameter single crystals

1.6 PROPERTIES OF INTEREST

Resistivity, Carrier Concentration and Mobility, Structural Perfection, Size (diameter), Homogeneity, Radiation Hardness, Carrier Lifetime

1.7 HISTORY OF INVESTIGATION

Ground-based theoretical models for growth kinetics and dopant segregation are well developed (Gatos et al). Laboratory scale prototypes have been successfully demonstrated. Flight research has been limited by availability of experimental apparatus. Microgravity Research Assoc. (MRA) are currently participating with NASA under a JEA to advance technology for space-based LPEE and to develop a prototype production scale system for bulk growth of single-crystal GaAs during the Space Station era.

1.8 KEY INDIVIDUALS

Gatos, H. / Lagowski, J. / Jastrzebski, L. / Pace, R. / Witt, A. / Ramsland, R. / Randolph, R.

1.9 FLIGHT REQUIREMENT

1993 Space Station Initial Operating Configuration (IOC)
360 Days

Status: Conceptual (> 5 Year Horizon)

1.10 SECURITY CONSIDERATIONS

Proprietary research can be anticipated. Provisions arerequired for:
(1) encryptionof downlinked data,
(2) crew function security,
(3) sample, payload, and video tape security during transport, and
(4) government confidentiality regarding specific experimental techniques. On-orbit PI accommodations are highly desirable.

1.11 PRIMARY EQUIPMENT

Primary equipment requirement is for an Electroepitaxial Crystal Growth Experiment System to support applied commercial research on both the LPEE process and candidate material systems. Advanced requirement is for a prototype Production Electroepitaxial Crystal Growth System (PECGS). The advanced requirement is for an apparatus to support applied commercial research in the bulk production of device quality semiconductor materials. As such, it represents a production scale system having resource requirements which extend as great as one order of magnitude beyond the requirements typical of small apparatus used in basic research. The requirements indicate that, although basic research may dominate the laboratory at IOC, provisions will be necessary to accommodate applied commercial research of a prototype production magnitude.

Descriptions located in "Experiment Apparatus" files.

1.12 SUPPORT EQUIPMENT

The following **Core Equipment Items** are required:

- High Resolution Video System
- Mass Measurement System
- Integrated Optical Microscopy Lab
- Integrated Electronics Lab
- Sample Cutting, Polishing, & Etching System
- Standardized Modular Lockers
- Reconfigurable Workbench
- Tool/Supplies Locker
- Tri-Axis Accelerometer System
- Attached External Pallet
- Automated Gas Distribution System
- Fluids Dispensing System
- Emergency Provisions Locker
- Science Airlock
- Waste Management System
- Central Data Storage/Transceiver System
- Heat Rejection System
- Power Conditioning/Distribution System
- Lighting System
- Environmental Control & Life Support System

Numerous additional support equipment items can be anticipated. These items are mission-specific and cannot be comprehensively defined at this time due to the nature of basic research. It is expected that mission-specific items can be accommodated via standardized storage lockers as the need arises.

Descriptions located in "Core Equipment" files

1.13 SAMPLE CHARACTERISTICS

Samples are anticipated to be sealed crystal growth cells which are inserted into the growth modules of the production system. Growth cells require transport to and from laboratory with provisions for adequate storage volume on-orbit.

2.0 ENVIRONMENTAL REQUIREMENTS

2.1 MICROGRAVITY ENVIRONMENT

Constant Unidirectional:....................1E-6g
Periodic Dynamic:..................1E-4 @ 0.001 Hz
..................1E-1 @ 0.100 Hz
..................1E+1 @ 1.000 Hz
Impulsive:................................Unknown

Additional flight experience and improved instrumentation required.

2.2 AMBIENT ENVIRONMENT

Temperature: 21.0 deg C +/- 2.0 deg C
(constant record required)
Pressure: 14.7 psi +/- 0.2 psi
(constant record required)
Humidity: 70% relative humidity +/- 10%
(constant record required)

2.3 ACOUSTIC ENVIRONMENT

No acoustic output or susceptibility identified.

2.4 RADIATION ENVIRONMENT

No radiation output or susceptibility identified.

2.5 ISOLATION REQUIREMENT

All research activities are anticipated to be performed in mission-specific experiment apparatus isolated from the pressurized laboratory environment. Required experiment environments (temperature, pressure, composition) are to be accommodated in the design of the specific apparatus during the payload planning phase. The lab environment should minimize large magnitude swings in environmental parameters that have the potential to affect operation of the experiment apparatus subsystems. Continuous monitoring is required.

3.0 UTILITY REQUIREMENTS

3.1 POWER

During warmup period power draw increases from ~5.0 - 20.0 kW over 10 hours. Continuous requirement is for instantaneous power at 27.0 kW level to support crystal growth, cycling of precision heaters, and peripheral components. Process is essentially continuous, however, 220 hour test cycles are anticipated during the prototype research phase. Values provided below represent the peak requirement for the production prototype system.

Operating Power:.......................27.00 kw
Typical Operating Cycle:.............220.00 hrs
Energy per Cycle:...................5940.00 kwh
Electric Service:.................28 vdc +/- 5%

3.2 HEAT REJECTION

Heat rejection requirements reflect peak power anticipated for the prototype production system. A liquid cooling loop at 93 deg C is required to reject up to 20 kW continuously. An additional 7.0 kW capacity @ 46 deg C is required for power controllers and electronics. Values provided below reflect peak requirement for the liquid cooling loop.

Peak Heat Rejection:.............20.00 kw
Sink Temperature:................93.00 deg C

3.3 DATA MANAGEMENT

Data acquisition, reduction, and display to be performed at the payload via an integral microcomputer. A Central Data Storage/Transceiver System (Core Equipment Item) is required for temporary data storage prior to downlink. Voice link is required, video link is desirable. Digital downlink requirement is estimated at 2.0 kbps for 2.24 hr duration. Frequency is estimated to be 3 downlink data transfers/month. Values provided below represent the requirements for a prototype production system.

Digital Data Rate:................2.00 kbps
Generation Period:................2.24 hrs
Interactive Audio:................0.50 hrs/day
Live Video:.......................Desirable

3.4 WASTE MANAGEMENT

A gaseous hydrogen recovery system is required. Primary waste product is hydrogen purge gas in quantities up to ~50,000 SCF throughput per 90 day period. Vacuum venting provision also required during process warmup period.

Solids: No solid wastes are currently anticipated. All crystalline material is to be returned to ground for analysis.

Liquids: All liquids are to be contained in sealed cells. Cells are all to be returned to ground for analysis.

Gases: Hydrogen purge gases are anticipated. Throughput may reach 50,000 SCF per 90 day period. A recovery system is required.

3.5 VACUUM

Vacuum venting will be required during process warmup period only.

3.6 CREW SUPPORT

Crew support required for: (1) loading/unloading crystal growth cells, (2) periodic monitoring via visual display, (3) response to alarm conditions, including corrective actions and audio sessions with ground personnel. A technician skill level is considered adequate. Process will be highly automatedduring the prototype production crystal growth activity.

4.0 LOGISTIC REQUIREMENTS

4.1 SUPPLY SCHEDULE

Resupply at 90 day intervals is considered adequate provided that sufficient on-board storage space is available for processed growth cells, input growth cells, spares, and consummable gases. Primary payload (PECGS) transport is single event and not included in 90-day resupply schedule.

Production Payload Mass:.......2450.00 kg
Production Payload Volume:........2.90 cu m
GTS Stowage Mass:.............2450.00 kg
GTS Stowage Volume:...............2.90 cu m
STG Stowage Mass:.............2450.00 kg
STG Stowage Volume:...............2.90 cu m
System Spares Mass:.............250.00 kg
System Spares Volume:.............0.42 cu m

GTS: Ground to Station
STG: Station to Ground

4.2 CONSUMMABLES

Small volume mission-specific consummable materials require transport in Standardized Modular Lockers (Core Equipment Item) and on-obit transfer via standard containers to the Fluids Dispensing System (Core Equipment Item), or an integral payload subsystem. Large volume consummables (gases) require storage on an Attached External Pallet (Core Equipment Item) and transfer via automated distribution system for end-use.

5.0 SAFETY

5.1 HAZARDS ASSESSMENT

Standard spaceflight provisions for control of shock hazard at all electrical interfaces. No hazardous temperatures/pressures identified. Provisions required for safe storage, handling, and recovery of hydrogen purge gas. All potential process hazards can be controlled via failsafe design during the payload planning phase.

ADDENDUM

CONTAINERLESS PROCESSING (CONDUCTIVE MELTS)

1.0 BACKGROUND

1.1 RESEARCH OBJECTIVES

Containerless processing of electrically conductive materials under conditions of microgravity allows the elimination of crucible walls and other melt/solid interfaces. In addition, reductions in segregation of melt compounds and minimization of convective flow has been demonstrated. Decreased contamination of the melt and solidified material can result in monolithic structures having high regularity, uniform dispersions of materials having dissimilar density, and new composite structures. The primary objective of research is to take advantage of the benefits of the microgravity enviroment and to investigate new material systems having unique properties with high value commercial applications. Near term objectives include advancing the technical maturity of electromagnetic levitation techniques which are used to control and manipulate the sample during processing. Electromagnetic positioning has several advantages including, (1) the flexibility to work in either a vacuum or inert gas environment, (2) the ability to accommodate either electron beam or induction heating, and (3) the capability to operate successfully at very high temperatures (> 3400 deg C.). Future objectives include extending the range of materials by the use of preheating techniques, and increasing contributions to the science base in the area of high temperature thermophysical properties measurement.

1.2 POTENTIAL APPLICATIONS

Identified product applications include: superconducting, supermagnetic, and superstrength materials for electrical equipment, electronic substrates, cathodes, gas turbine components, nuclear reactor rods, x-ray targets, and magnetic components. Uniform dispersions of particles within substrates have applications as phototropic windows, polarization lenses, light filters, and striking glasses. Refractory materials of high temperature corrosion resistance have also been identified.

1.3 PHENOMENA OF INTEREST

Nucleation, Solidification, Undercooling, Dispersion Uniformity, Materials Segregation

1.4 PROCESSES OF INTEREST

Melting, Positioning, Stirring, Cooling, Supercooling, Solidifying

1.5 PRODUCTS OF INTEREST

Superalloys, Superconductors, Magnetoresistive/Infrared Eutectics, High Purity Metals,etc.

1.6 PROPERTIES OF INTEREST

Conductivity/Resistivity, Strength, Dispersion Uniformity, Thermal Resistance, Microstructure

1.7 HISTORY OF INVESTIGATION

Initial investigations occurred in sounding rockets using an electromagnetic levitator (EML). Continuing studies with the EML are planned for the Shuttle Materials Science Lab (MSL). Ground-based research is proceeding jointly between General Electric, Rice Univ., and the National Bureau of Standards in the area of thermophysical properties measurement. Progress has been limited by the availability of experiment hardware and flight opportunities on the Shuttle.

1.8 KEY INDIVIDUALS

Frost, R. / Flemings, M. / Shiohara, Y. / Bayucizk, R. / Collings, E. / Chu, C. / Wouch, G. /Szekely, J.

1.9 FLIGHT REQUIREMENT

1993 Space Station Initial Operating Configuration (IOC)
360 Days

Status: Conceptual (> 5 Year Horizon)

1.10 SECURITY CONSIDERATIONS

Proprietary research can be anticipated. Provisions arerequired for:
(1) encryptionof downlinked data,
(2) crew function security,
(3) sample, payload, and video tape security during transport, and
(4) government confidentiality regarding specific experimental techniques. On-orbit PI accommodations are highly desirable.

1.11 PRIMARY EQUIPMENT

Primary equipment requirement is for advanced electromagnetic levitation apparatus and preheating systems utilizing electron beam and laser heating techniques. Ground-based apparatus are well developed and meet most research requirements, however, the development of flight hardware has lagged significantly. Currently used Electromagnetic Levitator Furnace (EML) developed at General Electric during SPAR rocket program is restricted in application.

Descriptions located in "Experiment Apparatus" files.

1.12 SUPPORT EQUIPMENT

The following **Core Equipment Items** are required:

- High Resolution Video System
- Mass Measurement System
- Integrated Optical Microscopy Lab
- Integrated Electronics Lab
- Sample Cutting, Polishing, & Etching System
- Standardized Modular Lockers
- Reconfigurable Workbench
- Tool/Supplies Locker
- Tri-Axis Accelerometer System
- Attached External Pallet
- Automated Gas Distribution System
- Fluids Dispensing System
- Emergency Provisions Locker
- Science Airlock
- Waste Management System
- Central Data Storage/Transceiver System
- Heat Rejection System
- Power Conditioning/Distribution System
- Lighting System
- Environmental Control & Life Support System

Numerous additional support equipment items can be anticipated. These items are mission-specific and cannot be comprehensively defined at this time due to the nature of basic research. It is expected that mission-specific items can be accommodated via standardized storage lockers as the need arises.

Descriptions located in "Core Equipment" files

1.13 SAMPLE CHARACTERISTICS

Samples are anticipated to consist largely of inorganic spheres, rods, boules, discs, etc., prepared on the ground for on-orbit loading into experiment apparatus. Dependent on apparatus design, samples may be contained in cartridges, crucibles, or ampoules. No limit to shelf life has been identified. Samples will require transport in a Standardized Modular Locker (Core Equipment Item) and storage on-orbit.

2.0 ENVIRONMENTAL REQUIREMENTS

2.1 MICROGRAVITY ENVIRONMENT

Constant Unidirectional:....................1E-6g
Periodic Dynamic:..................1E-6g @ 00.01 Hz
..................1E-5g @ 00.10 Hz
..................1E-3g @ 01.00 Hz
..................1E-1g @ 10.00 Hz
Impulsive:..............................Unknown

Additional flight experience and improved instrumentation required.

2.2 AMBIENT ENVIRONMENT

Temperature: 21.0 deg C +/- 2.0 deg C (constant record required)
Pressure: 14.7 psi +/- 0.2 psi (constant record required)
Humidity: 70% relative humidity +/- 10% (constant record required)

2.3 ACOUSTIC ENVIRONMENT

No acoustic output or susceptibility identified.

2.4 RADIATION ENVIRONMENT

High electromagnetic (including optical) output potential if the system is not adequately shielded. Range and magnitude have not yet been identified.

2.5 ISOLATION REQUIREMENT

All research activities are anticipated to be performed in mission-specific experiment apparatus isolated from the pressurized laboratory environment. Required experiment environments (temperature, pressure, composition) are to be accommodated in the design of the specific apparatus during the payload planning phase. The lab environment should minimize large magnitude swings in environmental parameters that have the potential to affect operation of the experiment apparatus subsystems. Continuous monitoring is required.

3.0 UTILITY REQUIREMENTS

3.1 POWER

Power required to bring specimens to melt temperature is anticipated to range from as low as 1.0 kW for small specimens up to 20.0 kW for large specimens such as beryllium and beryllia dispersion. At IOC a minimum requirement of 5.0 kW is desirable. During the growth phase, increases to the 20.0 kW level will be necessary to initiate applied research on potential commercial products. Values provided below represent the growth requirement.

Operating Power:..................20.00 kw
Typical Operating Cycle:..........1.00 hr
Energy per Cycle:................20.00 kwh
Electric Service:.........230 vac (400 Hz)

3.2 HEAT REJECTION

Heat rejection requirements reflect the peak power demand during the growth stage. Samples may require quenching to achieve cooling at rates as high as 1000 deg. C/sec. Both low temperature liquid cooling and inert gas quench can be anticipated.

Peak Heat Rejection:.............20.00 kw
Sink Temperature(s):.............25.00 deg C
.............80.00 deg C

3.3 DATA MANAGEMENT

Data acquisition, reduction (as required), and display (as required) is to be performed at the payload via integral microcomputer subsystem. Central Data Storage/Transceiver System (Core Equipment Item) required to accommodate temporary (90 minute) data storage and to serve as downlink interface. High Resolution Video System (Core Equipment Item) has the potential to accelerate research productivity by establishing a principal investigator telepresence during experiment performance.

Digital Data Rate:...............16.00 kbps
Generation Period:...............20.00 hrs
Interactive Audio:...............20.00 hrs/day
Live Video:......................20.00 hrs/day

3.4 WASTE MANAGEMENT

The following are considered essential Core Equipment Items: (1) Gas Evacuation/Adsorption /Venting System, (9) Solids Compaction/Containment System, (3) Liquids Filtration/Purification System. All waste materials should be assumed toxic.

Solids: Trace quantities of sample materials (Ti, TiO, LaO, Oxides, Sn, Fe, In, Sb, Borides, Silicides, Pd, Si, S, FeS, Ce, Eu, Mo, Nitrides) from cutting and polishing activities.

Liquids: Etchants (acids, bromides, hydroxides, peroxides) and wash slurries (solvents) in quantities < 1.0 liter/30 days.

Gases: Inert gases, carbon monoxide/dioxide, oxygen, nitrogen, and steam.

3.5 VACUUM

Processing environments may be either vacuum or inert gas. The choice exists to conduct experiments in a vacuum of ~1E-3 pa or with a high purity inert gas at pressures up to ~1 E+5 pa. In either case both an Automated Gas Distribution System and a Gas Evacuation/Adsorption/Venting System (Core Equipment Items) will be required. Values provided below represent the maximum requirements currently foreseen.

Vacuum Pressure:..................0.0010 pa
Evacuation Volume:................0.0850 cu m

3.6 CREW SUPPORT

The nature of basic research precludes the ability to fully automate containerless processing experiments. Process monitoring and real-time modification is essential to experiment design and research productivity. Most experiments are projected to be 5-15 minutes in duration. Crew support will be required for experiment initiation, process monitoring and evaluation, parameter adjustment, experiment rerun, and post-experiment diagnostics. Scientist skill level will yield highest productivity.

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4.0 LOGISTIC REQUIREMENTS

4.1 SUPPLY SCHEDULE

Resupply at 90 day intervals is considered adequate at IOC provided that: (1) video and digital data can be transmitted for ground-based evaluation and followed by interactive audio session, and (2) minimal characterization (sample preparation and microscopic examination) is available on-orbit.

Typical Payload Mass:...........350.00 kg
Typical Payload Volume:...........1.10 cu m
GTS Stowage Mass:................25.00 kg
GTS Stowage Volume:...............0.15 cu m
STG Stowage Mass:................25.00 kg
STG Stowage Volume:...............0.15 cu m

GTS: Ground to Station
STG: Station to Ground

4.2 CONSUMMABLES

Small volume mission-specific consummable materials require transport in Standardized Modular Lockers (Core Equipment Item) and on-obit transfer via standard containers to the Fluids Dispensing System (Core Equipment Item), or an integral payload subsystem. Large volume consummables (gases) require storage on an Attached External Pallet (Core Equipment Item) and transfer via automated distribution system for end-use.

5.0 SAFETY

5.1 HAZARDS ASSESSMENT

Temperature extremes up to 3400 deg C. and pressure extremes to 1 EE-8 torr can be anticipated. Toxic vapors and liquids will also be present. If electron beam heating is employed low electron particle radiation may occur. Specular reflection from use of lasers may be present, as well as, electromagnetic (including optical) radiation. Standard spaceflight provisions for control of shock hazard at all electrical interfaces are required.

ADDENDUM

CONTAINERLESS PROCESSING (NON-CONDUCTIVE MELTS)

1.0 BACKGROUND

1.1 RESEARCH OBJECTIVES

Near term objective is to develop a reliable capability to manipulate glass and ceramic melts at high temperature (>2400 deg C) by advanced levitation technologies (acoustic, gas-jet, electrostatic, electromagnetic). Achievement of capability represents limit to research progress. Primary research objective is to produce unique materials that cannot be manufactured by conventional techniques in the one-g earth environment. Modification to material properties, by alterations in microstructure and composition, can result in increased performance characteristics having value added exceeding the cost of processing. Supporting science objectives include: (1) increased knowledge of fluid, gas, and interface dynamics, (2) increased understanding of morphological phenomena having application to ground-based processes, (3) extension and/or addition of glass forming regions in materials, and (4) control over processing areas such as homogenization, fining, crystallization, and nucleation.

1.2 POTENTIAL APPLICATIONS

Potential applications include: (1) improved fiber optics having properties of infrared transparancy, low loss, and high purity, (2) laser hosts for higher power, new spectral ranges, and tailored bandwidths, (3) hollow spheres having high concentricity for fusion targets, encapsulation, and aerospace structural materials, (4) new compositions of fluorides, gallates, and tantalates having unique properties, and (5) contributions to the science base in thermophysical properties measurement.

1.3 PHENOMENA OF INTEREST

Crystallization, Nucleation, Surface Tension, Mass Transport, Phase Transformation/Separation

CONTAINERLESS PROCESSING (NON-CONDUCTIVE MELTS)

1.4 PROCESSES OF INTEREST	Positioning, Shaping, Fining, Homogenizing, Dispersion Strengthening, Directional Solidification
1.5 PRODUCTS OF INTEREST	Gradient & High Power Lasers, Mirrors, Lenses, Fiberoptics, Ceramic Reinforcements, Glass Shells
1.6 PROPERTIES OF INTEREST	Viscosity, Electrical Conductivity/Loss, Optical Emissivity/Transmissivity, Interfacial Tension
1.7 HISTORY OF INVESTIGATION	Active investigations underway at: JPL, MSFC, LeRC, MIT, RPI, KMS Fusion, Univ. of Missouri & Clarkson U. since mid-1970's. Ground studies focused on processes for glass formation, gel precursor preparation, diffusion in melts, bubble dynamics, and surface tension effects. Shuttle studies focused on basic research in crystallization, mixing, bubble dynamics, and specific material systems. Progress limited by flight opportunities, schedule slippage, and inadequate experiment equipment.
1.8 KEY INDIVIDUALS	Barmatz,M. / Day,D. / Doremus,R. / Downs,R. / Elleman,D. / Etheridge,E. / Dunn,S. / Lee,M. / Wang,T. / Mukherjee,S. / Neilson,G. / Weinberg, M. / Whymark,R. / Subramanian,S. / Cole,R. / Uhlmann,D. / Hendricks,C. / Kreidl,N. / Prochazka,S. / Snitzer,E. / Rey, C.
1.9 FLIGHT REQUIREMENT	1993 Space Station Initial Operating Configuration (IOC) 360 Days Status: Conceptual (> 5 Year Horizon)
1.10 SECURITY CONSIDERATIONS	Proprietary research can be anticipated. Provisions arerequired for: (1) encryptionof downlinked data, (2) crew function security, (3) sample, payload, and video tape security during transport, and (4) government confidentiality regarding specific experimental techniques. On-orbit PI accommodations are highly desirable.

1.11 PRIMARY EQUIPMENT

Primary equipment requirements include: (1) a High Temperature Levitating Furnace, (2) an Ultrahigh Temperature Levitating Furnace, and (3) a High Temperature Isothermal Furnace. Technology advance is required for the levitating furnaces; current techniques have not achieved desired capability. Candidates for advance include single/triple axis acoustic and gas-jet levitators. Following achievement of equipment technology, techniques may be applied to prototype production processing. At this phase primary equipment requirements may increase to include glass forming systems, fiber pulling systems, and a wide variety of similar prototype hardware. These apparatus cannot be comprehensively defined at this time due to the nature of basic research and the need to perform precursor experimentation prior to assessing commercial feasibility.

Descriptions located in "Experiment Apparatus" files.

1.12 SUPPORT EQUIPMENT

The following **Core Equipment Items** are required:

- High Resolution Video System
- Mass Measurement System
- Integrated Optical Microscopy Lab
- Integrated Electronics Lab
- Sample Cutting, Polishing, & Etching System
- Standardized Modular Lockers
- Reconfigurable Workbench
- Tool/Supplies Locker
- Tri-Axis Accelerometer System
- Attached External Pallet
- Automated Gas Distribution System
- Fluids Dispensing System
- Emergency Provisions Locker
- Science Airlock
- Waste Management System
- Central Data Storage/Transceiver System
- Heat Rejection System
- Power Conditioning/Distribution System
- Lighting System
- Environmental Control & Life Support System

Numerous additional support equipment items can be anticipated. These items are mission-specific and cannot be comprehensively defined at this time due to the nature of basic research. It is expected that mission-specific items can be accommodated via standardized storage lockers as the need arises.

Descriptions located in "Core Equipment" files

1.13 SAMPLE CHARACTERISTICS

Samples consist of 10-100 mm diameter solid spheres. Current research employs 6-7 mm samples; increased size is required to accelerate progress. Capability to work in 10-20 mm range is acceptable at IOC pending increased capability during growth stage. Many solid substances can reform to an amorphous or glassy structure under conditions available in the microgravity enviroment. Fluoride glasses are currently of high interest, however, numerous additional systems can be anticipated.

2.0 ENVIRONMENTAL REQUIREMENTS

2.1 MICROGRAVITY ENVIRONMENT

Constant Unidirectional:....................1E-5g
Periodic Dynamic:..........................Unknown
Impulsive:.................................Unknown

Additional flight experience and improved instrumentation required.

2.2 AMBIENT ENVIRONMENT

Temperature: 21.0 deg C +/- 2.0 deg C (constant record required)
Pressure: 14.7 psi +/- 0.2 psi (constant record required)
Humidity: 70% relative humidity +/- 10% (constant record required)

2.3 ACOUSTIC ENVIRONMENT

Potential high acoustic output (> 150 db) if acoustic positioning techniques are used and inadequately shielded.

2.4 RADIATION ENVIRONMENT

No radiation output or susceptibility identified.

2.5 ISOLATION REQUIREMENT

All research activities are anticipated to be performed in mission-specific experiment apparatus isolated from the pressurized laboratory environment. Required experiment environments (temperature, pressure, composition) are to be accommodated in the design of the specific apparatus during the payload planning phase. The lab environment should minimize large magnitude swings in environmental parameters that have the potential to affect operation of the experiment apparatus subsystems. Continuous monitoring is required.

3.0 UTILITY REQUIREMENTS

3.1 POWER

At IOC a minimum 5.0 kw accommodation is required to continue basic research with 10 mm (approx) samples. During growth stage capability to 25 kw is required for applied research. Lab design must include accommodations for expanding power capability to meet growth requirement. Parameters which follow represent the growth requirement.

Operating Power:.................25.00 kw
Typical Operating Cycle:..........4.00 hrs
Energy per Cycle:...............100.00 kwh
Electric Service:..115/230 vac (60/400 Hz)

3.2 HEAT REJECTION

Heat rejection requirements reflect peak power anticipated. During growth stage increased capacity (to 25.0 kw) is required. Initial design must include provisions for accommodating the growth requirement. Values provided below represent the growth requirement.

Peak Heat Rejection:.............25.00 kw
Sink Temperature:................90.00 deg C

3.3 DATA MANAGEMENT

Data acquisition, reduction (as required), and display (as required) to be performed at the payload via integral microcomputer subsytem. Central Data Storage/Transceiver System (Core Equipment Item) required to accommodate temporary (90 min.) data storage and to serve as downlink interface. High Resolution Video System (Core Equipment Item) required to achieve high research productivity. Best available technology at IOC perceived as critical to establish real-time telepresence.

Digital Data Rate:...............16.00 kbps
Generation Period:...............20.00 hrs
Interactive Audio:...............20.00 hrs/day
Live Video:......................20.00 hrs/day

3.4 WASTE MANAGEMENT

The following Core Equipment Items are required: (1) Gas Evacuation/Adsorption/Venting System, (2) Liquids Filtration/Purification System, and (3) Solids Compaction/Containment System. All waste materials should be assumed toxic.

Solids: Trace quantities of sample material from grinding and polishing activities; balance of solids returned to ground for analysis.

Liquids: Etchants (acids, bromides, hydroxides, peroxides) and wash slurries (solvents) in quantities < 1.0 liter/30 days.

Gases: Helium, hydrogen, nitrogen, oxygen, hydrogen fluoride, halogens, and noxious vapors. Quantities cannot be accurately predicted.

3.5 VACUUM

Access to a Gas Evacuation/Adsorption/Venting System (Core Equipment Item) is considered essential to accommodate apparatus purge and waste product removal prior to rerun of experiment and/or initiation of new experiment. Access to an ultrahigh vacuum (1E-14 torr) via a wakeshield facility is highly desirable during the growth stage to accommodate research activities having high susceptibility to contamination from trace materials.

Vacuum Pressure:..................0.0001 pa
Evacuation Volume:................0.0850 cu m

3.6 CREW SUPPORT

Nature of basic research precludes ability to fully automate experiment apparatus. Process monitoring and real-time modification is essential to experiment design and research productivity. Crew support will be required for experiment setup, initiation, process monitoring and evaluation, parameter adjustment, experiment rerun, and post-experiment diagnostics. Scientist skill level will yield highest research productivity. Technologist acceptable at the expense of research timelines.

4.0 LOGISTIC REQUIREMENTS

4.1 SUPPLY SCHEDULE

Resupply at 90 day intervals is adequate at IOC provided: (1) video and digital data can be transmitted to ground for evaluation and followed by interactive audio sessions, and (2) minimal characterization equipment (sample preparation and microscopic evaluation) is available on-orbit.

Typical Payload Mass:...........750.00 kg
Typical Payload Volume:...........2.00 cu
GTS Stowage Mass:...............250.00 kg
GTS Stowage Volume:...............0.50 cu m
STG Stowage Mass:...............250.00 kg
STG Stowage Volume:...............0.50 cu m

GTS: Ground to Station
STG: Station to Ground

4.2 CONSUMMABLES

Small volume mission-specific consummable materials require transport in Standardized Modular Lockers (Core Equipment Item) and on-obit transfer via standard containers to the Fluids Dispensing System (Core Equipment Item), or an integral payload subsystem. Large volume consummables (gases) require storage on an Attached External Pallet (Core Equipment Item) and transfer via automated distribution system for end-use.

5.0 SAFETY

5.1 HAZARDS ASSESSMENT

Temperature extremes to 1500 deg C and pressure extremes to 0.0001 pa can be anticipated. Electron particle, x-ray, and RF radiation may be present, dependent upon final selection of heating method and on-board characterization equipment. Toxic materials are required for sample etching. Standard spaceflight provisions for control of shock hazard required at all electrical interfaces. Hazard control provisions can each be accommodated during the payload design phase.

ADDENDUM

APPENDIX B

CORE EQUIPMENT REQUIREMENTS

The following items represent the semi-permanent core equipment required to support Microgravity Science and Applications research in a pressurized laboratory module at the initial operating capability (IOC) of the planned NASA Space Station.

Additional equipment items are anticipated such as experiment apparatus and a broad variety of supporting hardware, however, all supporting hardware is considered mission-specific. Potential Space Station users consistently advise that mission-specific equipment cannot be comprehensively defined at this time due to the nature of basic research. User preference is to incorporate mission-specific supporting hardware via standardized storage lockers as the need arises. A functional approach to laboratory planning and design has been encouraged.

Page

No further core equipment items have been identified at this time. Accurate description of the performance requirements for these items is of concern to the scientific user community.

HIGH RESOLUTION VIDEO SYSTEM

1.0 PURPOSE

1.1 FUNCTIONAL DESCRIPTION

The HRVS provides a video recording capability with integral interactive communications and image processing capability.

1.2 RATIONALE FOR INCLUSION

Many experimental phenomena produce data which cannot be interpreted accurately without a "well-trained eye". First-hand observation can be supplanted only by a real-time or recorded snapshot of the experiment. In addition, difficult or critical procedures which must be supervised by the P.I. as well as changes to the procedure due to unexpected results require a visual link.

1.3 IMPACT OF EXCLUSION

Experiments requiring procedures guided by the P.I. will be required to sacrifice significant payload space for for integral recording systems, thereby increasing payload size. Payloads with particularly ambiguous results may require additional flights, complicating payload traffic. Exclusion roughly triples communications system requirements as variations and unexpected events are handled solely by voice link.

1.4 USER DISCIPLINES

The following disciplines require the use of this Core Equipment Item:

- Electronic Materials
- Metals and Alloys
- Glasses and Ceramics
- Combustion Sciences
- Fluids and Transport Phenomena
- Polymer Science

2.0 PERFORMANCE

2.1 CAPABILITIES RANGE

The HRVS should provide state-of-the-art high resolution video sensing systems capable of storing 2000 frames per second at roughly a million pixels per frame. Continuous processing of five video input channles in color implies a 90 minute dynamic storage capacity of over 800 GB (gigabytes). Average demand, however, assuming judicious use of recording capacity, should not exceed around 3 GB/90 min. HRVS should allow interactive video communications as well as digital image processing capability, requiring an integral communications timing/buffering subsystem. Multichannel video access will require microprocessor-based time-sharing and data storage control systems to smoothly and efficiently integrate transactions.

2.2 INTERFACE PROVISIONS

HRVS must conform to the communications and data protocols of the Central Data Storage/Transceiver System (CDSTS - Core equipment Item), which is expected to drive data and communications interface planning. Ideally, the HRVS must act as a loosely-coupled buffering node of the CDSTS.

2.3 AUTOMATION LEVEL

HRVS requires manual control due to the unpredictable nature of video transactions.

2.4 OBSERVATION REQUIREMENTS

Observation requirments are minimal beyond a rudimentary status panel indicating recording/image processing status, channel selection, etc.

2.5 DATA REQUIREMENTS

HRVS should be capable of 800 GB worst-case 90 minute data storage, or 3 GB average-case 90 minute data storage. Automatic data packet shipment to CDSTS for downlink is desirable. In addition, HRVS must have direct access to the communications subsystem for interactive video when required.

2.6 MAINTENANCE REQUIREMENTS

HRVS will require periodic preventive maintenance as well as slave software updates. Low-level redundancy should be incorporated in critical components, as repairs are typically time-intensive. Component-level fault diagnosis and repair are expected.

2.7 SAFETY ASSESSMENT

Based on current technologies, HRVS should present no hazards other than electrical shock during repair/maintenance activity; however, projected technologies involve high-intensity laser light with unknown failure modes.

2.8 PHYSICAL PARAMETERS

Mass: 20 kg (estimated).
Volume: 0.2 cu m (estimated).

3.0 TECHNOLOGY STATUS

3.1 READINESS LEVEL

Currently available technology will not meet the frame-rate, video resolution, or compact data storage requirements of this system. However, current lines of research are expected to yield such capability prior to 1987. All other system requirements can be fulfilled under current technologies.

3.2 EQUIPMENT AVAILABILITY

Currently available equipment does not meet performance requirements. Video technology can be anticipated to change significantly over the next five years, resulting in a new generation of video systems available during the Space Station era.

3.3 DEVELOPMENT NEEDS

Technology assessment is required to provide a framework for tracking applicable technologies. Appropriate technology insertion points require identification and equipment selection.

RECOMMENDATION

INITIATE TECHNOLOGY ASSESSMENT OF MOST ACTIVE CURRENT VIDEO RECORDING AND IMAGE PROCESSING TECHNOLOGIES, TO PROVIDE A SYSTEM FOR EVALUATING APPLICABLE EMERGING TECHNOLOGIES.

NOTES

MASS MEASUREMENT SYSTEM

1.0 PURPOSE

1.1 FUNCTIONAL DESCRIPTION

Provides non-gravimetric determination of inertial mass by measuring the frequency or period of a linear spring-mass oscillator. Must accommodate powdered solids, lump solids, plastic mixtures, liquid masses, and gels.

1.2 RATIONALE FOR INCLUSION

Permits preparation of samples on-orbit, and basic evaluation of experimental results. Greatly increases flexibility for contingency experiments and fine tuning of process parameters.

1.3 IMPACT OF EXCLUSION

Limits lab capability to ground-prepared samples of premeasured mass/composition. Restricts performance of experiments of opportunity and on-orbit evaluation of experiment results.

1.4 USER DISCIPLINES

The following disciplines require the use of this Core Equipment Item:

- Electronic Materials
- Metals and Alloys
- Glasses and Ceramics
- Combustion Sciences
- Fluids and Transport Phenomena
- Polymer Science

2.0 PERFORMANCE

2.1 CAPABILITIES RANGE

Apparatus must measure masses of lump solids, powders, gels, and liquids up to 10.0 kilograms with precision of one part in 10,000 or one milligram, whichever is larger. Replaceable or disposable pre-calibrated sample holders equipped with means for internal immobilization of samples of all types and sizes within the above mass range must be supplied. Pychnometer capsules for measuring liquid density are also required. Apparatus should include decimal digital display with autoranging and an output for for transferring data to Central Data Storage/Transceiver System (Core Equipment Item). Local recording registers for up to 10 measurements and microprocessor controlled arithmetic functions for basic determinations such as tare mass, mixture calculations, etc. is required.

2.2 INTERFACE PROVISIONS

Rack mount with standardized electrical interfaces and input ports at Central Data Storage/Transceiver System.

2.3 AUTOMATION LEVEL

System should be fully automatic with the exception of manual sample loading and attachment of sample holders.

2.4 OBSERVATION REQUIREMENTS

Near real-time digital display for results of each measurement with warnings and diagnostics for over-range, malfunctions, loose samples, etc.

2.5 DATA REQUIREMENTS

Local temporary data register for up to ten masses, and connection to Central Data Storage/Transceiver System (Core Equipment Item).

2.6 MAINTENANCE REQUIREMENTS

Provisions for cleaning/decontaminating and recalibrating re-usable sample capsules. Modular replacement of failed electronics and mechanical parts. Microprocessor controlled re-calibration routine using standard masses.

2.7 SAFETY ASSESSMENT

Standard safety provisions for control of shock hazard at all electrical interfaces and in maintenance operations. No unusual hazards have been identified.

2.8 PHYSICAL PARAMETERS

Mass: 50.0 kilograms (estimated).
Volume: 0.3 cubic meters (estimated).

3.0 TECHNOLOGY STATUS

3.1 READINESS LEVEL

Low precision equipment for samples limited in mass from 1.0 gram to 10.0 kilograms is fully developed. Improved precision, range, and sample versatility is required.

3.2 EQUIPMENT AVAILABILITY

Low precision, limited range equipment is available (Life Science Flight Experiments Office/Code LBE, NASA Ames Research Center). Apparatus to meet materials science requirements does not currently exist.

3.3 DEVELOPMENT NEEDS

A fully integrated system meeting requirements for increased low-end range and precision, and a variety of specialized sample holders requires concept design and development activity.

RECOMMENDATION

FOLLOWING REVIEW BY SCIENCE WORKING GROUPS, INITIATE CONCEPT DESIGN AND DEVELOPMENT PLAN.

NOTES

1.0 PURPOSE

1.1 FUNCTIONAL DESCRIPTION

Provides instrumentation for troubleshooting, repair, and calibration of electronic acquisition, control, and support systems; equipped for in-rack or workbench fault diagnosis and repair to component level; configured with integral microprocessor-based ATE systems for interactive or slave diagnostics; configured at several levels of instrument integration to require no more than three instruments during most troubleshooting and calibration sessions; symmetrically integrated for reliable quick-disconnect reconfiguration and remote operation.

1.2 RATIONALE FOR INCLUSION

Required for repair and maintenance of onboard electronics beyond random substitution techniques; required for recalibration necessitated by launch and orbital transfer activity; required for quick-turnaround fault diagnosis and on-orbit repair, replacement, and recalibration; essential to maintain research continuity and achieve productivity levels expected on orbit; useful in implementing on-orbit experiment modifications and revisions; useful for temporary replacement of unspared payload instruments on a limited basis.

1.3 IMPACT OF EXCLUSION

Inability to perform most maintenance and repair functions on-orbit; inefficiency in performing very simple repair functions on-orbit; damage to payload components due to improper substitution based on limited or nonexistent diagnostics; acceptance or rejection of research results based on erroneous data from decalibrated systems; abandonment of productive lines of research based on results produced by calibration errors.

1.4 USER DISCIPLINES

The following disciplines require the use of this Core Equipment Item:

- Electronic Materials
- Metals and Alloys
- Glasses and Ceramics
- Combustion Sciences
- Fluids and Transport Phenomena
- Polymer Science

2.0 PERFORMANCE

2.1 CAPABILITIES RANGE

As a minimum, laboratory to include:

1. digital multimeters
2. multichannel storage oscilloscope
3. universal counters
4. function generators
5. programmable power supplies
6. decade resistors and capacitors
7. sweep oscillator
8. pulse generator
9. spectrum analyzer
10. multichannel A/D and D/A converters
11. GP OP-AMP board kits
12. signature analyzer
13. logic analyzer
14. specialized board/IC DIP handling tools

The integrated system must be shielded to inductive, electromagnetic, conductively coupled, and ground-loop interference. All systems must incorporate best available miniaturization technology and include provisions for device upgrading as warranted by technological advances.

The integrated electronics laboratory requires co-location with the Reconfigurable Workbench and Tool/Supplies Locker (Core Equipment Items) for optimum utilization.

2.2 INTERFACE PROVISIONS

Electrical/115 VAC +/- 4%, 5 amp service, standard I/O ports at all core equipment items and experiment apparatus.

2.3 AUTOMATION LEVEL

Menu-driven ATE software package required for short maintenance turnaround time and thorough troubleshooting and calibration.

2.4 OBSERVATION REQUIREMENTS

Mission specialist requires ability to view digital data and video signals during performance of equipment repair.

2.5 DATA REQUIREMENTS

Digital data may require storage prior to downlink in the event that 1) a failure analysis exceeds the on-orbit capability for diagnosis or 2) on-orbit calibration values must be submitted to ground for adjustment of experiment parameters. Real-time video has potential to enhance capability and accelerate diagnostics.

2.6 MAINTENANCE REQUIREMENTS

Periodic changeout of components to permit upgrading and expansion of capabilities. Replacement PC boards for critical devices, external patch cables, and probes maintained in supply on-orbit.

2.7 SAFETY ASSESSMENT

Standard spaceflight provisions for control of shock hazard at electrical interfaces. Dry chemical fire extinguisher to be maintained in Emergency Provisions Locker (Core Equipment Item).

2.8 PHYSICAL PARAMETERS

Mass: 100.00 kg (estimate).
Volume: 1.0 cubic meter (desired allocation).

3.0 TECHNOLOGY STATUS

3.1 READINESS LEVEL

All required subsystems represent currently available technology. No exotic techniques are being suggested for the IOC version of the electronics laboratory. Growth versions may include advanced technologies flown in a mission-specific mode.

3.2 EQUIPMENT AVAILABILITY

A fully integrated wide-spectrum electronics laboratory with high packing density and component changeout capability does not currently exist. All cited subsystems including software are available as off-the-shelf items; however, rack mounting, shielding, and hardware/software integration levels are not optimum.

3.3 DEVELOPMENT NEEDS

Subsystems integration project is required to identify optimum configuration and to develop design approaches to system interfacing. Microprocessor-related components require integration requirements definition. Mechanical and structural components and hardware/software integration levels require optimization.

RECOMMENDATION

INITIATE PRELIMINARY CONCEPT DESIGN AND DEVELOPMENT PLANS.

NOTES

INTEGRATED OPTICAL MICROSCOPY LAB

1.0 PURPOSE

1.1 FUNCTIONAL DESCRIPTION

Wide-spectrum capability for optical microscopy to be provided by integrated design approach at component level. System reconfiguration to be accomplished by interchangeable components with standardized interfaces and maximum packing density in allocated space.

1.2 RATIONALE FOR INCLUSION

Direct sample viewing via optical techniques permits rapid post-experiment analysis at macro-level and greatly enhances ability to modify process parameters and increase research productivity. Basic capability can yield high payoff.

1.3 IMPACT OF EXCLUSION

Degraded research productivity due to inability to incorporate results of previous experiments into design of ongoing work. Loss of critical capability for decision-making in real-time. Significant increase in research cycle timeline.

1.4 USER DISCIPLINES

The following disciplines require the use of this Core Equipment Item:

- Electronic Materials
- Metals and Alloys
- Glasses and Ceramics
- Combustion Sciences
- Fluids and Transport Phenomena
- Polymer Science

2.0 PERFORMANCE

2.1 CAPABILITIES RANGE

Objective is maximum capability in confined space. Requirements include:
(1) 1X-100X direct viewing
(2) field digitization
(3) video/photomicrography w/real-time display
(4) metallography
(5) micrometry
(6) interferometry (Nomarski, infrared)
(7) ultraviolet fluorescence
(8) contrast enhancement
(9) interchangeable light sources, filters, objectives, stages, mounts, mounting media, and mirrors
(10) microhardness attachment
(11) topographic measurement
(12) power supply

The integrated system requires both fixed and portable components to allow direct viewing of processes occuring remote from the base system. A microprocessor system for data acquisition, parameter control, and reduction/display is necessary prior to the transfer of data to the laboratory Central Data Storage/Transceiver System (Core Equipment Item) for downlink. Access to a Standardized Modular Locker (Core Equipment Item) is required to accommodate mission-specific equipment as the need arises.

2.2 INTERFACE PROVISIONS

Electrical/115 VAC +/- 4%, 5 amp service, access ports at Central Data Storage/Transceiver and Color Video Systems (Core Equipment Items), standardized mounts on mission-specific experiment systems to accommodate portable components.

2.3 AUTOMATION LEVEL

Requirements for human risk assessment and judgement in experimental design precludes ability to automate the microscopy lab.

2.4 OBSERVATION REQUIREMENTS

Mission Specialist requires ability to display parametric and visual data on video system in real-time. Stored data must be accessible for on-orbit playback in order to perform comparative assessment of results and implement efficient modifications to experiment and/or process parameters.

2.5 DATA REQUIREMENTS

All parametric and visual data to be transferred to Central Data Storage/Transceiver System (Core Equipment Item) for downlink every 90 minutes. Real-time video data transmission required during critical periods in experiment to establish principal investigator telepresence.

2.6 MAINTENANCE REQUIREMENTS

Backup components (light sources, lens, filters, etc.) required in storage. Provisions for damp-wipe, optic polish, and mechanical lubrication required for periodic routine cleaning/lubricating.

2.7 SAFETY ASSESSMENT

Provisions for safe handling of glass components (lens, filters, light sources, etc.) during storage and system reconfiguration. Standard spaceflight provisions for control of shock hazard at electrical interfaces. Modified techniques for immersion microscopy and fluids containment necessary.

2.8 PHYSICAL PARAMETERS

Mass: 100.00 kilograms (estimated).
Volume: 1.0 cubic meter (estimated).

3.0 TECHNOLOGY STATUS

3.1 READINESS LEVEL

All cited microscopy capabilities and techniques represent current technology, commonly available in ground-based labs. No exotic techniques are required for the IOC version of the microscopy lab. Growth versions may include advanced technologies flown in a mission-specific mode.

3.2 EQUIPMENT AVAILABILITY

A fully integrated wide-spectrum microscopy lab with high packing density and reconfiguration capability does not currently exist. All cited subsystems are available as off-the-shelf items, however, mechanical interfaces do not have required level of standardization for reconfiguration ability.

3.3 DEVELOPMENT NEEDS

Subsystems integration project is required to identify mechanical interface limitations and develop approaches to standardization that will maximize lab flexibility. Microprocessor related subsystems (e.g., data acquisition, reduction, display, and parameter control) require definition /design activity.

RECOMMENDATION

INITIATE PRELIMINARY CONCEPT DESIGN AND DEVELOPMENT PLANS.

NOTES

1.0 PURPOSE

1.1 FUNCTIONAL DESCRIPTION

Multifunctional apparatus to slurry cut, lap, and chemically or electrochemically etch samples for structural study via metallographic, optical, electronic, or ionic techniques.

1.2 RATIONALE FOR INCLUSION

Surface generation and preparation is a prerequisite to virtually all basic characterization techniques. System will permit specimen analysis on-orbit for all solidification experiments and accelerate research timelines by providing capability for experiment redesign in near real-time.

1.3 IMPACT OF EXCLUSION

Experiment redesign period will increase from 1 day to 180 days if specimens must be returned to ground for most basic characterization. Option for real-time experiment modification is lost. Research productivity is significantly degraded.

1.4 USER DISCIPLINES

The following disciplines require the use of this Core Equipment Item:

- ● Electronic Materials
- ● Metals and Alloys
- ● Glasses and Ceramics
- ○ Combustion Sciences
- ● Fluids and Transport Phenomena
- ● Polymer Science

2.0 PERFORMANCE

2.1 CAPABILITIES RANGE

Objective is to provide capability for preparing newly solidified specimens for on-orbit analysis. Materials of a wide range of hardness and fragility must be sawed with an abrasive slurry, mechanically lapped, and polished on cut or natural surfaces. A variety of abrasive slurries must be fed and recovered, and they must be separated from cutting detritus for recirculation.

Secondary capability is to chemically or electrochemically etch and polish cut or natural surfaces. Controlled circulation of corrosive etchants is required, within a clean safety containment system. All products of the cutting, polishing, and etching activity must be either recovered for re-use or collected for safe disposal.

2.2 INTERFACE PROVISIONS

28 vdc power source for operations and lighting, compressed air for bearings and cooling, access to waste management system for purge gases and cutting detritus, and access to gas and fluids distribution system.

2.3 AUTOMATION LEVEL

All apparatus set-up modes manual, automatic slicing/dicing modes and slurry control with alarm.

2.4 OBSERVATION REQUIREMENTS

Auxiliary lighting for direct and video viewing required.

2.5 DATA REQUIREMENTS

Access to High Resolution Video System (Core Equipment Item) required to establish principal investigator telepresence during sample preparation and analysis.

2.6 MAINTENANCE REQUIREMENTS

Periodic breakdown and cleaning of system components. On-orbit replacement of bearings and moving parts worn by abrasive slurries. Spare parts inventory maintained on-orbit.

2.7 SAFETY ASSESSMENT

Corrosive/explosive hazards of etchant materials require attention to containment and control. Toxic substances require safe handling procedures.

2.8 PHYSICAL PARAMETERS

Mass: 100 kilograms (estimated).
Volume: 0.3 cubic meters (estimated).

3.0 TECHNOLOGY STATUS

3.1 READINESS LEVEL

Ground-based technology is well advanced, however, operations in microgravity will require totally novel approach. No efforts have yet been initiated to identify potential system configurations.

SAMPLE CUTTING, POLISHING, & ETCHING SYSTEM

3.2 EQUIPMENT AVAILABILITY

An integrated system for use in microgravity is not available. Most mechanical parts that would be required are either available off-the-shelf or could be custom fabricated at relatively low cost.

3.3 DEVELOPMENT NEEDS

A complete integrated system designed for microgravity use is required. Particular attention to slurry/reagent recovery, and reprocessing is necessary. Mechanical design will involve novel components and custom fabrication.

RECOMMENDATION

FOLLOWING REVIEW BY SCIENCE WORKING GROUPS, INITIATE CONCEPT DESIGN AND DEVELOPMENT PLANS.

NOTES

1.0 PURPOSE

1.1 FUNCTIONAL DESCRIPTION

A multipurpose container system having standardized mechanical, electrical, and fluid interfaces that allow placement of the locker at various locations in the lab. Accommodates both transport and on-orbit storage/usage requirements for small apparatus flown in a mission-specific mode.

1.2 RATIONALE FOR INCLUSION

Shuttle middeck locker has proven exceptional in meeting unplanned requirements for accommodation of a wide range of apparatus/items. Universal system for transport, storage, and usage of small items enhances overall lab utility and provides baseline reference for unique design tasks.

1.3 IMPACT OF EXCLUSION

Limited lab reconfiguration capability. Extended integration timelines, resulting from undefined spectrum of interface choices. Non-standardized approaches to design and potential for numerous redundant efforts. Inability to rapidly integrate small apparatus and support items.

1.4 USER DISCIPLINES

The following disciplines require the use of this Core Equipment Item:

- Electronic Materials
- Metals and Alloys
- Glasses and Ceramics
- Combustion Sciences
- Fluids and Transport Phenomena
- Polymer Science

2.0 PERFORMANCE

2.1 CAPABILITIES RANGE

The locker represents an extension of the current shuttle middeck locker capabilities. Overall objective is to provide accommodations for the very broad variety of small apparatus and support hardware that is anticipated over the life of the laboratory. Basic resources such as power, cooling, vacuum pumping, and data transfer should be available at designated locations throughout the laboratory. Further analysis is necessary to determine the magnitude of each of these resources available to locker locations.

A standardized locker should be capable of accommodating not only storage requirements but active experiments and diagnostic equipment having moderate requirements for resources and space.

2.2 INTERFACE PROVISIONS

Locker requires 100% standardization of electrical, mechanical, and fluid interfaces.

2.3 AUTOMATION LEVEL

Not applicable, mission-specific equipment items are anticipated.

2.4 OBSERVATION REQUIREMENTS

Not applicable, mission-specific equipment items are anticipated.

2.5 DATA REQUIREMENTS

Access to Central Data Storage/Transceiver System (Core Equipment Item) is required.

2.6 MAINTENANCE REQUIREMENTS

Provision for quick exchange of lockers in response to mission-specific requirements. Maintenance performed on ground during exchange periods.

2.7 SAFETY ASSESSMENT

No hazards identified.

2.8 PHYSICAL PARAMETERS

Two basic configurations are desirable:

#1) Volume: 0.26 cu. meter
Mass Capacity: 120 kilograms

#2) Volume: 0.13 cu. meter
Mass Capacity: 60 kilograms

3.0 TECHNOLOGY STATUS

3.1 READINESS LEVEL

Equipment item is a structural system; no new technology is required. Existing techniques and materials are adequate to support all identified functions. Innovative approaches to maximizing overall utility require identification and evaluation.

STANDARDIZED MODULAR LOCKERS

3.2 EQUIPMENT AVAILABILITY

Structural materials and interface hardware can all be obtained off-the-shelf at the component level. A fully integrated modular locker system does not currently exist.

3.3 DEVELOPMENT NEEDS

Design of a fully integrated modular locker system that will achieve maximum utility is required. Component elements require identification, selection, and design integration with the structural accommodations of the presurized laboratory module.

RECOMMENDATION

FOLLOWING REVIEW BY SCIENCE WORKING GROUPS, INITIATE PRELIMINARY CONCEPT DESIGN AND DEVELOPMENT PLANS. PLANS MUST ADDRESS CURRENTLY IDENTIFIED LABORATORY ARCHITECTURE OPTIONS.

NOTES

1.0 PURPOSE

1.1 FUNCTIONAL DESCRIPTION

Reconfigurable planar surface(s) to support mounting of small apparatus and support equipment for brief duration activities. Provides rigid structure and attachment hardware to accommodate a wide spectrum of unplanned operations.

1.2 RATIONALE FOR INCLUSION

Essential to accommodate small experiments and a wide variety of equipment servicing functions. Flexibility allows significant expansion of capability to respond to unplanned events. Basic capability can yield high payoffs.

1.3 IMPACT OF EXCLUSION

Inability to effectively service on-orbit equipment in safe/controllable mode. Limited capacity to perform small experiments having potential high value/impact on concurrent research activities. Reduction in basic laboratory utility.

1.4 USER DISCIPLINES

The following disciplines require the use of this Core Equipment Item:

- Electronic Materials
- Metals and Alloys
- Glasses and Ceramics
- Combustion Sciences
- Fluids and Transport Phenomena
- Polymer Science

2.0 PERFORMANCE

2.1 CAPABILITIES RANGE

Objective is maximum capability to accommodate unplanned events in a flexible mode. Requirements include ability to support small apparatus/devices used to perform:

(1) short duration small experiments
(2) trouble-shooting
(3) basic repairs
(4) mechanical/electrical modifications
(5) parts fabrication
(6) hardware maintenance and servicing

Workbench system requires (1) design to facilitate rapid deployment and set-up in multiple configurations, (2) provisions for attachment of devices in fixed stable modes, and (3) capability for knock-down and storage at maximum packing density. Items of mission-specific equipment intended for use on the workbench require standard mechanical interfaces to facilitate simple quick integration with the workbench system. These items can be stored in the Standardized Modular Lockers (Core Equipment Item) for deployment and assembly on-orbit.

2.2 INTERFACE PROVISIONS

Electrical/120 and 240 VAC =/- 4% ; 5, 10, 20, and 40 amp services. Bulkhead attachment points to provide maximum stability. Breadboard design to accommodate wide range of mechanical, electrical, and fluid interfaces in safe mode.

2.3 AUTOMATION LEVEL

Not applicable to this equipment item.

2.4 OBSERVATION REQUIREMENTS

High Resolution Video System (Core Equipment Item) must be accessible to workbench area in order to provide monitoring capability and establish principal investigator telepresence during the performance of small experiments and/or equipment servicing operations.

2.5 DATA REQUIREMENTS

Video records of all workbench operations required at IOC phase. During growth phase video records of selected activities can be anticipated. All video records require transmission to ground. Critical operations require transmission in real-time.

2.6 MAINTENANCE REQUIREMENTS

Provisions for (1) damp-wipe with liquid sterilant, (2) neutralization of electrostatic charge accumulation, and (3) demagnetization. Item (1) required as routine operation prior to knockdown /storage and items (2 & 3) performed on as required basis.

2.7 SAFETY ASSESSMENT

Following determination of the general laboratory architecture, an assessment of alternative locations for the workbench system must be initiated and impacts on restrictions to crew mobility identified and evaluated. Potential safety restrictions include duration of set-up time and location.

2.8 PHYSICAL PARAMETERS

Mass: 30.0 kilograms (estimated).
Volume: 0.1 cubic meter (estimated).

3.0 TECHNOLOGY STATUS

3.1 READINESS LEVEL

Equipment item is a flexible structural system; no new technology is required. Existing techniques and materials are adequate to support all identified equipment functions. Innovative approaches to maximizing the utility of the overall system require identification and evaluation.

3.2 EQUIPMENT AVAILABILITY

Structural members, materials for planar surfaces, and mounting hardware can all be obtained off-the-shelf at the component level. A fully integrated system for laboratory module applications does not currently exist due to the unique nature of the requirements.

3.3 DEVELOPMENT NEEDS

Design of a fully integrated workbench system that will permit maximum achievable utility is required. Component elements require identification, selection, and design integration with the structural accommodations of the pressurized laboratorymodule.

RECOMMENDATION

FOLLOWING REVIEW BY SCIENCE WORKING GROUPS, CONCEPT DESIGN AND DEVELOPMENT PLANS SHOULD BE INITIATED. PLANS MUST ADDRESS CURRENTLY IDENTIFIED LABORATORY ARCHITECTURE OPTIONS.

NOTES

TOOL/SUPPLIES LOCKER

1.0 PURPOSE

1.1 FUNCTIONAL DESCRIPTION

Dedicated storage space for frequently used handtools, assemblies, and critical replacement parts.

1.2 RATIONALE FOR INCLUSION

Unplanned activities such as non-scheduled equipment servicing and repair, fabrication of small assemblies, and innovative experiments of opportunity can be anticipated.

1.3 IMPACT OF EXCLUSION

Limits ability to respond to unplanned requirements and is likely to result in cancellation of potentially valuable activities.

1.4 USER DISCIPLINES

The following disciplines require the use of this Core Equipment Item:

- Electronic Materials
- Metals and Alloys
- Glasses and Ceramics
- Combustion Sciences
- Fluids and Transport Phenomena
- Polymer Science

2.0 PERFORMANCE

2.1 CAPABILITIES RANGE

Locker must maintain running record of inventory. Provisions for secured storage of parts and tools in an easily accessible configuration are required.

Functional operations to be supported by locker supplies include:

(1) cutting
(2) grinding
(3) polishing
(4) adhesion
(5) soldering
(6) fastening
(7) bending
(8) drilling
(9) lubricating
(10) measuring

Additional functions can be anticipated and must be accommodated on an "as required" basis. A collapsible hood system is required for control of detritus around operations generating particulate materials.

2.2 INTERFACE PROVISIONS

The Tool/Supplies Locker should be located adjacent to the Reconfigurable Workbench (Core Equipment Item) area for optimum utility.

2.3 AUTOMATION LEVEL

All anticipated functions are performed manually.

2.4 OBSERVATION REQUIREMENTS

Not applicable.

2.5 DATA REQUIREMENTS

Not applicable.

2.6 MAINTENANCE REQUIREMENTS

A running inventory of all supplies is required. Periodic replacement of tools and resupply of parts will be necessary.

2.7 SAFETY ASSESSMENT

No unusual hazards have been identified. Safety gloves/masks may be required for certain operations.

2.8 PHYSICAL PARAMETERS

Volume: 0.5 cubic meter (estimated).
Mass: 100 kilograms (estimated).

3.0 TECHNOLOGY STATUS

3.1 READINESS LEVEL

No new technology is required. All functions represent common workbench activities performed in ground-based laboratories.

3.2 EQUIPMENT AVAILABILITY

All equipment is available off-the-shelf. Minor modifications will be required for power tools. Fabrication of the hood system for detritus control is required.

3.3 DEVELOPMENT NEEDS

No significant development activity is currently required.

RECOMMENDATION

INCLUDE PROVISIONS FOR A TOOL/SUPPLIES LOCKER IN PRELIMINARY LABORATORY DESIGN.

NOTES

TRI-AXIS ACCELEROMETER SYSTEM

1.0 PURPOSE

1.1 FUNCTIONAL DESCRIPTION

Three mutually orthogonal linear accelerometers and three orthogonal single rate gyros to monitor microgravity environment and digitally display G values at all points in the laboratory, in near real-time.

1.2 RATIONALE FOR INCLUSION

Anticipated experiments require low gravity environment free from spurious events. Processes of interest are highly gravity sensitive, thus good quantitative results require precise knowledge of existing gravity conditions.

1.3 IMPACT OF EXCLUSION

Experiments would require integral gravity monitors, resulting in non-standardized equipment and potential correlation uncertainty. Experiments without integral monitor would lack essential data and carry extreme dimension of uncertainty.

1.4 USER DISCIPLINES

The following disciplines require the use of this Core Equipment Item:

- Electronic Materials
- Metals and Alloys
- Glasses and Ceramics
- Combustion Sciences
- Fluids and Transport Phenomena
- Polymer Science

2.0 PERFORMANCE

2.1 CAPABILITIES RANGE

System must provide sufficient data to calculate the microgravity acceleration environment at any point in the laboratory with the effect of rotation included, and must have processing capability to make calculation and record result in near real-time. The linear accelerometers require a range of 3.0 EE-2 G and resolution of 3.0 EE-8 G (20 bits). The rate gyros require a range of 1000 degrees/minute and resolution of 0.1 degree/minute (14 bits). Sampling rate of 800 samples/second is required. The system must be installed such that its measurements represent the laboratory as a whole, and not limited to a specific rack or subsystem.

Data of interest include gravity gradient related acceleration (instantaneous center of Space Ststion rotation and angular velocity), internally produced vibrations and impulse accelerations from thrusters or external events. Sensitivity should reach the level of aerodynamic drag and the sample rate must provide for frequency analysis of vibrations from rotating equipment up to the first few harmonics (180 Hz).

2.2 INTERFACE PROVISIONS

Electric power, 400 Hz and/or 28 VDC; data transfer ports at Central Data Storage/Transceiver System (Core equipment Item) for digital downlink.

2.3 AUTOMATION LEVEL

System should be fully automated with output data available on demand at all times. Automatic test/verification on periodic schedule

2.4 OBSERVATION REQUIREMENTS

Graphic display monitors visible from laboratory workstations and via groundlink.

2.5 DATA REQUIREMENTS

A continuous time history of the on-orbit microgravity environment should be maintained. Short term storage may be accommodated on-board prior to periodic downlink and reduction/permanent storage as required.

2.6 MAINTENANCE REQUIREMENTS

Capability to change out accelerometers, gyros, and PC boards in the Event of failure. Replacement provisions should be maintained on-orbit.

2.7 SAFETY ASSESSMENT

Containment required in the event of gyro-wheel failure. Standard electrical safety provisions (interlocks, circuit breakers, surge suppressors, etc.) required.

2.8 PHYSICAL PARAMETERS

3.0 TECHNOLOGY STATUS

3.1 READINESS LEVEL

Principles are well understood, however, hardware upgrade is required to meet levels for range and sensitivity. Current technology is considered inadequate for laboratory service.

3.2 EQUIPMENT AVAILABILITY

Adequate hardware and software is not now available as an integrated system.

3.3 DEVELOPMENT NEEDS

An integrated system including all hardware/software elements requires concept design and development activity. State of the art technology requires incorporation.

RECOMMENDATION

FOLLOWING REVIEW BY SCIENCE WORKING GROUPS, INITIATE PRELIMINARY CONCEPT DESIGN AND DEVELOPMENT PLANS.

NOTES

1.0 PURPOSE

1.1 FUNCTIONAL DESCRIPTION

Provides accessible space for storage of consummable materials, raw materials, and finished products. Also accommodates potentially hazardous experiments, materials degradation studies, and the servicing of remote payloads on tethers and platforms.

1.2 RATIONALE FOR INCLUSION

Interior laboratory volume is limited and must be utilized to maximum efficiency. Storage function requires virtually no resources and can be adequately accommodated via external provisions. Capability to perform external servicing functions is essential during growth phase.

1.3 IMPACT OF EXCLUSION

Inefficient use of valuable internal space. Severe limitation to consummable materials. Inability to service external payloads. Significant curtailment of overall research activity.

1.4 USER DISCIPLINES

The following disciplines require the use of this Core Equipment Item:

- Electronic Materials
- Metals and Alloys
- Glasses and Ceramics
- Combustion Sciences
- Fluids and Transport Phenomena
- Polymer Science

2.0 PERFORMANCE

2.1 CAPABILITIES RANGE

Pallet should provide capacity to 8000 kilograms (minimum) and include 50.0 sq. meters (minimum) mounting area.

Provisions for addition of (1) remote manipulator system, (2) scientific windows, (3) OMV docking trunion, and (4) remote utilities are required.

2.2 INTERFACE PROVISIONS

Provisions for addition of a science airlock at the module-pallet interface are required. Module bulkhead must provide attachment points for external utilities.

2.3 AUTOMATION LEVEL

Not applicable.

2.4 OBSERVATION REQUIREMENTS

Provisions for addition of scientific windows are required.

2.5 DATA REQUIREMENTS

Provisions for addition of data management utilities are required.

2.6 MAINTENANCE REQUIREMENTS

Passive structure, no maintenance requirements identified. Degradation of structural materials may be subject of investigations.

2.7 SAFETY ASSESSMENT

Availability of windows and remote manipulator will significantly decrease hazards associated with extravehicular activities.

2.8 PHYSICAL PARAMETERS

Mass: 5000 kilograms (estimated).
Volume: Not applicable; open structure.

3.0 TECHNOLOGY STATUS

3.1 READINESS LEVEL

No technology development required. Equipment is a structural system similar to structures previously flown in the shuttle cargo bay.

3.2 EQUIPMENT AVAILABILITY

ESA Spacelab pallets may have applicability. Potential to duplicate existing designs with minor modifications to mounting interfaces may be feasible.

3.3 DEVELOPMENT NEEDS

Assessement of applicability of previous designs followed by development of a laboratory dedicated pallet system.

RECOMMENDATION

INCLUDE PROVISIONS IN PRELIMINARY LABORATORY DESIGN FOR EXTERNAL ATTACHED PALLET AND IDENTIFIED SUPPORT EQUIPMENT ITEMS.

NOTES

AUTOMATED GAS DISTRIBUTION SYSTEM

1.0 PURPOSE

1.1 FUNCTIONAL DESCRIPTION

Distribution service system for up to eight individual condensable and non-condensable gasses. System to supply, regulate, and meter gasses on demand at each equipment rack position, with provisions for laboratory-external storage of replaceable supply tanks.

1.2 RATIONALE FOR INCLUSION

Common gas supplies allow greater payload/experiment flexibility and more efficient equipment utilization. Frequently used gasses are stored in bulk and centrally controlled. Eliminates requirements for redundant consummable provisions.

1.3 IMPACT OF EXCLUSION

Increased payload volume and complexity, redundant gas handling subsystems, decrease in payload reliability, and reduced resupply efficiency. Increased hazard potential.

1.4 USER DISCIPLINES

The following disciplines require the use of this Core Equipment Item:

- Electronic Materials
- Metals and Alloys
- Glasses and Ceramics
- Combustion Sciences
- Fluids and Transport Phenomena
- Polymer Science

AUTOMATED GAS DISTRIBUTION SYSTEM

2.0 PERFORMANCE

2.1 CAPABILITIES RANGE

Minimum requirements have been identified for the following gasses.

Argon	40 kg/90 days
Oxygen	30 kg/90 days
Helium	25 kg/90 days
Hydrogen	25 kg/90 days
Dry Nitrogen	20 kg/90 days
Carbon Dioxide	10 kg/90 days
Fuel Gas (Butane)	30 kg/90 days
Freon (Liquid)	65 kg/90 days

Non-condensable gasses require supply at an absolute pressure of 3.0 atmospheres at 20.0 +/- 10.0 deg C., freon to be supplied as liquid at pressure sufficient to maintain liquid at 40.0 deg C.

Supply tanks used to transport gasses to and from station require an external bulkhead coupling to the distribution manifolds. Empty supply tanks require evacuation and pumping capability to return used, compatible inert purge gases to ground. Zeolite adsorption system required for preliminary gas clean-up on an as required basis.

2.2 INTERFACE PROVISIONS

Quick disconnect outlets with shutoff valves at each equipment rack position. Manifold couplings on external bulkhead for transport/storage tanks.

2.3 AUTOMATION LEVEL

Automatic line pressure control and continuous record of gas inventories.

2.4 OBSERVATION REQUIREMENTS

Pressure and flow monitors at source manifolds and at each equipment rack position. Central display of remaining gas supplies.

2.5 DATA REQUIREMENTS

Periodic downlink of pressure records and supply inventories.

2.6 MAINTENANCE REQUIREMENTS

Routine periodic checks of valves. Scheduled calibrations for flow and pressure sensors. System integrity verified at each resupply cycle by checking pressure loss rate with user systems off-line.

2.7 SAFETY ASSESSMENT

Protection required for leak prevention, particularly for toxic and flammable gasses. Leak alarms and auto-shutoff provisions required.

2.8 PHYSICAL PARAMETERS

Mass: 1000 kg minimum (tanks full)
Volume: 2.0 cubic meters minimum.

3.0 TECHNOLOGY STATUS

3.1 READINESS LEVEL

No technology development required. Systems are typical of previously developed spaceflight technology.

3.2 EQUIPMENT AVAILABILITY

All anticipated equipment is available off-the-shelf.

3.3 DEVELOPMENT NEEDS

An integrated system design activity is required.

RECOMMENDATION

PRELIMINARY SYSTEM DESIGN REQUIRES REVIEW BY THE NASA MICROGRAVITY SCIENCE AND APPLICATIONS DIVISION PRIOR TO PROCEEDING WITH FINAL DESIGN.

NOTES

FLUIDS DISPENSING SYSTEM

1.0 PURPOSE

1.1 FUNCTIONAL DESCRIPTION

Cartridge based dispensing system for common laboratory solvents and receiving system to recapture used fluids for recycling or disposal.

1.2 RATIONALE FOR INCLUSION

Common laboratory operations require the use of solvents which cannot be free in the microgravity environment due to potential toxicity hazards.

1.3 IMPACT OF EXCLUSION

Cleaning, etching, and purging, operations would become difficult or impossible. Increased hazard level during the manual handling of potentially toxic and/or corrosive fluids.

1.4 USER DISCIPLINES

The following disciplines require the use of this Core Equipment Item:

- Electronic Materials
- Metals and Alloys
- Glasses and Ceramics
- Combustion Sciences
- Fluids and Transport Phenomena
- Polymer Science

2.0 PERFORMANCE

2.1 CAPABILITIES RANGE

Requirements have been identified for the following reagent purity solvents as a minimum:

- o acetone
- o methyl-ethyl ketone
- o methanol
- o toluene
- o carbon tetrachloride
- o trichloroethylene
- o benzene
- o ethanol
- o xylene

Quantities up to ~100 ml at a time must be dispensed under direct operator control for cleaning/rinsing laboratory equipment. Escape of vapors or droplets must be prevented and provision must be made to recapture used liquids for recycling or disposal. Inter contamination of the supplied fluids must be prevented. The dispensing device must meter the quantities delivered and maintain a running inventory record.

2.2 INTERFACE PROVISIONS

Consummable fluids require storage in the dispensing system in interchangeable containers of at least two standard volumes.

2.3 AUTOMATION LEVEL

Portions of the system such as inventory control, metering, and dispensing may be automated as in similar ground systems.

2.4 OBSERVATION REQUIREMENTS

Ability to determine remaining supply of each fluid is required.

2.5 DATA REQUIREMENTS

Inventory record may require periodic transmission to ground.

2.6 MAINTENANCE REQUIREMENTS

Periodic replacement of empty cartridges from on-orbit supply.

2.7 SAFETY ASSESSMENT

Solvents may have high vapor pressure, toxicity, corrosivity, and/or flammability. Containment techniques and dispensing method are critical.

2.8 PHYSICAL PARAMETERS

Mass: 50 kg plus supplies
Volume: 0.5 cu. meter

3.0 TECHNOLOGY STATUS

3.1 READINESS LEVEL

Automated fluids dispensing systems are common fixtures in ground based labs, however, new technology is required to control and dispense small quantities of fluid under microgravity conditions.

FLUIDS DISPENSING SYSTEM

3.2 EQUIPMENT AVAILABILITY	A fluids dispensing system for use in a microgravity environment does not currently exist.
3.3 DEVELOPMENT NEEDS	Entire system requires concept design and development activity. Storage vessel sizes, dispensing techniques, contamination/leakage control, and metering elements require definition.
RECOMMENDATION	FOLLOWING REVIEW BY SCIENCE WORKING GROUPS, INITIATE PRELIMINARY CONCEPT DESIGN AND DEVELOPMENT PLANS.
NOTES	

1.0 PURPOSE

1.1 FUNCTIONAL DESCRIPTION

Dedicated locker space for the storage of emergency articles in the case of accidents, containment system failures, and unplanned hazardous events. Includes standard provisions for medical aid.

1.2 RATIONALE FOR INCLUSION

Nature of hazardous condition may preclude the ability to rapidly obtain emergency articles from remote locations. Quick response is essential reaction to events having potential for rapid proliferation.

1.3 IMPACT OF EXCLUSION

Increased hazard potential. Inability to rapidly contain and control unplanned events. Increased time requirement for medical attention.

1.4 USER DISCIPLINES

The following disciplines require the use of this Core Equipment Item:

- Electronic Materials
- Metals and Alloys
- Glasses and Ceramics
- Combustion Sciences
- Fluids and Transport Phenomena
- Polymer Science

EMERGENCY PROVISIONS LOCKER

2.0 PERFORMANCE

2.1 CAPABILITIES RANGE

As a minimum, locker must provide dedicated storage space for the following items:

1) medical supplies for cuts, abrasions, punctures, burns, and eyewash.
2) bottled oxygen
3) portable wet/dry vacuum
4) portable lighting
5) dry chemical fire extinguisher

Locker contents must be in accessible packing configuration with capability for rapid deployment

2.2 INTERFACE PROVISIONS

2.3 AUTOMATION LEVEL

2.4 OBSERVATION REQUIREMENTS

EMERGENCY PROVISIONS LOCKER

2.5 DATA REQUIREMENTS

Periodic inspection of contents and resupply as necessary.

2.6 MAINTENANCE REQUIREMENTS

2.7 SAFETY ASSESSMENT

The emergency provisions locker is an essential Core Equipment Item.

2.8 PHYSICAL PARAMETERS

3.0 TECHNOLOGY STATUS

3.1 READINESS LEVEL

All items represent common technology.

3.2 EQUIPMENT AVAILABILITY

All items currently available off-the-shelf.

3.3 DEVELOPMENT NEEDS

No development required at this time.

RECOMMENDATION

INCLUDE PROVISIONS IN LABORATORY PRELIMINARY DESIGN FOR DEDICATED SPACE TO STORE EMERGENCY ARTICLES.

NOTES

1.0 PURPOSE

1.1 FUNCTIONAL DESCRIPTION

Closed environment adjacent to the pressurized laboratory utilized for potentially hazardous experiments, servicing of small external equipment, and as staging area for payloads moving between the internal/external environment.

1.2 RATIONALE FOR INCLUSION

The science airlock provides a secure and easily accessible volume that will allow the performance of activities which are unsuitable to the internal laboratory environment.

1.3 IMPACT OF EXCLUSION

Reduction in overall laboratory flexibility and capability to accommodate potentially hazardous experiments. Increase in logistic complexity associated with the movement of materials and payloads between the External Attached Pallet (Core Equipment Item) and the laboratory facility.

1.4 USER DISCIPLINES

The following disciplines require the use of this Core Equipment Item:

- Electronic Materials
- Metals and Alloys
- Glasses and Ceramics
- Combustion Sciences
- Fluids and Transport Phenomena
- Polymer Science

2.0 PERFORMANCE

2.1 CAPABILITIES RANGE

The airlock may require accommodation of payloads as large as 2.5 cubic meters, having a geometry of 1.0 x 1.0 x 2.5 meters.

2.2 INTERFACE PROVISIONS

Airlock requires capability to employ a remote manipulator arm during growth phase in order to reduce need for extravehicular activity (EVA).

2.3 AUTOMATION LEVEL

2.4 OBSERVATION REQUIREMENTS

2.5 DATA REQUIREMENTS

2.6 MAINTENANCE REQUIREMENTS

Periodic inspection and servicing of all components to maintain required safety levels.

2.7 SAFETY ASSESSMENT

The availability of the science airlock will enhance overall laboratory safety through provision of an isolated environment.

2.8 PHYSICAL PARAMETERS

Mass: 1000 kilograms (estimated).
Volume: 4.5 cubic meters (estimated).

3.0 TECHNOLOGY STATUS

3.1 READINESS LEVEL

Technology has been developed under previous manned spaceflight programs.

3.2 EQUIPMENT AVAILABILITY

A science airlock designed specifically for the pressurized laboratory module does not presently exist.

3.3 DEVELOPMENT NEEDS

Following determination of pressurized laboratory module architecture, a complete science airlock system requires concept design and development activity.

RECOMMENDATION

INCLUDE PROVISIONS IN PRELIMINARY LABORATORY DESIGN FOR A SCIENCE AIRLOCK.

NOTES

WASTE MANAGEMENT SYSTEM

1.0 PURPOSE

1.1 FUNCTIONAL DESCRIPTION

Provides for capture, control, recovery (as required), temporary storage, and disposal of liquid, solid, and gaseous waste products generated in the course of laboratory research activities. Includes provisions for the safe handling of potentially hazardous materials.

1.2 RATIONALE FOR INCLUSION

Materials science research inherently involves the use of a variety of liquids, solids, and gases which occur as test samples, process environments, reactants, and byproducts. The ability to manage waste materials efficiently is essential to laboratory safety and productivity.

1.3 IMPACT OF EXCLUSION

Individual payloads would be required to provide integral waste control at high cost and redundancy. In the case of production process research, volumes may exceed practical design limits for single items of equipment.

1.4 USER DISCIPLINES

The following disciplines require the use of this Core Equipment Item:

- Electronic Materials
- Metals and Alloys
- Glasses and Ceramics
- Combustion Sciences
- Fluids and Transport Phenomena
- Polymer Science

2.0 PERFORMANCE

2.1 CAPABILITIES RANGE

Three general capabilities are required.

1) Solids Compaction and Containment System: must provide capability to control used packaging materials, small containers, cleaning wipes, and assorted detritus from repair and servicing operations. Potentially hazardous test specimen materials, in small quantities, can be anticipated.

2) Liquids Filtration and Recovery System: must provide capability to filter waste fluids and, where practical, recover liquids for re-use. Potentially hazardous test specimen materials, in small quantities, can be anticipated.

3) Gas Evacuation, Adsorption, and Venting System: must provide capability to purge and backfill experiment systems. Adsorption of gas contaminants and recycling of frequently used gases is highly desireable to reduce requirements on resupply missions. Potentially hazardous gas effluents can be anticipated.

2.2 INTERFACE PROVISIONS

Commonality with functions of the Automated Gas Distribution System (Core Equipment Item) suggests integration in such a manner as to provide gas service and vacuum pumping capabilities at designated locations throughout the laboratory.

2.3 AUTOMATION LEVEL

Full automation level is desirable.

2.4 OBSERVATION REQUIREMENTS

Visual confirmation of positive containment for disposed materials.

2.5 DATA REQUIREMENTS

A record of waste throughput levels is desirable as a reference for future design activities related to space habitation.

2.6 MAINTENANCE REQUIREMENTS

Routine periodic maintenance procedures for each subsystem are anticipated.

2.7 SAFETY ASSESSMENT

Integrated system will be required to handle potentially hazardous liquids, solids, and gases. All wastes should be assumed hazardous for design purposes.

2.8 PHYSICAL PARAMETERS

3.0 TECHNOLOGY STATUS

3.1 READINESS LEVEL

Technology development in filtration, purification, adsorption, and recovery techniques may be required. Current technology does not focus on handling materials in closed systems (e.g., recycling).

3.2 EQUIPMENT AVAILABILITY

Limited availability of adequate equipment. Advanced systems may be required.

3.3 DEVELOPMENT NEEDS

A state-of-the-art technology assessment is required to determine appropriate options and practical design objectives. Following evaluation an integrated waste management system requires design and development.

RECOMMENDATION

PRELIMINARY DESIGN REQUIRES REVIEW BY NASA MICROGRAVITY SCIENCE AND APPLICATIONS DIVISION PRIOR TO PROCEEDING WITH FINAL DESIGN AND DEVELOPMENT.

NOTES

1.0 PURPOSE

1.1 FUNCTIONAL DESCRIPTION

The CDSTS utility is threefold: real-time STG/GTS data link, buffering node for queued STG data communications, and central off-line storage resource for non-perishable acquired payload digital data.

1.2 RATIONALE FOR INCLUSION

Sequential experiments require data feedback loops which incorporate P.I. and ground-based data processing resources. Centralized off-line storage resources reduce average payload size by eliminating redundancy. CDSTS further functions as an intercessory buffering/data queueing node with independent processing capability, reducing resource demands on station central systems and allowing loosely-coupled modular communications and data resource network configurations.

1.3 IMPACT OF EXCLUSION

Experiments requiring feedback from ground-based processing and decision resources will be forced to terminate without substantial gains. Exclusion of the CDSTS effectively triples the capability required of the station central computing resource, hence implying an exponential increase in the throughput requirement placed on the station central communications system.

1.4 USER DISCIPLINES

The following disciplines require the use of this Core Equipment Item:

- Electronic Materials
- Metals and Alloys
- Glasses and Ceramics
- Combustion Sciences
- Fluids and Transport Phenomena
- Polymer Science

2.0 PERFORMANCE

2.1 CAPABILITIES RANGE

The CDSTS encompasses an independent communications system and a loosely-coupled data processing and mass storage resource system. The communications system must provide digital data signal conversion and transmission with encryption at the maximum bit-rate available in the prescribed transmission band, on the order of 200 kB/s. Synchronization and handshaking data should be provided on the carrier. Information processing resources must contain subsystems for queued data acquisition, data blocking and identification, transmission formatting, and analog to digital signal conversion at moderate (20 MHz) rates, since the limiting node is expected to be the communications system. High-throughput data should be handled by virtual memory buffering techniques, utilizing a reserved area of the mass storage resource. Dynamic RAM need not exceed 20 MB for normal processing loads. The mass storage resource must provide the bulk of temporary data storage, and therefore should include approximately 500 MB in some configuration which provides very short seek times. Mass storage should avail the processing system of at least 200 MB of dynamic virtual memory access with media separate from the static storage capability.

2.2 INTERFACE PROVISIONS

CDSTS must drive data interface planning in the laboratory. Interfaces will include multiple data acquisition channels per payload, providing either digital or analog lines (analog lines will require integral A/D conversion hardware). Also included should be digital and analog control links and a minimal user interface for occasional reprogramming/diagnostics. The system should receive conditioned power but is not expected to be an excessive power user. CDSTS must incorporate data and control interfaces to the station master computer.

2.3 AUTOMATION LEVEL

Normal operation must be fully automatic with a minimal user interface for reprogramming or diagnostic self-evaluation.

2.4 OBSERVATION REQUIREMENTS

CDSTS should "check in" with the station master computer at given intervals to report hardware/firmware/software status. In addition, CDSTS should provide a status/alarm panel in the lab to alert nearby personnel of major malfunctions.

2.5 DATA REQUIREMENTS

CDSTS should maintain a dynamic status log which is periodically transmitted to the station master computer for "check-in".

2.6 MAINTENANCE REQUIREMENTS

CDSTS will require periodic preventive maintenance to hardware/firmware, as well as software bug removal, updating, and reprogramming. Software and firmware should be "self-healing" at low fault rates. Hardware/firmware/software should be redundant as dictated by the reliability of the integrated system. The system as a whole should perform periodic diagnostic self-tests and maintain a scrolling status log of self-test results.

2.7 SAFETY ASSESSMENT

Based on current technology, the CDSTS should present no hazards other than electrical shock during repair/maintenance activity; however, it should be noted that projected technologies involve high-intensity laser light, hazardous gases, and potentially toxic biological materials with unknown failure modes.

2.8 PHYSICAL PARAMETERS

Mass: not expected to exceed 100 kg (current technology).

Volume: not expected to exceed 4 cubic meters; however, one can reasonably expect the volume to fall to less than 1 cubic meter by integration time.

3.0 TECHNOLOGY STATUS

3.1 READINESS LEVEL

Currently available technology will meet or exceed all requirements imposed on the system; however, only one in four design generations reaches the development stage because of technology growth. There is no doubt that any system developed today would be obsolete by IOC. The lines of research are so diverse that some concept framework will be necessary so that stable technologies can be incorporated into the design as they are recognized.

3.2 EQUIPMENT AVAILABILITY

As the various technologies stabilize, components are expected to become available as plug compatible or "load and go" systems, with few if any integration requirements. Current technology would mainly require I/O backplane and bus construction and configuration, and development of appropriate software system.

3.3 DEVELOPMENT NEEDS

Some framework for tracking and fixing applicable lines of research is needed. Technology projections are needed to assess proper design insertion points.

RECOMMENDATION

A CONCEPT DESIGN BASED ON MOST ACTIVE CURRENT TECHNOLOGIES MUST BE ESTABLISHED TO PROVIDE A MATRIX FOR EVALUATING AND INSERTING STABILIZING FUTURE TECHNOLOGIES. A STUDY SHOULD BE UNDERTAKEN TO ACCURATELY ASSESS THE CURRENT STATE OF INFORMATION PROCESSING TECHNOLOGY AND PREDICT RELEVANT FUTURE STATES AND APPROPRIATE TECHNOLOGY INSERTION POINTS.

NOTES

1.0 PURPOSE

1.1 FUNCTIONAL DESCRIPTION

Dual liquid loop system to transfer waste heat from experiment payloads to Space Station radiators. Nominal 70/95 deg C high temperature sink and 2/4.5 deg C low temperature sink. Temperature control by thermostatic mixing.

1.2 RATIONALE FOR INCLUSION

System is essential to removal of waste heat from all experiments having energy losses. Dual loop allows more efficient heat rejection at the Space Station level and provides thermostat capability as a side benefit, using waste heat.

1.3 IMPACT OF EXCLUSION

Virtually all experiment activity in the materials science area would be eliminated. Generation of waste heat is intrinsic to all research performed at elevated temperatures. Passive experiments at ambient temperature have low payoff.

1.4 USER DISCIPLINES

The following disciplines require the use of this Core Equipment Item:

- Electronic Materials
- Metals and Alloys
- Glasses and Ceramics
- Combustion Sciences
- Fluids and Transport Phenomena
- Polymer Science

2.0 PERFORMANCE

2.1 CAPABILITIES RANGE

Objectives of the system are to provide (1) efficient heat extraction from each payload system, and (2) basic thermal control over the 5-70 deg C range, using waste heat. Some payloads (e.g., float zone) may require up to 60.0 kW of heat rejection, while most can be accommodated at the 20.0 kW level. The high temperature loop must be capable of accepting a total load of 100 kW. At IOC lower levels can be anticipated, however, during the growth stage applied research involving prototype production scale apparatus will necessitate the full requirement. Provisions for accommodating the growth requirement must be included in the baseline design.

The low temperature refrigerated loop should be capable of absorbing 5.0 kW by raising a portion of its fluid from 2.0 to 4.5 deg C, and an additional 27 kW by raising the remainder of its fluid from 2.0 to 27.0 deg C. These two functions may be cascaded if fluid bypass is provided.

Thermostated environments from 4.0 to 70.0 deg C should be provided using controlled heat exchange to both loops without fluid mixing. The loop pressure differential should be centrally maintainedat 5 E+5 pascal.

2.2 INTERFACE PROVISIONS

Supply and return to each cooling loop at each rack position by self-closing quick-disconnect taps, providing up to 0.2 kg/sec each. Larger flows to be accommodated by use of two taps in double racks.

2.3 AUTOMATION LEVEL

Supply temperature and pressure to be autocontrolled. Automatic fluid makeup, and auto cutoff if accidental loss is detected.

2.4 OBSERVATION REQUIREMENTS

Temperature, pressure, and flow rate at each rack, for each loop, should be displayed on central utility control panel, with provisions for data transfer to individual payload systems.

2.5 DATA REQUIREMENTS

Temporary data storage required for fault diagnosis. Science data need not be centrally located.

2.6 MAINTENANCE REQUIREMENTS

Isolation valves and segment draining is required so that portions of the system can be serviced without complete laboratory research activity shutdown. Filtering and chemical (anti-corrosion) control required to prevent contamination of fluid systems in payload apparatus.

2.7 SAFETY ASSESSMENT

Catastrophic fluid loss represents significant hazard, particularly at high temperature. Reliable auto shutoff of all lines is required. Fluid must not be toxic or corrosive to payload systems, if practical. Fluid formulation should minimize electrical hazard from spills.

2.8 PHYSICAL PARAMETERS

Mass: 1000 kg (estimated)
Volume: 1.0 cu. meter (estimated)

3.0 TECHNOLOGY STATUS

3.1 READINESS LEVEL

No unique hardware is required, however, evolutionary improvement is likely.

3.2 EQUIPMENT AVAILABILITY

All components could now be supplied off-the-shelf if necessary. Improvements are desirable in quick-disconnects designed to minimize spillage.

3.3 DEVELOPMENT NEEDS

Safety shutoffs with suitable snubbers should be developed to serve as hydraulic circuit breakers and to minimize catastrophic losses. Improved, safer fluid formulations require further study.

RECOMMENDATION

FOLLOWING REVIEW BY USER WORKING GROUPS, SYSTEM DEFINITION SHOULD PROCEED AT AN EARLY STAGE SO AS TO ALLOW INITIATION OF PAYLOAD PRELIMINARY DESIGN IN ACCORDANCE WITH AVAILABLE ACCOMMODATIONS.

NOTES

POWER CONDITIONING & DISTRIBUTION SYSTEM

1.0 PURPOSE

1.1 FUNCTIONAL DESCRIPTION

Electric power bussing system to supply payloads and support equipment with direct and alternating current for both process power (non-precision) and instrumentation power (precision) at decentralized laboratory locations.

1.2 RATIONALE FOR INCLUSION

All planned equipment will require electric power. Levels and quality will vary among specific items. Operations require 100% equipment changeout capability, necessitating accommodation of all equipment at all locations.

1.3 IMPACT OF EXCLUSION

Greater than two order of magnitude reduction in critical power resource if equipment is constrained to operate on self-sufficient power supply (e.g., batteries). Very low research productivity with numerous disciplines excluded.

1.4 USER DISCIPLINES

The following disciplines require the use of this Core Equipment Item:

- Electronic Materials
- Metals and Alloys
- Glasses and Ceramics
- Combustion Sciences
- Fluids and Transport Phenomena
- Polymer Science

2.0 PERFORMANCE

2.1 CAPABILITIES RANGE

During Space Station growth phase a minimim 100 kW requirement is anticipated. IOC requirement may be lower however provisions for expanding capacity to meet future needs for applied research with prototype production scale apparatus must be accommodated in the baseline configuration. 80% of power may be non-precision process power for furnaces, RF heating, electromigration, etc. Process power may be supplied as generated by Space Station for conversion to required energy form at the payload rack. Process power regulation must allow no more than 5% voltage drop at full load, and inductive spikes must be limited to +/- 5 %.

At least 20 % of power must be precision, supplied as 3-phase 115/230 volt AC, frequency controlled to +/- 0.1 %, and voltage controlled to +/- 4.0 % including EMI. At least 5% of the precision power should be supplied at 60 Hz, and an additional 5% at 400 Hz. The balance may be supplied at either 60 or 400 Hz.

2.2 INTERFACE PROVISIONS

Process power connectors with adjustable circuit breakers at each rack and at least 10 outlets each for 60 and 400 Hz precision power. Distinct, non-interchangeable, connectors with mechanical security latches and overload protection.

2.3 AUTOMATION LEVEL

System should be capable of 100% automation.

2.4 OBSERVATION REQUIREMENTS

Recording monitors for all voltages, frequencies, and currents are desirable at all rack locations.

2.5 DATA REQUIREMENTS

Permanent record is required only for anomolous conditions.

2.6 MAINTENANCE REQUIREMENTS

Provisions should be made available in the Tool/Supplies Locker (core equipment item) for repair of basic components such as cables and interfaces.

2.7 SAFETY ASSESSMENT

Circuit breaker protection required at each rack on all circuits, with adjustable trip levels to accommodate different loads. Complete EMI shielding is required, and supply inductance must be minimized.

2.8 PHYSICAL PARAMETERS

Mass: 2000 kg (estimated).
Volume: 1.0 cu. meter (estimated).

3.0 TECHNOLOGY STATUS

3.1 READINESS LEVEL

No additional technology development is required. All specified components represent common spaceflight and/or ground-based hardware.

3.2 EQUIPMENT AVAILABILITY

All equipment available off-the-shelf.

3.3 DEVELOPMENT NEEDS

A systems integration effort is required to identify optimum configurations for power delivery, control, and safety maintenance.

RECOMMENDATION

FOLLOWING REVIEW BY SCIENCE WORKING GROUPS, SYSTEM DEFINITION SHOULD PROCEED AT AN EARLY STAGE SO AS TO ALLOW INITIATION OF PAYLOAD PRELIMINARY DESIGN IN ACCORDANCE WITH ACCOMMODATIONS.

NOTES

LIGHTING SYSTEM

1.0 PURPOSE

1.1 FUNCTIONAL DESCRIPTION

Provides ambient illumination with provisions for concentrated spot lighting of critical areas and brightness control to reduce background light to very low levels for specific operations such as film loading and light sensitive microscopy techniques.

1.2 RATIONALE FOR INCLUSION

A variable lighting system will allow the performance of experiment activities which are light sensitive and/or involve materials that are subject to photodegradation.

1.3 IMPACT OF EXCLUSION

Research activities involving controlled light levels will require additional fixtures to be fabricated and stored on orbit at additional cost and inefficiency.

1.4 USER DISCIPLINES

The following disciplines require the use of this Core Equipment Item:

- Electronic Materials
- Metals and Alloys
- Glasses and Ceramics
- Combustion Sciences
- Fluids and Transport Phenomena
- Polymer Science

2.0 PERFORMANCE

2.1 CAPABILITIES RANGE

The general illumination level should extend up to at least 1000 lumens/sq. meter at maximum intensity. Illumination should be continuously adjustable from zero to 1000 lumens/sq. meter with provisions for spot lighting that has both brightness and collimation control.

2.2 INTERFACE PROVISIONS

The ability to control lighting levels by audio sensing of voice commands is highly desirable as an assist during hands off procedures at very low illumination.

2.3 AUTOMATION LEVEL

2.4 OBSERVATION REQUIREMENTS

2.5 DATA REQUIREMENTS

2.6 MAINTENANCE REQUIREMENTS

2.7 SAFETY ASSESSMENT

2.8 PHYSICAL PARAMETERS

3.0 TECHNOLOGY STATUS

3.1 READINESS LEVEL

All required technology is available off-the-shelf.

3.2 EQUIPMENT AVAILABILITY

All required equipment is available off-the-shelf.

3.3 DEVELOPMENT NEEDS

No technology development is presently required.

RECOMMENDATION

INCLUDE PROVISIONS FOR A VARIABLE LIGHTING SYSTEM DURING LABORATORY PRELIMINARY DESIGN PHASE.

NOTES

1.0 PURPOSE

1.1 FUNCTIONAL DESCRIPTION

Provides all environmental conditions necessary to support manned presence, without personal life support equipment, in a shirtsleeve atmosphere within the pressurized laboratory module.

1.2 RATIONALE FOR INCLUSION

A continuous manned presence will significantly accelerate research productivity by allowing real-time experiment interaction, parameter adjustment, diagnostics, and experiment redesign/rerun.

1.3 IMPACT OF EXCLUSION

All anticipated research would require 100% automation level, without capability for real-time corrective actions, and at high cost. A significant portion of basic research activities would be excluded. Research timelines may include large inactive periods.

1.4 USER DISCIPLINES

The following disciplines require the use of this Core Equipment Item:

- Electronic Materials
- Metals and Alloys
- Glasses and Ceramics
- Combustion Sciences
- Fluids and Transport Phenomena
- Polymer Science

2.0 PERFORMANCE

2.1 CAPABILITIES RANGE

The system must provide all conditions necessary to environmental control and life support for manned spaceflight. In addition, moderate tolerances must be maintained on environmental parameters having the potential to affect operation of the experiment apparatus subsystems. Tolerances include:

(1) pressure, 14.7 psi +/- 0.2 psi,
(2) temperature, 21.0 deg C. +/- 2.0 deg C.,
(3) humidity, 70% relative +/- 10%.

Laboratory atmosphere requires monitoring to maintain class 100,000 clean room standard. Record of particulate levels and composition is desirable.

2.2 INTERFACE PROVISIONS

Space Station main utilities.

2.3 AUTOMATION LEVEL

System requires 100% automation.

2.4 OBSERVATION REQUIREMENTS

Continuous digital display of average temperature, pressure, and humidity levels, with audible fault alarms for out of tolerance conditions.

2.5 DATA REQUIREMENTS

Continuous time history of environmental parameters temporarily stored on orbit and periodically downlinked for archival storage.

2.6 MAINTENANCE REQUIREMENTS

Microprocessor controlled autotesting routines. Spare parts inventory for critical components. Standard provisions for subsystems redundancy in manned spaceflight.

2.7 SAFETY ASSESSMENT

A monitoring system to detect hazardous environmental conditions such as gases, vapors, and particulates is required. Audible alarms at both the lab and remote locations are necessary to detect hazard conditions during manned/unmanned lab periods.

2.8 PHYSICAL PARAMETERS

3.0 TECHNOLOGY STATUS

3.1 READINESS LEVEL

Technology has been developed under previous manned spaceflight programs.

3.2 EQUIPMENT AVAILABILITY

Equipment has been developed under previous manned spaceflight programs.

3.3 DEVELOPMENT NEEDS

Integration of existing technology with final laboratory configuration.

RECOMMENDATION

PRELIMINARY SYSTEM DESIGN REQUIRES REVIEW BY NASA MICROGRAVITY SCIENCE AND APPLICATIONS DIVISION PRIOR TO PROCEEDING WITH FINAL DESIGN AND DEVELOPMENT PLANS.

NOTES

APPENDIX C

EXPERIMENT APPARATUS REQUIREMENTS

The following items represent the currently identified experiment apparatus required to support Microgravity Science and Applications research in a pressurized laboratory module at the initial operating capability (IOC) of the planned NASA Space Station.

In most cases, the apparatus are required to support basic research which has not proceeded due to the lack of flight-qualified hardware, or the limitations imposed by obsolescent hardware. These apparatus represent fundamental requirements as perceived by the scientific user community.

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Unique requirements will arise to perform basic phenomenological experiments in support of ongoing research programs. These experiments are required to obtain basic data necessary to the achievement of concurrent program objectives. Numerous unplanned experiments, and corresponding requirements for apparatus, can therefore be anticipated.

EXPERIMENT APPARATUS

ACOUSTIC LEVITATION SYSTEM

REQUIRED CAPABILITY

The ability to perform fundamental experiments on fluid behavior, and to obtain empirical data validating theoretical models is needed. An Acoustic Levitation System having the capability to position and manipulate a free drop, and to observe the dynamics of rotating and oscillating drops is required.

CURRENT CAPABILITY

A fully integrated experiment apparatus, the JPL-developed Drop Dynamics Module (DDL), has been flight tested and successfully demonstrated on Spacelab-3. The apparatus meets all currently identified experiment requirements and can be modified to accommodate additional specific investigations as the need arises.

DEVELOPMENT NEEDS

No further need for technology development has been identified at this time. Following final determination of the MSA laboratory architecture, the DDM requires review of electrical, mechanical, and fluid interfaces and compatibility assessment. A minimal redesign activity may be necessary to allow integration of the DDM with the new laboratory.

ACOUSTIC LEVITATION SYSTEM

COMMONALITY ASSESSMENT

The DDM apparatus provides fundamental scientific data in the Fluids, Gas, and Interface Dynamics research class. As such, it contributes to the science base in support of all identified research classes.

RISK ASSESSMENT

The DDM has been flight tested and successfully demonstrated. No risks have been identified related to its continued use.

RECOMMENDATION

A HIGH FREQUENCY OF USE CAN BE ANTICIPATED. THE NEED FOR A DUPLICATE OF THE EXISTING APPARATUS REQUIRES REVIEW BY SCIENCE WORKING GROUPS AND IMPLEMENTATION AS APPROPRIATE.

NOTES

COMBUSTION CALORIMETER

REQUIRED CAPABILITY

An insulated pressure vessel that is capable of igniting premixed gas and liquid systems and recording temperature, pressure, and species concentrations during the experiment. The internal atmosphere and initial temperature must be controlled and ports are required to allow for state-of-the-art optical measurement techniques, as well as video recording of the combustion process. Sampling ports are required around the facility for drawing internal atmosphere samples for analysis. Evacuation and venting capabilities are required.

Mass:............................100.00 kg
Volume:............................2.25 cu m
Peak Power:........................0.10 kw
Average Power:.....................0.05 kw
Typical Operating Cycle:...........0.2 hrs

CURRENT CAPABILITY

Spaceflight qualified system does not currently exist.

DEVELOPMENT NEEDS

Preliminary design and development activity is required.

COMBUSTION CALORIMETER

COMMONALITY ASSESSMENT

The Combustion Calorimeter will support research in the following classes:
(1) Combustion Sciences
(2) Fluid, Gas, and Interface Dynamics

In addition, combustion apparatus contribute valuable data on experiment safety requirements, thereby supporting the objectives of all remaining research classes.

RISK ASSESSMENT

Ground-based apparatus are well developed and tested. Electromechanical complexity is relatively low. No unusual risks are associated with apparatus development.

RECOMMENDATION

FOLLOWING FURTHER DEFINITION OF OPERATING PARAMETERS, INITIATE PRELIMINARY CONCEPT DESIGN AND DEVELOPMENT PLANS.

NOTES

COMBUSTION FURNACE

REQUIRED CAPABILITY

A pressure vessel that is enclosed in an electric furnace capable of very precise temperature control. The apparatus must record temperature and pressure and include ports around the chamber for obtaining internal atmosphere samples for analysis. Ports for state-of-the-art optical measurement techniques, as well as video recording of the combustion process are required. Evacuation and venting capabilities are required.

Mass:............................200.00 kg
Volume:...........................2.40 cu m
Peak Power:......................10.00 kw
Average Power:....................6.00 kw
Typical Operating Cycle:..........1.00 hrs

CURRENT CAPABILITY

Spaceflight qualified system does not currently exist.

DEVELOPMENT NEEDS

Preliminary design and development activity is required.

COMBUSTION FURNACE

COMMONALITY ASSESSMENT

The Combustion Furnace will support research in the following classes:
(1) Combustion Sciences
(2) Fluid, Gas, and Interface Dynamics

In addition, combustion apparatus contribute valuable data on experiment safety requirements, thereby supporting the objectives of all remaining research classes.

RISK ASSESSMENT

Ground-based apparatus are well developed and tested. Electromechanical complexity is relatively low. No unusual risks are associated with apparatus development.

RECOMMENDATION

FOLLOWING FURTHER DEFINITION OF OPERATING PARAMETERS, INITIATE PRELIMINARY CONCEPT DESIGN AND DEVELOPMENT PLANS.

NOTES

COMBUSTION TUNNEL

REQUIRED CAPABILITY

A pressure tested flow apparatus that can generate a variable laminar flow profile across the central section of the test chamber. Accommodations for solid sample holders and nozzles for gas and liquid fuel built into the chamber. Optical quality windows for state-of-the-art velocity, temperature, and species concentration measurements as well as video and film recording of combustion process. Evacuating and venting capabilities required.

Mass:............................200.00 kg
Volume:...........................0.60 cu m
Peak Power:.......................0.15 kw
Average Power:....................0.05 kw
Typical Operating Cycle:..........0.20 hrs

CURRENT CAPABILITY

Spaceflight qualified system does not currently exist.

DEVELOPMENT NEEDS

Preliminary design and development activity is required.

COMBUSTION TUNNEL

COMMONALITY ASSESSMENT

The Combustion Tunnel will support research in the following classes:
(1) Combustion Sciences
(2) Fluid, Gas, and Interface Dynamics

In addition, combustion apparatus contribute valuable data on experiment safety requirements, thereby supporting the objectives of all remaining research classes.

RISK ASSESSMENT

Ground-based apparatus are well developed and tested. Electromechanical complexity is relatively low. No unusual risks are associated with apparatus development.

RECOMMENDATION

FOLLOWING FURTHER DEFINITION OF OPERATING PARAMETERS, INITIATE PRELIMINARY CONCEPT DESIGN AND DEVELOPMENT PLANS.

NOTES

REQUIRED CAPABILITY

A pressure vessel that is capable of generating single fuel droplet sprays, igniting the fuel and recording pressures, temperature changes before, during, and after ignition and combustion. The internal atmosphere and temperature must be controlled and ports are required for state-of-the-art optical measuring techniques, as well as video recording of the combustion process. Sampling ports require location around the facility for drawing internal atmosphere samples for analysis. Evacuation and venting capabilities are required.

Mass:..........................100.00 kg
Volume:..........................1.35 cu m
Peak Power:......................0.30 kw
Average Power:...................0.10 kw
Typical Operating Cycle:.........0.20 hrs

CURRENT CAPABILITY

Spaceflight qualified system does not currently exist.

DEVELOPMENT NEEDS

Preliminary design and development activity is required.

DROPLET/SPRAY COMBUSTION FACILITY

COMMONALITY ASSESSMENT

The Droplet/Spray Combustion Facility will support research in the following classes:
(1) Combustion Sciences
(2) Fluid, Gas, and Interface Dynamics

In addition, combustion apparatus contribute valuable data on experiment safety requirements, thereby supporting the objectives of all remaining research classes.

RISK ASSESSMENT

Ground-based apparatus are well developed and tested. Electromechanical complexity is relatively low. No unusual risks are associated with apparatus development.

RECOMMENDATION

FOLLOWING FURTHER DEFINITION OF OPERATING PARAMETERS, INITIATE PRELIMINARY CONCEPT DESIGN AND DEVELOPMENT PLANS.

NOTES

ELECTROEPITAXIAL CRYSTAL GROWTH SYSTEM

REQUIRED CAPABILITY

The ability to investigate the kinetics associated with crystal growth by the liquid phase electroepitaxy technique, and to perform applied research on potential semiconductor material systems is needed. An Electroepitaxial Crystal Growth System (ECGS) is required.

CURRENT CAPABILITY

Present capability is limited to ground-based laboratory scale apparatus. Flight qualified apparatus does not currently exist.

DEVELOPMENT NEEDS

A complete integrated ECGS including, microprocessor control, crystal growth cell, gas handling subsystem, and modular assembly requires design and development. The system is required to support research in the MSA laboratory by a commercial organization which is currently participating with NASA under a Joint Endeavor Agreement.

ELECTROEPITAXIAL CRYSTAL GROWTH SYSTEM

COMMONALITY ASSESSMENT

No commonalities have been identified. The proposed process is a unique technique of proprietary interest.

RISK ASSESSMENT

Ground-based laboratory apparatus have been successfully demonstrated. Space-based research represents high risk, potentially high payoff technology.

RECOMMENDATION

EVALUATE GOVERNMENT ROLE IN SUPPORTING APPLIED COMMERCIAL RESEARCH IN SPACE AND INITIATE APPARATUS DESIGN AND DEVELOPMENT AS APPROPRIATE.

NOTES

ELECTROMAGNETIC LEVITATOR FURNACE

REQUIRED CAPABILITY

The ability to melt, manipulate, and resolidify inorganic, electrically conductive materials, and to perform thermophysical properties measurement on the free sample at elevated temperatures is needed. An Electromagnetic Levitator Furnace (ELF) having the following general characteristics is required:

Maximum Temperature:....................3420 deg C.
Preheater Maximum Temperature:..........2000 deg C.
Heating Rate:......................5-100 deg C/sec.
Cooling Rate:....................0.1-100 deg C/sec.
Quench Rate:.........................1000 deg C/sec.
Sample Size (spherical):................0.5 cm dia.
Atmosphere:....................vacuum or inert gas.
Sample Exchange:.....................10-20 samples.

CURRENT CAPABILITY

Present apparatus are limited to the Electromagnetic Levitator (EML) developed under the Space Processing Applications Rocket (SPAR) program during the mid 70's. The EML does not meet current requirements for temperature, preheat, and sample exchange.

DEVELOPMENT NEEDS

A complete integrated Electromagnetic Levitator Furnace including the furnace chamber, levitation system, electromechanical components, preheat system, and microprocessor control is required for the MSA laboratory.

ELECTROMAGNETIC LEVITATOR FURNACE

COMMONALITY ASSESSMENT

The ELF system can be used to support studies in the following research classes:
(1) Containerless Processing of Conductive Melts
(2) Containerless Processing of Non-Conductive Melts
(3) Fluid, Gas, and Interface Dynamics
(4) Isothermal Solidification

RISK ASSESSMENT

Electromagnetic levitation technology is well developed at elevated temperatures. Previous apparatus have been successfully demonstrated on both sounding rockets and the shuttle. The reliability of the technology is likely to attract a broad user base.

RECOMMENDATION

INITIATE PRELIMINARY CONCEPT DESIGN AND DEVELOPMENT PLANS.

NOTES

FLOAT ZONE SOLIDIFICATION FURNACE

REQUIRED CAPABILITY

The ability to produce high purity, large diameter (150 mm) single crystal semiconductor materials by the directional solidification of floating melt zones is needed. Prior to achieving success with large diameter materials, the fundamental capability to produce small diameter (7.0 mm) samples must be demonstrated. A Microgravity Thin Rod Zoner (MTRZ) having the following characteristics is required:

Maximum Temperature:....................1500 deg C.
Overall Crystal Length:....................41.0 cm.
Zoned Crystal Length:......................15.0 cm.
Furnace Translation Rate:.........0.1 - 6.5 mm/min.
Seed Translation Rate:...........1.0 - 50.0 mm/min.
Rotation Rate:......................0.1 - 20.0 rpm.

CURRENT CAPABILITY

American capability is currently limited to Fluids Experiment Apparatus (FEA) developed by Rockwell Int'l and configured for student experiment. No significant American flight apparatus presently exists. German Mirror Heating Facility (MHF) meets most of the above requirements and has flown.

DEVELOPMENT NEEDS

Access to the MHF by American investigators may be limited. A dedicated float zoning apparatus is necessary. Preliminary concept design and prototype development have been completed by Westech Systems, Inc. A MTRZ having the above characteristics has been proposed for flight development.

FLOAT ZONE SOLIDIFICATION FURNACE

COMMONALITY ASSESSMENT

The Float Zone Directional Solidification Furnace will support research in the following classes:

(1) Float Zone Directional Solidification
(2) Containerless Processing of Conductive Melts
(3) Containerless Processing of Non-Conductive Melts
(4) Fluid, Gas, and Interface Dynamics

RISK ASSESSMENT

Extensive empirical and theoretical ground-based research has been completed and prototype hardware has been in operation since 1982. Float zoning of silicon is an established process which has been used successfully by industry to produce high purity material at very small diameters since 1955.

RECOMMENDATION

EVALUATE AMERICAN NEED FOR A DEDICATED CAPABILITY IN FLOAT ZONE CRYSTAL REFINEMENT AND INITIATE FINAL DESIGN AND DEVELOPMENT OF A FLIGHT APPARATUS AS APPROPRIATE.

NOTES

HIGH TEMPERATURE ISOTHERMAL FURNACE

REQUIRED CAPABILITY

Prior to initiation of advanced research in a containerless mode, a fundamental capability to thermally process samples in a sealed container (crucible/tube) is needed. A High Temperature Isothermal Furnace (HTIF) having the following characteristics is required:

Maximum Temperature:....................1700 deg C.
Isothermal Zone Length:....................10.0 cm.
Isothermal Zone Control:............+/- 2.0 deg C.
Heating/Cooling Rate:..............1-20 deg C/min.
Quench Rate:......................1000 deg C/sec.
Crucible/Tube Size:....................5.0 cm dia.
Sample Exchange Capability:.........10-20 samples.
Observation Capability:......Ability to directly view samples during the processing sequence, is also desirable.

CURRENT CAPABILITY

The General Purpose Rocket Furnace (GPRF) is the only available apparatus for isothermal processing. It does not meet current requirements for maximum temperature, zone control, sample size, and sample exchange. Nor does it include provisions for direct viewing. In addition, the GPRF contains outmoded electronics developed during the mid 70's under the Space Processing Applications Rocket (SPAR) program.

DEVELOPMENT NEEDS

A complete integrated HTIF system including the furnace core, electromechanical components, microprocessor based control electronics, and direct viewing capability is required for the MSA laboratory. State-of-the-art technology should be incorporated in the concept design phase.

HIGH TEMPERATURE ISOTHERMAL FURNACE

COMMONALITY ASSESSMENT

The HTIF system will support research in the following classes:

1) Isothermal Solidification
2) Containerless Processing of Conductive Melts
3) Containerless Processing of Non-Conductive Melts
4) Fluid, Gas, and Interface Dynamics

RISK ASSESSMENT

Flight furnace technology has advanced significantly since the SPAR program. Current technology includes improved materials and electronics of demonstrated capability. The HTIF system represents a fundamental research capability having application in the areas of glass and ceramics, metals and alloys, and composite materials. High demand has been observed in workshops, contractor studies, and investigator discussions.

RECOMMENDATION

INITIATE PRELIMINARY CONCEPT DESIGN AND DEVELOPMENT PLAN.

NOTES

HIGH TEMPERATURE LEVITATING FURNACE

REQUIRED CAPABILITY

A general capability to melt and resolidify glass and ceramic materials in a containerless mode is required to support research on those materials which cannot be produced on earth due to the contaminating influence of a container wall. A High Temperature Levitation Furnace (HTLF) having the following characteristics is required.

Maximum Temperature:....................1800 deg C.
Temperature Uniformity:............ +/- 5.0 deg C.
Heating/Cooling Rate:..........0.1-20.0 deg C/sec.
Spin Rate:.........................< 0.1 rad/sec.
Sample Size Capability:.............up to 10.0 mm.
Sample Density:.......................20 grams/cc.
Sample Exchange Capability:.........10-20 samples.
Observation Capability:...Ability to directly view samples, along two orthogonal axes, is also desirable.

CURRENT CAPABILITY

The Single Axis Acoustic Levitator (SAAL) and Acoustic Containerless Experiment System (ACES) represent currently available experiment apparatus. Neither of these systems meet the requirements for maximum temperature, heating/cooling rate, sample size, and sample exchange. In addition the SAAL contains outmoded electronics developed during the mid 70's.

DEVELOPMENT NEEDS

A complete integrated HTLF system including the furnace chamber, levitation system, electromechanical components, microprocessor based control electronics, and direct viewing capability is required for the MSA laboratory.

HIGH TEMPERATURE LEVITATING FURNACE

COMMONALITY ASSESSMENT

The HTLF system will support research in the following classes:

1) Containerless Processing of Conductive Melts
2) Containerless Processing of Non-Conductive Melts
3) Isothermal Solidification
4) Fluid, Gas, and Interface Dynamics

RISK ASSESSMENT

Levitation and furnace technology has advanced significantly since the design of the SAAL and ACES systems. Gas-jet levitation techniques have demonstrated success at ambient temperatures and may represent a viable approach to high temperature applications. Acoustic techniques have been under development for greater than ten years, however, sufficient control over the acoustic pressure and sample positioning has been difficult to achieve at elevated temperatures.

RECOMMENDATION

RE-ASSESS POTENTIAL ADVANTAGES OF GAS-JET LEVITATION TECHNIQUES AND INITIATE PRELIMINARY CONCEPT DESIGN AND DEVELOPMENT PLANS AS APPROPRIATE.

NOTES

MODULAR CRYSTAL GROWTH FACILITY

REQUIRED CAPABILITY

A modular crystal growth facility comprising a power control unit, a charge placement/translation unit, and a thermal insulation and heat extraction unit is required to support fundamental studies in crystal growth. The apparatus should also include a compatible general purpose hot zone that can be reconfigured to meet heat transfer requirements of specific investigations. The following parameters represent one potential configuration.

Cold Zone Operating Range:........200-800 deg C.
Hot Zone Operating Range:........200-1250 deg C.
Ampoule Size:..........2.0 cm o.d. X 25.0 cm long.
Ampoule Translation Rate:.........0.4 - 50.0 mm/hr.
Gradient Zone Length:....................10-20 cm.
Passively Cooled Zone Length:.............2-10 cm.
Control Setpoint Stability:.........+/- 0.5 deg C.
Control Setpoint Accuracy:..........+/- 5.0 deg C.

CURRENT CAPABILITY

No current capability exists.

DEVELOPMENT NEEDS

A complete integrated Modular Crystal Growth System (MCGS) including microprocessor control, charge placement/translation, thermal insulation and heat extraction, and general purpose hot zone is required for the MSA laboratory. Specific hot zone configurations require development as identified.

MODULAR CRYSTAL GROWTH FACILITY

COMMONALITY ASSESSMENT

The MCGS will support research in the following classes:
(1) Plane Front Directional Solidification
(2) Fluid, Gas, and Interface Dynamics
(3) Vapor Crystal Growth

RISK ASSESSMENT

The MCGS represents an integration of existing furnace technologies and functional subsystems in such a manner as to allow a wide variety of experiments via reconfigurable hot zones. Previous integrated experiment apparatus have been successfully demonstrated on Spacelab-3.

RECOMMENDATION

INITIATE PRELIMINARY CONCEPT DESIGN AND DEVELOPMENT PLANS.

NOTES

REQUIRED CAPABILITY

The ability to melt and re-solidify inorganic materials by the plane front directional solidification technique, and to precision control the thermal environment at the liquid-solid interface is needed. A series of directional solidification furnaces (four) have been identified as necessary to meet the full range of requirements. These include:

- a high temperature high gradient furnace (1500 deg C / 400 deg C/cm)
- a high temperature low gradient furnace (1500 deg C / 100 deg C/cm)
- a low temperature high gradient furnace (1100 deg C / 400 deg C/cm)
- a low temperature low gradient furnace (1100 deg C / 100 deg C/cm).

CURRENT CAPABILITY

Present apparatus are limited to the General Purpose Rocket Furnace (GPRF) and Advanced Directional Solidification Furnace (ADSF). These apparatus do not meet anticipated requirements for temperature control and sample exchange.

DEVELOPMENT NEEDS

Plans are currently underway at NASA/MSFC for development of an Advanced Automated Directional Solidification Furnace (AADSF) and a Multiple Experiment Processing Facility (MEPF). These apparatus represent state-of-the-art technology. Further development of furnace technology may be required following test and evaluation of these apparatus.

DIRECTIONAL SOLIDIFICATION FURNACES

COMMONALITY ASSESSMENT

The directional solidification furnaces will support studies in the following research classes:
(1) Plane Front Directional Solidification
(2) Fluid, Gas, and Interface Dynamics
(3) Vapor Crystal Growth

RISK ASSESSMENT

Significant flight experience and ground-based research have been achieved with furnace technologies. Advances have been limited by available funds as opposed to technical obstacles. Risk is largely in attempting to over-design one apparatus to meet all requirements.

RECOMMENDATION

INCLUDE PROVISIONS IN THE MSA LABORATORY TO ACCOMMODATE CURRENTLY PLANNED AADSF AND MEPF APPARATUS. ASSESS FUTURE REQUIREMENTS FOLLOWING TEST AND EVALUATION OF CURRENT APPARATUS.

NOTES

SLOW SOLUTE DIFFUSION SYSTEM

REQUIRED CAPABILITY

The ability to grow organic crystals by the slow solute diffusion technique and to observe growth phenomena such as diffusion mass transport and thermal flow is needed. A Slow Solute Diffusion System (SSDS) having the following characteristics is required:

Maximum Temperature:....................350 deg C.
Thermal Stability:..................+/- 0.1 deg C.
Thermal Uniformity:...............+/- 0.01 deg C.
Reactor Volume:.........................2.0 liter.
Reactant Volume:........................1.0 liter.
Sample Exchange Capability:..................100%
Observation:.................Ability to directly view crystallization process is highly desirable.

CURRENT CAPABILITY

Apparatus for slow solute diffusion have been developed by industry (Rockwell/3M) for proprietary research, and by governments (Germany/USA) for biological macromolecule crystallization studies. None of the existing systems have sample exchange capabilities, multiple reaction vessels have been designed to accommodate from 1-20 experiments.

DEVELOPMENT NEEDS

Techniques for interchanging reactant vessels and purging reactant chambers following sample removal require concept design and development. Direct viewing systems require advance over current techniques which are limited to 35 mm photographic records.

SLOW SOLUTE DIFFUSION SYSTEM

COMMONALITY ASSESSMENT

The SSDS will support research in the following classes:
(1) Solution Crystal Growth
(2) Fluid, Gas, and Interface Dynamics
(3) Polymer Science
(Applications to biotechnology have also been demonstrated.)

RISK ASSESSMENT

Slow solute diffusion is a relatively passive technique having low utility/resource requirements and potential high pay-off. Increasing interest has been demonstrated by both domestic and foreign organizations based on the success of preliminary experiments. Hardware technology has a relatively low electromechanical complexity.

RECOMMENDATION

FURTHER IDENTIFY POTENTIAL USER GROUPS, REVIEW GENERAL REQUIREMENTS, AND INITIATE PRELIMINARY CONCEPT DESIGN AND DEVELOPMENT PLANS.

NOTES

REQUIRED CAPABILITY

The fundamental capability to produce polymer materials through solution polymerization at moderate temperature and pressure, and to monitor key parameters during the process is needed. A Solution Chemical Reactor System (SCRS) having the following general characteristics is required:

Reactor Volume:..........................500 ml.
Maximum Temperature:.....................200 deg C.
Temperature Stability:...............+/- 0.1 deg C.
Temperature Uniformity:.............+/- 0.01 deg C.
Stir Rate:................................1.0 rpm.
Heating Rate:........................0.5 deg C/min.
Cooling Rate:.................0.5 to 100 deg C/min.
Sample Exchange:.....................10-20 samples.
Observation:..........Ability to directly view the reaction process is highly desireable.

CURRENT CAPABILITY

The Monodisperse Latex Reactor (MLR) is the only existing apparatus available for solution polymerization studies. It does not meet current requirements for sample volume/exchange, maximum temperature, and direct observation.

DEVELOPMENT NEEDS

A complete integrated SCRS system including reactor core, thermal control system, sample exchange interfaces, electromechanical components, microcomputer, and direct viewing capability is required for the MSA laboratory. State-of-the-art technology should be incorporated in the concept design phase.

COMMONALITY ASSESSMENT

The SCRS system will support research in the following classes:
(1) Polymer Science
(2) Fluid, Gas, and Interface Dynamics
(3) Solution Crystal Growth

RISK ASSESSMENT

The electromechanical complexity of the SCRS system is relatively low compared to other experiment apparatus. In addition the performance requirements are less stringent and successful apparatus have been previously developed for spaceflight. Finally, the number of experiments that could be accommodated is very high, with broad commercial applications cited.

RECOMMENDATION

INITIATE PRELIMINARY CONCEPT DESIGN AND DEVELOPMENT PLANS.

NOTES

REQUIRED CAPABILITY

The ability to grow crystals by the low temperature solution growth technique and to observe growth phenomena such as mass transport and heat flow in a diffusion controlled system is needed. A solution crystal growth system having the following characteristics is required:

Maximum Temperature:......................70 deg C.
Heating/Cooling Rate:................0.5 deg C/min.
Thermal Stability:...................+/- 0.1 deg C.
Temperature Uniformity:.............+/- 0.01 deg C.
Observation:.................holographic imaging in primary and transverse planes is highly desirable.

CURRENT CAPABILITY

The Fluids Experiment System (FES) meets all requirements necessary to achieve controlled solution crystal growth and has been succesfully demonstrated on Spacelab-3.

DEVELOPMENT NEEDS

No further need for technology development has been identified at this time. Following final determination of the MSA laboratory architecture, the FES requires review of electrical, mechanical, and fluid interfaces and compatibility assessment. A minimal redesign activity may be necessary to allow integration of the FES with the new laboratory.

SOLUTION CRYSTAL GROWTH FACILITY

COMMONALITY ASSESSMENT

The FES system will support research in the following classes:
(1) Solution Crystal Growth
(2) Fluid, Gas, and Interface Dynamics
(3) Polymer Science

RISK ASSESSMENT

The FES system represents existing equipment which has been successfully flight tested.

RECOMMENDATION

INCLUDE PROVISIONS IN THE MSA LABORATORY TO ACCOMMODATE THE EXISTING FES SYSTEM.

NOTES

ULTRAHIGH TEMPERATURE LEVITATING FURNACE

REQUIRED CAPABILITY

The ability to measure thermophysical properties of glass and ceramic materials having very high melting points is of exceptional scientific interest due to the current abscence of such data. A containerless mode is necessary in order to avoid extreme chemical reactivity of all container wall materials. An Ultra-High Temperature Levitation Furnace (UHTLF) having the following general characteristics is required to provide this capability.

Maximum Temperature:..................2400 deg.C.
Cooling Rate:............~1.0 deg C/sec.(minimum).
Sample Size:..............................5.0 mm.
Sample Exchange Capability:..........5-10 samples.
Observation Capability:....Ability to directly view samples during the processing sequence is desirable.

CURRENT CAPABILITY

No current capability exists. Previous studies in thermophysical properties measurement have employed the Electromagnetic Levitator Furnace (EML), however, this apparatus is limited to conductive melts.

DEVELOPMENT NEEDS

A complete integrated UHTLF system including the furnace chamber, levitation system, electromechanical components, microprocessor control electronics, and direct viewing capability is required for the MSA laboratory. A significant advance over current technology is necessary to achieve the desired capability level.

ULTRAHIGH TEMPERATURE LEVITATING FURNACE

COMMONALITY ASSESSMENT

The UHTLF system will support research in the following classes:
(1)Containerless Processing of Non-Conductive Melts
(2) Containerless Processing of Conductive Melts
(3) Fluid, Gas, and Interface Dynamics

RISK ASSESSMENT

The ability to achieve the desired levels of performance are first contingent on achieving a similar levitating capability at lower temperatures (e.g., 1800 deg C. as in the HTLF system). A considerable advance, employing exotic materials, will be necessary to attain the 2400 deg C. objective.

RECOMMENDATION

FOLLOWING ACHIEVEMENT OF CAPABILITY AT THE 1800 DEG. C. LEVEL, RE-ASSESS TECHNOLOGY AND INITIATE PRELIMINARY CONCEPT DESIGN AND DEVELOPMENT PLANS.

NOTES

REQUIRED CAPABILITY

The ability to grow crystals by the physical vapor transport (PVT) technique, and to observe growth phenomena such as mass transport and heat flow in a diffusion controlled system is needed. A vapor crystal growth system having the following characteristics is required:

Source Heater Range:..................100-120 deg C.
Source Heater Modulation:............+/- 2.5 deg C.
Source Heater Rate:..................2.5 deg C/min.
Ring Heater Range:...................120-180 deg C.
Sting Heater Range:....................40-80 deg C.
Ampoule Size:.........8.0 cm dia. X 11.0 cm length.

CURRENT CAPABILITY

The Vapor Crystal Growth System (VCGS) meets all currently identified requirements necessary to meet controlled PVT crystal growth and has been successfully demonstrated on Spacelab-3.

DEVELOPMENT NEEDS

No further need for technology development has been identified at this time. Following final determination of the MSA laboratory architecture, the VCGS requires review of electrical, mechanical, and fluid interfaces and compatibility assessment. A minimal redesign activity may be necessary to allow integration of the VCGS with the new laboratory.