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CONCEPTS FOR MICROGRAVITY EXPERIMENTS UTILIZING GLOVEBOXES

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Science and Engineering Directorate

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16. ABSTRACT

The need for glovebox facilities on spacecraft in which microgravity materials processing experiments are performed is discussed. At present such facilities are being designed, and some of their capabilities are briefly described. A list of experiment concepts which would require or benefit from such facilities is presented.

17. KEY WORDS

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Maintenance Work Station
Life Science Glovebox
Microgravity Science

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CONCEPTS FOR MICROGRAVITY EXPERIMENTS UTILIZING GLOVEBOXES

INTRODUCTION

Experiments designed to study the effects of microgravity on physical processes frequently involve the handling of materials which are either toxic or which constitute a hazard because they involve liquids or gases which must be contained. Compromises in experiment design must often be made in order to assure containment of these materials. Gloveboxes are commonly used in laboratories to contain hazardous materials. Gloveboxes suitable for use in Spacelab and Space Station Freedom have been planned, and a biological glovebox is scheduled for flight in the International Microgravity Lab series of Spacelab flights. These gloveboxes are being designed to provide containment, manipulation capabilities, photography, and electrical power and data interfaces to the spacecraft.

On April 24, 1989, a meeting was held in the Space Science Laboratory (SSL) of the Marshall Space Flight Center (MSFC) to discuss the potential uses of gloveboxes in microgravity science experiments. At this meeting a committee composed of Dr. Roger Kroes, Dr. Donald Reiss, and Ms. Barbara Facemire of the Microgravity Science and Applications Division of Space Science Laboratory, which had been assigned the task of investigating the uses of gloveboxes, reported its results to Dr. Robert J. Naumann, Chief of the Microgravity Science and Applications Division. The purpose of this document is to present the results of that investigation.

These results are presented in two parts. The first part is a list of experiments and science demonstrations which were performed on Apollo, Skylab, or STS missions. This list was abstracted from a database being developed at SSL/MSFC. Further information and details of these experiments may be obtained from Cheryl M. Winter, ES42, MSFC. The second part consists of brief descriptions of typical experiments proposed by Microgravity Science and Applications Division personnel.

BACKGROUND

The solution crystal growth experiment flown in the Fluids Experiment System on Spacelab 3 illustrates the compromises which are often imposed on flight experiments by safety considerations. In this experiment crystals of triglycine sulfate were grown from an aqueous solution which, being acidic, presents such a potential hazard. In a ground-based laboratory, seed crystals are inserted in the solution manually, and the grown crystals are retrieved and immediately dried the same way. Since safety considerations prevented this in the flight experiment, the seeds were stored under sealed caps in solution-filled cells until the start of the experimental run, when the caps were retracted. After the growth runs the caps were replaced. The experimental results were compromised because the caps leaked enough during storage to damage the seed surfaces, and cap replacement trapped some growth solution which remained in contact with the new growth.

In order to perform seeded growth experiments properly, the seed insertion and crystal removal procedures normally used in the ground-based laboratory should also be used in flight. However, this could result in the release of drops of acidic solution into the cabin. Other experiments involving the insertion of liquid samples into cells or the removal of objects from liquid-filled cells could cause similar potentially hazardous conditions.

The proposed materials sciences glovebox[1] provides negative pressures and inflow to meet class III requirements, controls gaseous, liquid, and particulate contamination of the interior work space, and removes all trace contaminants from the cabinet atmosphere before exhaust to the cabin. The users will be provided with access to electrical power, gases, ultrapure water, and interfaces to the control and data subsystem. The internal temperature will be controlled, and visibility and video for operations and analysis will be available. About 38 cu. ft. of workspace accessible through an airlock will be provided. Figure 1 shows the materials sciences glovebox rack with the cabinet and airlock.

The laboratory maintenance work station[2] provides 35.4 cu. ft. of temperature-controlled work space, access to data management, power, air and vacuum, and provides either a class 10K clean environment or a negative pressure environment for contaminant containment. Video observation and downlink and visibility for crew operations is provided. Figure 2 shows the key features of this system.

The life sciences glovebox[2] provides 17.4 cu. ft. of temperature-controlled work space, with access to data management, power, air, and vacuum. It provides positive pressure for clean operations and negative pressure for class III containment requirements. A viewing window for crew operations, video equipment, and a microscope are available. The key features of this apparatus are shown in Figure 3.

The European Space Agency has developed a glovebox intended for use in the Biorack program.[3] This glovebox provides a class III type safety cabinet for containment of hazardous materials, a class 100 clean work area for small equipment when class III containment is not required, a viewing window, small internal drawers for stowage of small tools and provision for a microscope (x 200), a camera with macro lens (60 x 45 mm FOV on working area floor) and a video camera.

The authors would like to thank Charles Baugher for information he provided on various planned glove box facilities. Requests for additional information on the capabilities and status of the glove boxes should be directed to Mr. Baugher at (205) 544-7417.

1. Teledyne/Brown Engineering; Presentation for WP-01 Laboratory Equipment Technical Interchange Meeting, March 21-23, 1989
2. Lockheed Missiles & Space Co.; Presentation for WP-01 Laboratory Equipment Technical Interchange Meeting, March 21-23, 1989
3. P. Genzel, ESA Publication IMP-TN/1022; Handling and Containment of Hazardous Material of Experiments within Biorack Facilities, 1987

MATERIAL SCIENCES GLOVEBOX

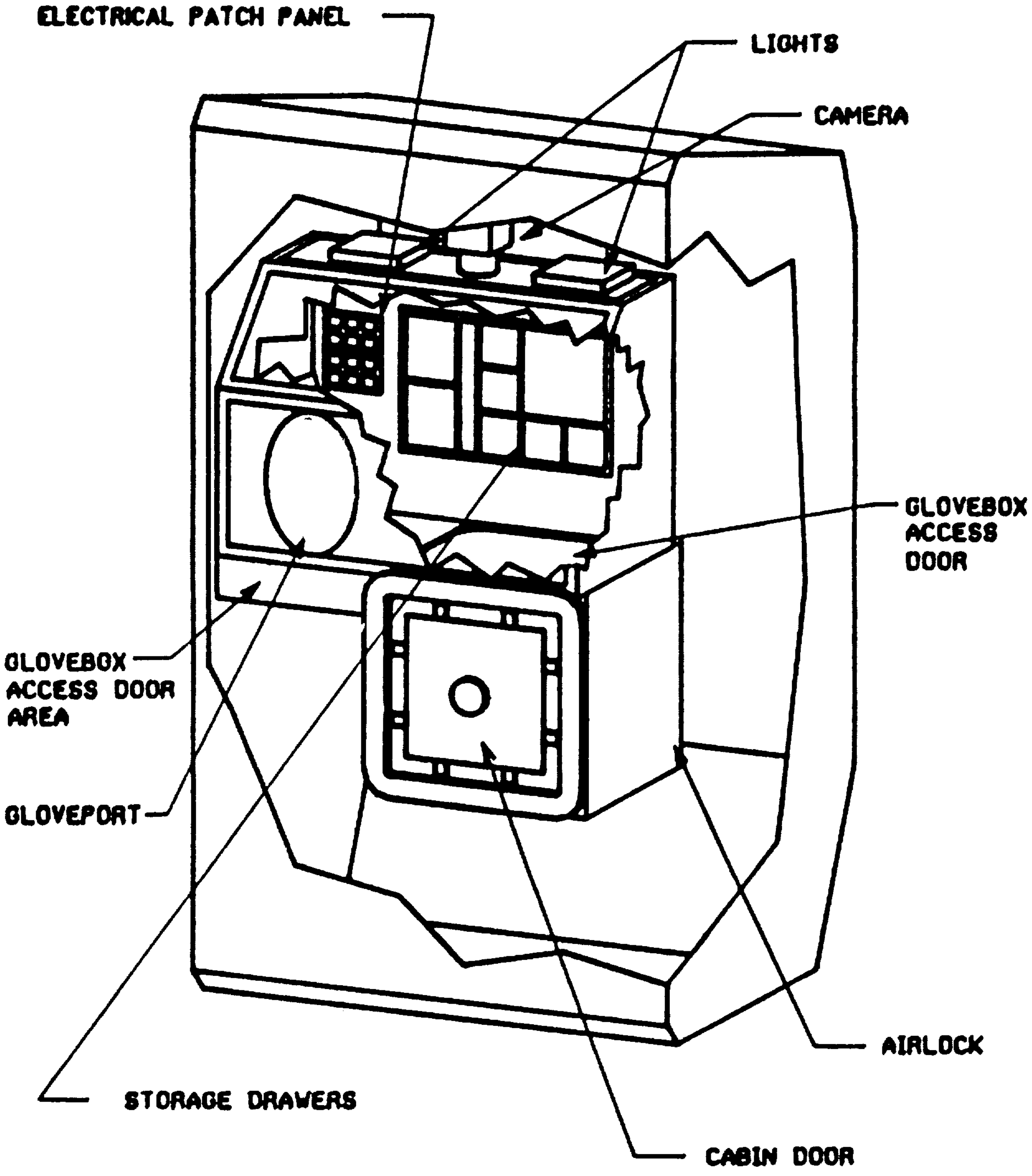

Figure 1. Materials sciences glovebox.

MAINTENANCE WORK STATION

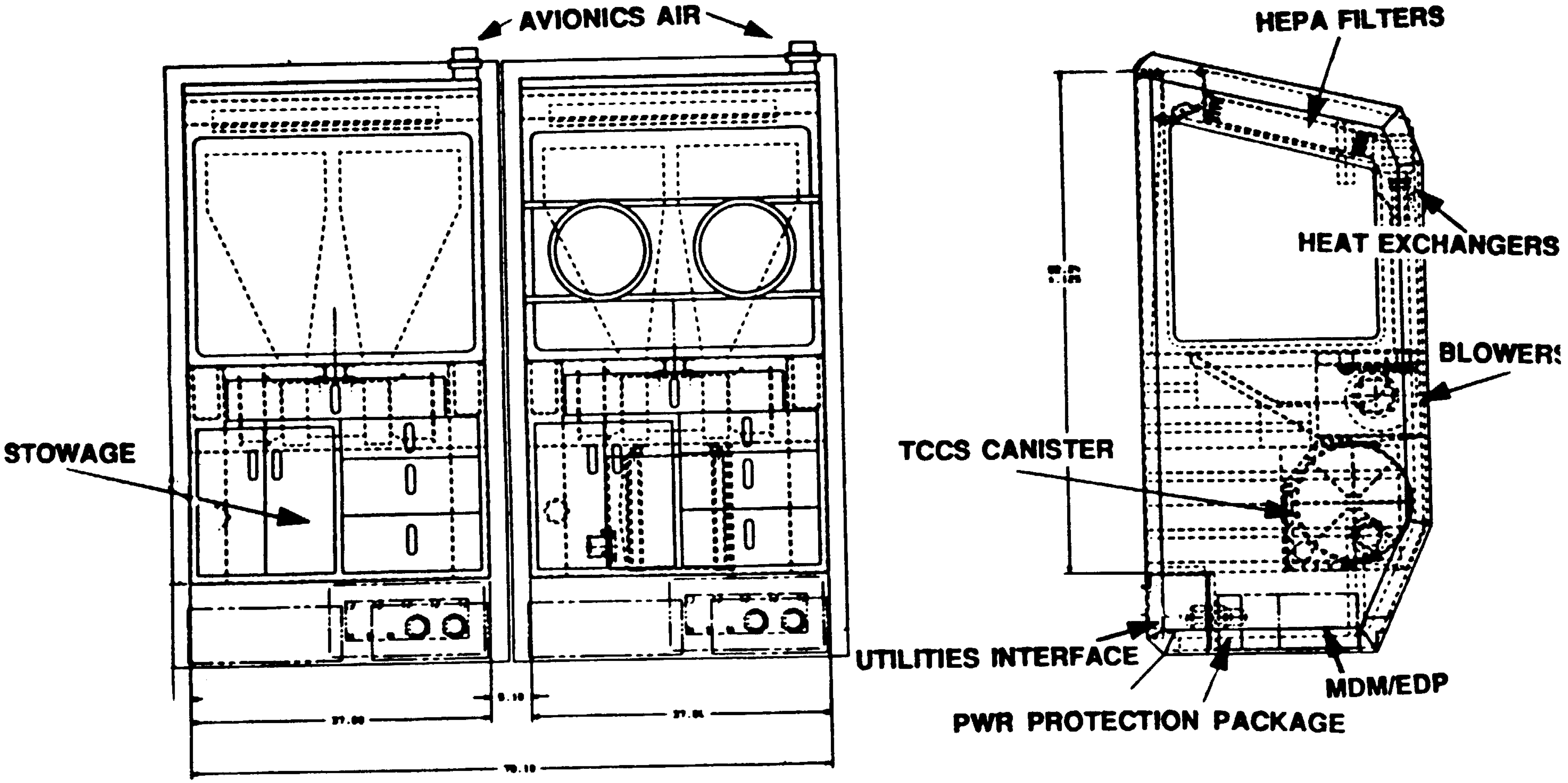

Figure 2. Maintenance work station.

LIFE SCIENCE GLOVEBOX

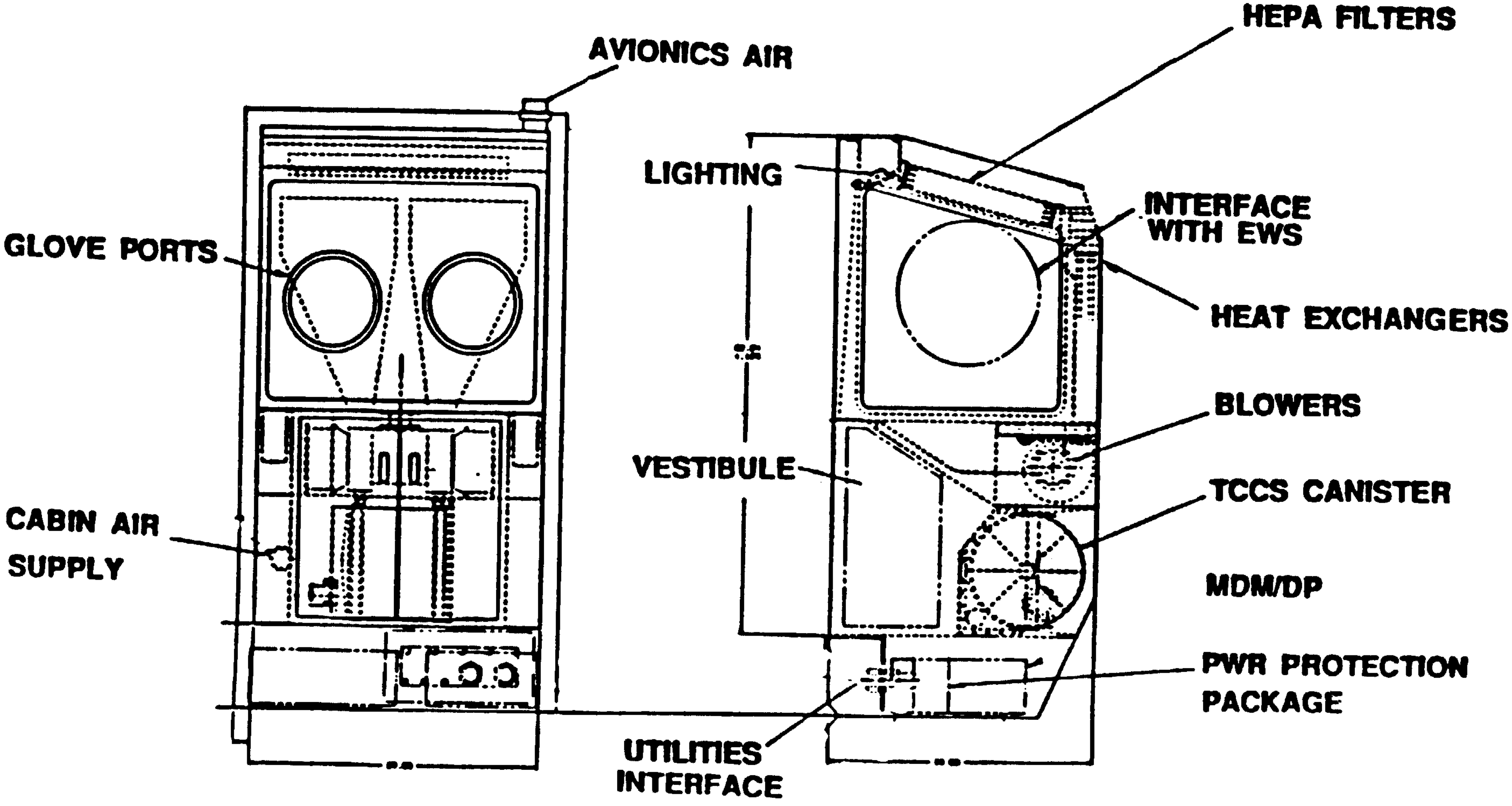

Figure 3. Life science glovebox.

EXPERIMENTS

PREVIOUS EXPERIMENTS
WITH POTENTIAL FOR UTILIZATION OF GLOVEBOX

	EXPERIMENT TITLE	RESPONSIBLE PERSONNEL
1.	Composite Casting (Apollo 14)	J. L. Reger, W. H. Steurer
2.	Role of Gravity in Preparative Electrophoresis (TV117-SD35 Skylab 4)	M. Bier
3.	Liquid Floating Zone (TV101-SD20 Skylab 4)	J. Carruthers
4.	Liquid Films (TV103-SD22 Skylab 4)	W. Darbro
5.	Diffusion in Liquids (TV115-SD15 Skylab 4)	B. Facemire
6.	Ice Formation (TV112-SD17 Skylab 4)	B. Facemire, P. Grodzka
7.	Water Studies, Physics of Water Globule (TV111-SD16 Skylab 4)	P. Grodzka, B. Facemire
8.	Deposition of Silver Crystals (TV106-SD21 Skylab 4)	P. Grodzka, B. Facemire
9.	Effervescence (TV113-SD18 Skylab 4)	A. R. Hibbs
10.	Immiscible Liquids (TV102-SD19 Skylab 4)	L. L. Lacy
11.	Rochelle Salt Growth (TV105-SD33 Skylab 4)	I. Miyagawa
12.	Ice Melting (TV111-SD16 Skylab 4)	G. H. Otto, L. L. Lacy

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13.	Water Drop and Fluid Mechanic Series (TV107-SD9 Skylab 4)	O. Vaughan, B. Facemire, S. Bourgeois, R. Frost
14.	Acoustic Positioning SD24 Skylab 4)	O. Vaughan, T. Wang (TV114-
15.	Cloud Formation (TV118-SD29 Skylab 4)	O. Vaughan
16.	Equilibrium Shift Reaction (Chemical Foams) (ASTP)	P. Grodzka, B. Facemire
17.	Capillary Wicking (ASTP)	A. Whitaker
18.	Formaldehyde Clock Reaction (ASTP)	P. Grodzka, B. Facemire
19.	Spreading of Liquids (ASTP)	S. Bourgeois
20.	Powder Flow (Skylab proposal)	K. M. Sherhart (student)
21.	Mass Measurement (ED74 Skylab 3)	V. Converse (student)
22.	Liquid Motion (ED78 Skylab 3)	B. Dunlap (student)
23.	Brownian Motion (Skylab proposal)	G. A. Merkel (student)
24.	Capillary Study (ED72 Skylab 4)	R. G. Johnston (student)
25.	Effect of Zero Gravity on the Colloidal State of Matter (Skylab proposal)	K. McGee (student)
26.	Crystal Growth of Tri-Glycine Sulfate (STS-005)	M. A. Issel (student)

27.	Convection Study (STS-005)	D. S. Thomas (student)
28.	Crystal Growth of Liquid Salt Solution (STS-007)	Kayser-Threde GmbH (student)
29.	Single Crystal Growth of Indium Using Floating Zone (STS-014)	S. Murphy (student)
30.	Crystallization of Potassium Aluminum Sulfate (STS-025)	M. Moore (student)
31.	Wicking of Freon (STS-025)	K. Foster (student)
32.	Honeycombing Structures (Creation of Metallic Foam) (STS-032)	R. Safman (student)
33.	Formation of Paper (STS-032)	D. J. Herbert (student)
34.	Liquid Transfer Demonstration (Apollo 14)	K. L. Abdalla, E. P. Symons
35.	Heat Flow and Convection (Apollo 14)	T. C. Bannister, P. Grodzka
36.	Exothermic Brazing (M552 Skylab)	J. Williams
37.	Radioactive Tracer Diffusion (M558 Skylab 3)	A. O. Ukanwa
38.	Soldering (STS-004)	G. C. Alford (student)
39.	Composite Curing (STS-004)	A. M. Dalley (student)

40.	Surface Tension Experiment Shape of Liquid Meniscus (STS-004)	J. K. Elwell (grad. student)
41.	Thermal Conductivity of Two Immiscible Components (STS-004)	R. Lahar (student)
42.	Interfacial Phenomena (STS-005)	J. M. Haynes
43.	Separation of Oil and Water (STS-007)	California Inst. of Tech (students)
44.	Motion of Mercury Under Low-G (STS-007)	Purdue University (students + Dr. Snow)
45.	Various Experiments on Soldering (STS-007)	EDSYN, Inc.
46.	Liquid Phase Miscibility Gap Materials: (1) Gradient Cooling Experiment and (2) Isothermal Plunger Exp. (STS-007)	S. H. Gelles
47.	Floating Zone Stability in Zero Gravity (1ES331 STS-009)	I. DaRiva, I. Martinez
48.	Vacuum Brazing (1ES305 STS-009)	K. Frieler, R. Stickler
49.	Kinetics of Spreading of Liquids on Solids (1ES327 STS-009)	J. M. Haynes
50.	Interfacial Instability and Capillary Hysteresis (1ES339 STS-009)	J. M. Haynes
51.	Free Convection in Low Gravity (1ES328 STS-009)	L. G. Napolitano, R. Monti

52.	Tribological Experiments in Zero Gravity (INT011 STS-009)	C. H. T. Pan, R. L. Gause, A. F. Whitaker
53.	Oscillation of Semi-Free Liquid in Space (1ES326 STS-009)	H. Rodot
54.	Coupled Motion of Liquid-Solid Systems in Near Zero Gravity (1ES330 STS-009)	J. P. B. Vreeburg
55.	Soldering Experiment and Electrophoresis Concept Experiment (STS-011)	(students)
56.	Capillary Wave Study (STS-011)	T. Kitatura
57.	Thermocapillary Convection (Float Zone) (STS-011)	S. Thomas
58.	Growth of Crystals from Solutions in Low Gravity (AO139A STS-013)	M. D. Lind, K. F. Nielsen
59.	Physics of Solids and Liquids (Water Ball Collision) (STS-017)	Asahi National Broadcasting Co.
60.	Zero G Fuel System Test: Propellant Tank and Transfer (STS-017)	McDonnell Douglas Co.
61.	Thermocapillary Convection (STS-017)	S. Thomas
62.	Heat Pipe Experiment (STS-017)	V. Walden
63.	Phase Partitioning Experiment (STS-023)	D. E. Brooks, J. Van Alstine J. M. Harris

64.	Protein Crystal Growth Experiment (STS-023)	C. E. Bugg
65.	Liquid Sloshing: Dynamic Behavior of Liquid Propellants (STS-025)	MBB/ERNO
66.	Small Helium-Cooled Infared Telescope (STS-026)	G. G. Fazio
67.	Bubble Transport by Chemical Waves (PL-HOL-01 STS-030)	A. Bewersdorff
68.	Marangoni Convection in Relation to Mass Transfer from the Liquid to the Gas Phase (WL-FPM-01 STS-030)	A. A. H. Drinkenburg
69.	Mixing and Demixing of Transparent Liquids (WL-FPM-03 STS-030)	D. Langbein
70.	Surface Tension Induced Convection Around a Surface Tension Minimum-Thermocapillary Motions in Aqueous Solutions (WL-FPM-05 STS-030)	J. C. Legros
71.	Separation of Fluid Phases and Bubble Dynamics in a Temperature Gradient (WL-FMP-02 STS-030)	R. Nahle
72.	Marangoni Flows-A Study of Surface Tension Driven Convection Phenomena in Very Low Gravity (WL-FPM-07 STS-030)	L. G. Napolitano

73.	Surface Tension Studies Bubble Motions Caused by Thermal Gradients (without Convection and Buoyancy) (PK-HOL-03 STS-030)	D. Neuhaus
74.	Liquid Motions in Partially Filled Containers Growth of Free Surface Resonant Motions in mg (WL-FPM-08 STS-030)	J. P. B. Vreeburg
75.	Convection Experiment (STS-032)	D. Moul and M. Kedzierski (student)
76.	Terminal Velocity Experiment (STS-032)	J. Rice, B. Kline (students)
77.	Liquid Sloshing Experiment (STS-032)	M. Thames and J. Bieber
78.	Boundary Layer Convection (TEM 06-1 TEXUS 1, 2, 11)	R. Bruckner, H. Christ
79.	Wetting Kinetics (TEM 06-2 TEXUS 2, 3, 3b, 5)	P. J. Sell, D. Renzow
80.	Marangoni Convection in Float Zones (TEM 06-4 TEXUS 3, 3b)	Ch. Chun, W. Wuest
81.	Soldering of Sn-Ag Between Cu Tubes (TEXUS 5)	T. Carlberg
82.	Immiscible Alloys (TEXUS 5)	H. Fredriksson
83.	Effects of Surface Tension Minimum on Thermocapillary Convection (TEM 06-6 TEXUS 8)	J. C. Legros, G. Petre

84.	Maximum Injection Rate in a Floating Zone (TEM 06-9 TEXUS 10, 12)	I. Martinez, A. Sanz
85.	Floating Zone Experiments with Germanium Crystals (TEXUS 12)	T. Carlberg
86.	Unidirectional Solidification of Zn-Bi Samples (TEXUS 12)	H. Fredriksson
87.	Three-Dimensional Marangoni Convection (MASER 1)	Dr. Lichtenbelt

PREVIOUS FLIGHT TIMELINE

FLIGHT	DATE
Apollo 14	Feb. 1971
Skylab 3	included Sept. 1973
Skylab 4	Nov. 1973-Feb. 1974
ASTP	July 1975
STS-004 (Launch #4) (OFT-4 Columbia)	June 1982
STS-005 (Launch #5) (31-A Columbia)	Nov. 1982
STS-007 (Launch #7) (31-C Challenger)	June 1982
STS-009 (Launch #9) (41-A Columbia Spacelab 1)	Nov. 1983
STS-011 (Launch #10) (41-B Challenger)	Feb. 1984
STS-013 (Launch #11) (41-C Challenger LDEF)	Apr. 1984
STS-014 (Launch #12) (41-D Discovery)	Aug. 1984
STS-017 (Launch #13) (41-G Challenger)	Oct. 1984
STS-023 (Launch #16) (51-D Discovery)	Apr. 1985
STS-025 (Launch #18) (51-G Discovery)	June 1985
STS-026 (Launch #19) (51-F Challenger Spacelab 2)	July 1985

STS-030 (Launch #22) (61-A Challenger Spacelab D1)	Oct. 1985
STS-032 (Launch #24) (61-C Columbia)	Jan. 1986

TITLE: Thermal and Solutal Convection During Solution Crystal Growth in a Low-g Environment

INVESTIGATORS: Dr. Roger L. Kroes - PI
Dr. Donald A. Reiss - Co-I

OBJECTIVES: To evaluate solution crystal growth under controlled conditions in a low-gravity environment.

- Measure thermal convection.
- Evaluate transport mechanism of solute to crystal interface.
- Compare diffusive transport versus convective mixing and transport as controlling factors in solution crystal growth.

APPROACH:

Crystalline material will be placed at opposite ends of a chamber across which a temperature gradient is imposed. One end will be undersaturated, causing the crystalline material to dissolve, forming a boundary layer of high concentration. The other end will be cooled to supersaturation, causing the crystal to grow and a concentration depletion region to form. Mass transport through the temperature and concentration gradients will be observed. The crystals will be aluminum alum, $KAl(SO_4)_2 \cdot 12H_2O$. The source crystal will be heavily doped with chromium, giving it a dark purple color. The seed crystal at the growth end will be pure aluminum alum, which is transparent and colorless. The growth solution will be an aqueous solution of aluminum alum which is also transparent and colorless.

REQUIREMENT FOR GLOVEBOX:

Because dissolution or growth of the crystalline material in the ends of the cell will occur as soon as it is put in contact with the solution, the cell must be filled on orbit, immediately before the start of the experiment. The glovebox will be used to contain any liquid that may escape from the cell or fill tube during the filling procedure. This liquid is not hazardous to the crew, but it could damage sensitive electronic equipment.

TITLE: Nucleation of Crystals from Solutions in a Low-g
Environment

INVESTIGATORS: Dr. Roger L. Kroes - PI
Dr. Donald A. Reiss - Co-I

OBJECTIVES:

To investigate the behavior of supersaturated solutions and the initiation of nucleation in a low-gravity environment.

APPROACH:

Solutions of potassium alum, $KAl(SO_4)_2 \cdot 12H_2O$, will be placed in a cell with four separate chambers. Each of the first three chambers will have a different mechanism for initiating nucleation. These will be a stirrer, a vibrating needle, and a cold finger. The fourth chamber will be a control. The desired supersaturation will be achieved by adjusting the temperature of the solution. After activating the nucleation initiators, the crystals will be allowed to grow until they are large enough for analysis, at which time they will be withdrawn and stored. Several runs at different supersaturations will be made.

REQUIREMENT FOR GLOVEBOX:

The cell will be filled on orbit, immediately before the start of the experiment, to prevent nucleation due to storage. At the end of each run the chambers will be opened to allow crystal withdrawal. The glovebox will be used to contain any liquid that may escape from the cell or fill tube during these procedures. This liquid is not hazardous to the crew, but it could damage sensitive electronic equipment.

TITLE: Rayleigh Instability in Phase Separation

CONTACTS: Dr. D. O. Frazier and B. R. Facemire

OBJECTIVE: Investigate the influence of Rayleigh instability on phase separation of two phase systems

APPROACH: The experiment will use a two-component system containing a miscibility gap, such as succinonitrile/water. Several transparent tubes ranging in diameter and with different wetting characteristics will each contain a different composition. The samples will be heated above the miscibility gap, shaken, and then cooled yielding various volume fractions of the two liquid phases. The separation of the phases will be recorded photographically.

GLOVEBOX CAPABILITY USED: Containment

REQUIREMENTS:
- Power to heat samples
- Temperature control and monitoring
- Ability to observe samples
- Photography (16 mm movie or, preferably, video)

BACKGROUND: When a binary solution with a miscibility gap is quenched from the homogeneous region into the two phase region, the separation of the phases is controlled by several phenomena. The morphology of the final ingot is determined by the nature of and the interaction between these phenomena. Experiments with neutrally buoyant systems and rapid quench experiments in the KC-135 indicate that the dispersed phase migrates in the thermal gradient to the center of the container where the resulting column of second phase breaks up due to Rayleigh instability. The absence of sedimentation in low-g would allow for performing this experiment without precise controls on the temperature and composition (required for maintaining equal density phases in 1-g). The quantity of second phase available to migrate and subsequently the degree of droplet formation from the column are influenced by the wetting characteristics of the container.

This experiment will give more reliable data on the magnitude of the separations effected by these phenomena.

TITLE: A Definitive Test of Cahn's Critical Wetting Theory

CONTACTS: Dr. D. O. Frazier and B. R. Facemire

OBJECTIVE: To perform a definitive experiment which would test the effect of container material on the applicability of Cahn's Critical Wetting Theory.

APPROACH: Containers will be selected which have different wetting characteristics relative to the two liquid phases. Wetting will be varied from totally nonwetting by one phase to totally nonwetting by the other. The shape and position of each phase and the interface between phases will be observed and recorded photographically.

GLOVEBOX CAPABILITY USED: Containment

REQUIREMENTS: Power to heat samples
Temperature control and monitoring
Ability to observe samples
Photography (35 mm or, preferably, video)

BACKGROUND: Cahn's theory of Critical Wetting is widely used in studies of two phase systems. However the interpretation of the theory is not universally accepted by all researchers. Therefore, an experiment which would clarify the conditions of critical wetting would be of significant benefit.

In his work on critical wetting, Cahn states that his theory applies only in the absence of long range forces at the third phase surface (container or surrounding vapor). Since adsorption may be long range, depending on strength of affinities, we interpret this to mean that any container which is strongly wet by one phase of the other really does not meet the criteria for critical wetting as stated by Cahn. By varying the wettability of the container from wetting by each of the phases to nonwetting (for example using a teflon container with succinonitrile/water) a definitive experiment which would test this widely debated theory could be performed.

EXPERIMENT TITLE: Container Effects on Diffusion

CONTACTS: Dr. D. O. Frazier and B. R. Facemire

OBJECTIVE: Verify the reported result from Skylab 3 that the shape of a diffusion front is influenced by interaction of the diffusing material and/or the matrix fluid with the walls of the container

APPROACH: Several transparent tubes will be filled with water and equipped with gate valves. This will allow introduction of a plug of water/dye solution. The tube characteristics (wettability, surface charge, diameter, etc.) will be selected based on known interactions with water and the selected dye material. Photography will record the shape of the diffusion front with time.

GLOVEBOX CAPABILITY USED: Containment

REQUIREMENTS:
Temperature control and monitoring
Ability to observe samples
Intermittent photography (35 mm still...time recorded)
Several days (2-5) quiescent period

BACKGROUND: An early science demonstration on Skylab 3 which looked at diffusion of tea in water indicated that there may be an influence of the container on the diffusion rate. In this demonstration the diffusion front appeared to be retarded at the container walls in that the front was observed to be "bullet shaped." This result, if verified, would be of critical importance to any experiment in which mass diffusion near a wall is involved. Experiments such as ones involving crystal growth from the vapor or from a contained melt could be strongly influenced by this effect.

EXPERIMENT TITLE: Ostwald Ripening Drop Deployment Test

CONTACTS: Dr. D. O. Frazier and B. R. Facemire

OBJECTIVE: To test methods of deploying a matrix of drops of varying sizes of one fluid phase into another

APPROACH: Several test cells (2-4 of the most promising configurations as determined by ground tests) will contain one phase of a transparent binary miscibility gap system. Each cell will be equipped with a matrix of syringes which have been treated to give varying wettability to the second phase contained in the syringes. Activation of an injection mechanism will deploy the second phase drops into the matrix fluid. The effectiveness of each configuration/syringe will be assessed by observation of the deployed drops.

GLOVEBOX CAPABILITY USED: Containment

REQUIREMENTS: Power to maintain test cells at a constant temperature
Temperature control and monitoring
Ability to observe samples
Photography (16 mm movie or preferably video)

BACKGROUND: One technique proposed to form an array of droplets for Ostwald Ripening studies in low-g is to inject them using syringes. Previous experiments which used syringes to deploy liquid were plagued with problems related to wetting of the fluid and the needle. Since the Ostwald Ripening studies involve injecting one fluid in another, the wetting characteristics of each fluid relative to the needle material becomes important. Methods of effectively deploying and maneuvering fluid drops must be developed for this experiment.

EXPERIMENT TITLE: Thin Film Deposition Experiment

CONTACTS: Dr. D. O. Frazier and B. R. Facemire

OBJECTIVE: To test the film thickness homogeneity of low-g deposited films

APPROACH: Perform an experiment designed to deposit a thin film of a nonlinear optic material on a substrate(s). The returned substrate(s) will be analyzed for uniformity, morphology, and non-linear optical properties.

GLOVEBOX CAPABILITY USED: Containment

REQUIREMENTS: Power for establishing the thermal gradient for growth
Temperature control and monitoring
Return of samples

BACKGROUND: Uniform films of nonlinear optic materials are required for many device applications. Since convection in the vapor is greatly reduced in low-g, a properly designed deposition apparatus should be limited by mass transport and thus give more uniform coatings than in 1-g.

EXPERIMENT TITLE: Thermosolutal Convection due to Heating Perpendicular to a Concentration Gradient

CONTACTS: Dr. D. O. Frazier and B. R. Facemire

OBJECTIVE: To study the magnitude and relative importance of solutal effects on convection in the absence of gravity

APPROACH: A concentration gradient will be established in a transparent test cell. Heat will be applied such that a thermal gradient is perpendicular to the concentration gradient. The resulting convection patterns will be visualized by using tracer particles and/or by shadowgraph and recorded photographically.

GLOVEBOX CAPABILITY USED: Containment

REQUIREMENTS: Transfer of fluids
Power for heating
Temperature control and monitoring
Ability to observe test cell
Photography (16 mm movie or preferably video)
Shadowgraph optics if possible

BACKGROUND: When a test cell containing a concentration gradient is heated perpendicular to the gradient on Earth, bands of convection are formed within the layers of varying concentration. These convection bands result from the interplay of gravity driven convection, density gradients, and solutal effects. Removing the influence of gravity would give useful data on the magnitude and relative importance of the other convective driving forces.

TITLE: Slip Coefficients Measured along Gas-Liquid and Gas-Solid Interfaces

INVESTIGATORS:

Dr. David A. Noever
Dr. Franz E. Rosenberger

OBJECTIVE:

The experiments will examine a series of vapor transport properties measured along solid and liquid interfaces. It will determine:

- the coefficient of slip between differing phases found to a fine precision (10^{-7} cm.), such that results can distinguish definitively between various theories for kinetics, molecular dynamics and cosmic dust settling

- the coefficient of diffusive reflection, such that results can predict the dominant surface effects, either specular or diffusive reflection, in solids crystallized from the vapor

APPROACH:

The experiment will use the classic technique owing to R. Millikan (a version of the oil drop method) in which charged droplets are electrostatically suspended between plates of differing potentials. The principal limit to collecting good earth-bound data continues to stem from convective and molecular inhomogeneities found in the gas.

REQUIREMENTS FOR THE GLOVEBOX:

The project will require: 1) two metal plates capable of supporting a constant (=1%) and variable voltage difference and total voltage of up to 10 Volts (this can either be supplied from the spacecraft or battery packs, and optimally, all voltages should be adjustable); 2) optical viewing system capable of both still and motion photography, low heat lighting and high resolution film; 3) equipment to insert and center droplets (e.g., needle injection).

TITLE: Solder Adhesion, Durability and Removal

INVESTIGATORS: C. A. Winter (NASA Marshall Space Flight Center, Huntsville, AL) and N. Ramachandran (University Space Research Association (USRA), NASA Marshall Space Flight Center, Huntsville, AL)

OBJECTIVES:

On board a manned space facility, repairs of failing circuitry during prolonged missions are anticipated. In this demonstration solder adhesion, durability and removal are examined.

APPROACH:

In a simple demonstration, a battery/light bulb(or LED) arrangement is created via soldering connections. Four soldering connections are required, 2 at the light socket, and one each at the positive and negative terminals of the battery compartment. Once the soldering is completed, the battery and bulb are inserted, and the circuitry is tested for continuity and durability. Continuity is demonstrated if the light shines on, durability is demonstrated by applying hand agitated tension on the wire. Different solders, with and without resin core can be tested for wetting and surface tension properties on several types of metallic connections. In addition, soldering tips to control solder flow at the tip can be employed to prevent fluid flow up the iron. In the space environment where gravitational forces are reduced, surface tension forces will dominate the solder flow, and the solder will tend to flow from an area of hot to cold, possibly up the iron, and not to the circuitry of interest. Different thicknesses of solder can be tested, and their adhesion properties examined. Removal of the solder after connections are achieved should also be examined. When re-heated, solder removal would be attempted by suction, sponge wiping or other means. Small, battery operated computer keyboard vacuums may prove to be an effective suction device. Application and removal of solder from a printed circuit board would also be tested. Some preliminary soldering demonstrations, which have been completed in unmanned Getaway special canisters (see for example, ref. 1) will lend insight into solder behavior and appropriate solder choice.

Because improved capability semiconductors may be a product of the space facility, a circuit which completes an audio amplifier may represent a more typical space laboratory need for soldering connections. In this configuration, an audio oscillator powered by a small battery acts as input to a silicon amplifier. The amplified signal is then examined by an oscilloscope for improved performance. In this more realistic scenario, several connections are required to test the amplified signal. First the audio oscillator is connected without the amplifier, to examine the resultant signal. Then, the audio oscillator is disconnected from the oscilloscope and now connected to the amplifier. In turn, the amplifier is connected to the oscilloscope and the improved signal examined. Similar testing of soldering adhesion, durability and removal as outlined above are possible.

TITLE: Liquid Spreading/Liquid Injection Techniques

INVESTIGATORS: C. A. Winter (NASA Marshall Space Flight Center, Huntsville, AL) and
N. Ramachandran (University Space Research Association (USRA), NASA Marshall Space Flight Center, Huntsville, AL)

OBJECTIVES:

Low gravity fluid wetting properties of a fluid to a solid surface have generated much concern in the formation of liquid bridges, maintenance of floating zones, completion of soldering connections, lubrication of ball bearings, injection of fluid through hypodermic needles, etc. For example, During Skylab liquid bridge experiments, suspending disk edges were wetted by the bridge fluid, distorting the resultant bridge shape. (2) In an effort to alleviate this affect, Krytox grease was applied to control the wetting. In the TEXUS 12 experiments of Martinez, (3) during which silicon oil bridges were created, aluminum disks with rims cut back at a 45 degree angle helped to anchor the fluid to the disk. Reference (4) describes two liquid bridge experiments during Spacelab 1 during which the test fluid overan the disk edge even though the disks were treated with an anti-spread barrier. An outline of the kinetics of spreading liquids in microgravity are outlined in reference (5).

Control of the spreading of the liquid over several metal, plastic, glass and fluid surfaces will be examined. The capability of the small, battery operated computer keyboard vacuum used in the soldering experiment, may prove to be an effective cleanup device for small fluid spills. Because the creation of a liquid bridge is desired during the next glove box experiment, much attention will be placed on controlling fluid spreading over several small discs which could eventually act as end plates for the circular cylinder liquid zone.

APPROACH:

Several types of materials, including aluminum, pyrex, steel, teflon, etc. will each be fashioned into specialized small round discs. The spreading nature of two fluids, water and silicon oil will be examined over the disc surfaces. Injection of the liquids via a hypodermic needle will be examined. In addition, injection of liquids through the plastic syringe will also be examined. These injection mediums may also have to be treated with anti spreading materials or methods. Fluid motion barriers such as disk circumference lubrication, disk circumference angling, etc. will be examined. If spreading over the disk is effectively controlled, these discs will be candidates for the following float zone ex-periments of the next section. Rate of spreading, surface shape change, and liquid thickness will also be examined.

TITLE: Absorption of a Sponge in Space

INVESTIGATORS: C. A. Winter (NASA Marshall Space Flight Center, Huntsville, AL) and N. Ramachandran (University Space Research Association (USRA), NASA Marshall Space Flight Center, Huntsville, AL)

OBJECTIVES:

Clean up of spilled liquids in space may prove to be a difficult procedure. Sponging and foam, employed during the soldering and liquid zone experiments detailed before, will be examined for absorption characteristics.

APPROACH:

Small sections of the foaming, each with a different porosity size will be inserted into petri dishes partially filled with colored water, and their absorption characteristics examined. Extent of absorption will be discerned by the distribution of color within the sponge. Sponge absorption might also be tested if spills from the liquid spreading/ liquid injection experiment require cleanup.

TITLE: Liquid Stability /Vibration Isolation Techniques

INVESTIGATORS: C. A. Winter (NASA Marshall Space Flight
Center, Huntsville, AL) and
N. Ramachandran (University Space Research
Association (USRA), NASA Marshall Space
Flight Center, Huntsville, AL)

OBJECTIVES:

A reduction in gravity, while tending to eliminate buoyancy-driven convection, also results in the reduction of hydrostatic pressure. Such a reduction in pressure prevents liquid in a float zone situation from deforming under its own weight and allows longer, more stable zones to be formed. From these zones larger crystals can be solidified. Several space investigations have examined the float zone setup. This simple experiment will investigate some of the common difficulties in creating and maintaining the bridge, examine the length limit at which the zone still remains a right circular cylinder (the Rayleigh limit), observe the convective flow due to surface tension driven gradients, and discern the stability of the zone to imposed disturbances.

APPROACH:

A liquid column suspended between two circular disks is created by one of two methods. In the first method, a liquid column will be maintained within the confines of a micrometer measuring device. Discs from the liquid spreading/liquid injection experiment which demonstrated good fluid control will be employed as zone end plates and are attached to the micrometer " measuring fingers" (or contact points).

When there is no separation between the micrometer contact points, the disks will be side by side (touching). When the disks are separated by the manual smooth rotation of the micrometer screw, a drop of liquid placed between the disks with the injection devices outlined above, should allow wetting of both end discs. Slow separation of the discs allows a float zone to form. The Rayleigh limit of liquid zones can be exmined. Measurement of the zone length is made especially easy by reading the value off the micrometer. A photograph showing a metric scale as well as the liquid bridge will allow subsequent zone radii determination.

In the second method, a liquid zone is created by melting a solid cylinder of paraffin (or solder) between two soldering irons. (The irons are available from the soldering experiment outlined above). This technique (melted wax between soldering tips) has been successfully created before in a Getaway Special Canister on the space shuttle. (6). As noted during that experiment, melting of the solid wax allows examination of a phase change and the re-solidification of the wax allows the flow field to be preserved. The Separation of the two irons allows the Rayleigh limit to once more be examined. Marangoni flow of the paraffin bridge can be examined by introducing small dust particles at the liquid wax free surface. More sophisticated measurements of this flow may be worth pursuing.

Stability of the bridge (either method) can be examined with and without external zone excitation. An accelerometer placed in the glove box will provide measurement of the imposed disturbance field. Foam/sponging of different pore size and characteristics (also remaining from the soldering and sponge absorption experiments), placed about the cylindrical column setup can act as a passive isolator. The resultant fluid motion can be examined. Hand agitated impulse disturbances to the column setup with and without the passive isolator will allow examination of column stability. A series of planned astronaut motions outside the box will also allow observation of column stability to typical disturbances. An additional external disturbance produced by the audio oscillator (previously employed for the soldering experiment) now implemented with a microphone, may be possible and could warrant investigation. Implementation of the zone setup with a commercial isolation system would be most beneficial if the size of the glove box allows such implementation. However, simple passive isolation techniques may prove to be sufficiently advantageous over an expensive commercial isolation system.

A clear box, partially filled with liquid would also be a simple setup for examining the stability of a free surface to external and spacecraft imposed disturbances. Current research analysis examining the stability of both liquid columns and box free surfaces have been initiated under the Vibration Isolation Advanced Technology Development (ATD) work at MSFC. Such experimentation would aid this research as well as comprise basic information on isolation techniques, the effects of disturbances on the liquid column, etc. Data correlation of fluid stability to imposed accelerometer data would also be possible.

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TITLE: Rotating Fluid Surface Behavior In Low Gravity

INVESTIGATORS: Dr. Fred W. Leslie, ES42
Dr. Ru Hung, UAH

OBJECTIVES:

One way to control large amounts of liquid in near Earth orbit is to rotate the container, holding the liquid against the outer wall. In many applications it is important not only to know where the vapor is, but to know that it is symmetrically distributed. Of particular interest is the shape and stability of a free surface in contact with boundaries. Both of these phenomena are controlled by the magnitude of the surface tension, the centrifugal force and to a lesser extent the low gravity. An equation for the equilibrium shape of the bounded interface was derived using LaPlace's relation between the pressure drop across the interface and its total curvature. In an effort to verify to the solutions, small partially filled cylinders could be rotated about its axis in the glove box and its interface shape recorded on video. The small cylinders could be made of plexiglass and contain air and ethanol. They could be rotated with a simple pull string while the spin-down could be controlled with drag cups. This investigation is similar to the investigations of Veldman and Vreeburg on Spacelab-1 and D-1, except that some containers would also have baffles to evaluate their stabilizing effect. Their analysis shows no development of inertial oscillations for the spin-down case while our numerical model does.

An analytical formulation of the stability of the equilibrium configuration showed under what conditions the interface would be unstable to perturbations which excite inertial-capillary waves. One result for a rapidly rotating cylinder was that nonaxisymmetric disturbances (e.g. azimuthal waves) are stable. This simple glovebox experiment could help resolve these issues.

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TITLE: Bearing Strength of Granular Materials in Low-g Environment

INVESTIGATORS: Dr. Nicholas C. Costes, PI
Dr. M. Monte Mehrabadi, Co-I

OBJECTIVES:

To determine the resistance to penetration and load bearing strength of granular materials of given gradation, packing characteristics and consistency in a low-g environment.

APPROACH:

Penetration resistance tests will be performed on granular material specimens inside the "glovebox". The specimens will be prepared in rectangular lexan containers in terrestrial laboratories and placed in the glovebox prior to launching. The number, type and consistency of the specimens will be determined for optimum results during the definition phase of the glovebox experiment. The penetration resistance tests will be performed by portable, hand-held, spring-loaded, "pocket-type" soil penetrometers having conical and/or flat-ended circular tips of different sizes and stored inside the glovebox. If feasible, rectangular bearing plates with large length-to-width ratio, as well as shear vanes, will be used as penetrators using appropriate, manualy operated compression apparatus attached to the glovebox. It is assumed that adequate illumination will be available inside the glovebox for the crew member to read off and record the force-deformation data obtained from these tests. Upon returning to earth, the glovebox will be transferred to a terrestrial laboratory for further observations and other diagnostic testing.

SPECIAL REQUIREMENTS:

It will be highly desirable to provide continuous coverage of each penetration test by a movie camera placed inside the glovebox with its field of view covering the test area so that the mode of deformation of the granular material during loading is discernible and the force-deformation, measurements can be read from dial gages. Otherwise, the mission specialist performing the experiment should be equipped with an audio cassette to record his measurements and observations on the mode of the specimen deformation under load.

If a capability for freezing the specimens upon the completion of each test can be provided, then it may be possible to discern the post failure fabric (or induced anisotropy) of the specimens, upon their return to earth, through tomographic techniques and/or microscopic analysis of thin sections.

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APPROVAL

CONCEPTS FOR MICROGRAVITY EXPERIMENTS UTILIZING GLOVEBOXES

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The information in this report has been reviewed for technical content. Review of any information concerning Department of Defense or nuclear energy activities or programs has been made by the MSFC Security Classification Officer. This report, in its entirety, has been determined to be unclassified.

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