

OAST Technology For the Future

Volume I—Experiment Descriptions

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NASA

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IN-SPACE TECHNOLOGY EXPERIMENTS WORKSHOP

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Structure Automation Robotics

Environment Effect Fluid Management

Propulsion System Power Thermal

Management Integration Sensor

Information Human

IN-STEP 88 WORKSHOP

FOREWORD

At the workshop, Dr. Harrison H. Schmitt emphasized that the nations which effectively exploit the advantages of space will lead human activities on earth. The major space goal of the National Aeronautics and Space Administration's Office of Aeronautics and Space Technology (OAST) is to provide enabling technologies, validated at a level suitable for user-readiness, for future space missions in order to ensure continued U.S. Leadership in space. An important element in accomplishing this goal is the In-Space Technology Experiments Program whose purpose is to explore and validate in space advanced technologies that will improve the effectiveness and efficiency of current and future space systems. OAST has worked closely with the aerospace community over the last few years to utilize the Space Shuttle, expendable launch vehicles, and, in the future, the Space Station Freedom for experimentation in space in the same way that we utilize wind tunnels to develop aeronautical technologies. This close cooperation with the user community is an important, integral part of the evolution of the In-Space Technology Experiments Program which was originated to provide access to space for technology research and experimentation for the entire U.S. aerospace community.

On December 6 through 9, 1988, almost 400 researchers, technologists, and managers from U.S. companies, universities, and the government participated in the OAST IN-STEP 88 Workshop. The participants reviewed the current in-space technology flight experiments, identified and prioritized the technologies that are critical for future national space programs and that require verification or validation in space, and provided constructive feedback on the future plans for the In-Space Technology Experiments Program. The attendees actively participated in the identification and prioritization of future critical space technologies in eight major discipline theme areas. These critical space technologies will help focus future solicitations for in-space flight experiments. The material within these four volumes is the culmination of the workshop participants' efforts to review the planning for the future of this program.

Dr. Leonard Harris
Chief Engineer
Office of Aeronautics and
Space Technology, NASA

IN-REACH/OUT-REACH EXPERIMENTS AND EXPERIMENT INTEGRATION PROCESS

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IN-REACH/OUT-REACH EXPERIMENTS AND EXPERIMENT INTEGRATION PROCESS

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INTRODUCTION TO VOLUME I

NASA's Office of Aeronautics and Space Technology (OAST) conducted a workshop on the In-Space Technology Experiments Program (IN-STEP) December 6-9, 1988, in Atlanta, Georgia. The purpose of this workshop was to identify and prioritize space technologies which are critical for future national space programs and which require validation in the space environment. A secondary objective was to review the current NASA (In-reach) and Industry/University (Out-Reach) experiments. Finally, the aerospace community was requested to review and comment on the proposed plans for the continuation of the In-Space Technology Experiments Program. In particular, the review included the proposed process for focusing the next experiment selection on specific, critical technologies and the process for implementing the hardware development and integration on the Space Shuttle vehicle. The product of the workshop was a prioritized listing of the critical space technology needs in each of eight technology disciplines. These listings were the cumulative recommendations of nearly 400 participants, which included researchers, technologists, and managers from aerospace industries, universities, and government organizations.

The identification and prioritization of the critical space technology needs were initiated by assigning NASA chairpersons (theme leaders) to the eight major technology disciplines or themes requiring consideration. These themes were as follows:

- space structures
- space environmental effects
- power systems and thermal management
- fluid management and propulsion systems
- automation and robotics
- sensors and information systems
- In-space systems
- humans in space

In order to provide further structure within each theme, the chairpersons divided their themes into three theme elements each. The theme element concept allowed focused technical discussions to occur within the broad discipline themes. For each theme element, the theme leader selected government, industry, and university experts to present the critical space technology needs of their respective organizations. The presentations were reviewed and discussed by the theme audiences (other members of the aerospace community), and prioritized lists of the critical technologies which require verification and validation in space were established for each theme element.

The comments and conclusions for each theme were incorporated into a summary listing of the critical space technology needs and associated flight experiments representing the combined inputs of the speakers, the audience, and the theme leader. The critical space technology needs and associated space flight experiments identified by the participants provide an important part of the strategic planning process for space technology development and provide the basis for the next solicitation for space technology flight experiments. The results of the workshop will be presented to the IN-STEP Selection Advisory Committee in early 1989. This committee will review the critical technology needs, the funding available for the program, and the space flight opportunities available to determine the specific technologies for which space flight experiments will be requested in the next solicitation .

These proceedings are organized into an Executive Summary and three volumes: Executive Summary; In-Reach/Out-Reach Experiments and Experiment Integration Process (Volume I); and Critical Technology Presentations (Volumes II and III).

Volume I contains brief overviews of the objectives, technology needs and backgrounds, descriptions, and development schedules for current industry, university, and NASA space flight technology experiments. This was a very important part of the workshop, providing an opportunity for the aerospace community to interact with experimenters and provide feedback on the flight experiments. Presentations describing the experiment integration process are also included in this volume.

IN-REACH/OUT-REACH EXPERIMENT PRESENTATIONS

1. SPACE STRUCTURES

SPACE STRUCTURES	IN-SPACE TECHNOLOGY EXPERIMENTS WORKSHOP DECEMBER 6-9, 1988	STRUCTURES

IN-SPACE STRUCTURAL DYNAMICS EVALUATION OF A SKEWED SCALE TRUSS

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**Contract NAS1-18688
NASA Langley Research Center
Stanley E. Woodard**

OUTREACH	IN-SPACE STRUCTURAL DYNAMICS EVALUATION OF A SKEWED SCALE TRUSS	MDAC

EXPERIMENT OBJECTIVE

Define a flight experiment for a hybrid scaled truss in the Orbiter's cargo bay. This experiment may be used to :

- Validate analytical techniques for predicting nonlinear dynamic behavior in truss structures
- Validate Hybrid Scale theory
- Validate 1g ground test techniques
- Address other technology issues

OUTREACH	IN-SPACE STRUCTURAL DYNAMICS EVALUATION OF A SKEWED SCALE TRUSS	MDAC

BACKGROUND/TECHNOLOGY NEED

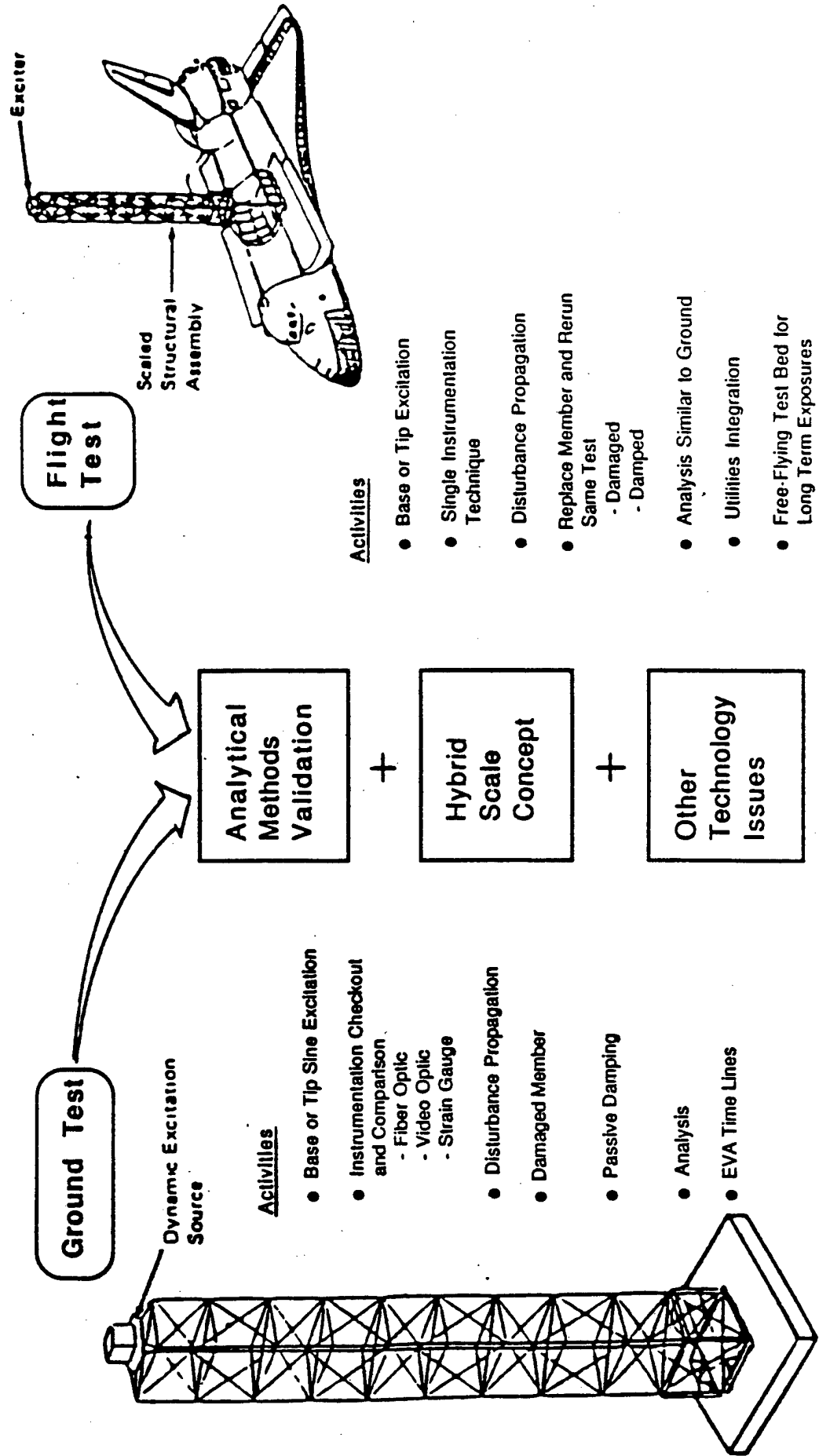
- Many space truss structures envisioned for the future will be too large to dynamically test in full-scale on the ground
- Truss joints can dominate dynamic behavior and are not easily scaled due to their complexity
- Nonlinear characteristics in joints, such as free play, nonlinear stiffness, damping, and friction can only reasonably be simulated in a 0g space environment
- Analytical methods for predicting nonlinear behavior and damping need to be validated
- A hybrid scaled truss with full-size joints and subscale struts offers a smaller, more manageable structure for dynamic testing on the ground and in space. The truss will be used to validate analytic predictive methods, ground test techniques, the hybrid scale concept, and investigate other important technology issues.

OUTREACH	IN-SPACE STRUCTURAL DYNAMICS EVALUATION OF A SKEWED SCALE TRUSS	MDAC

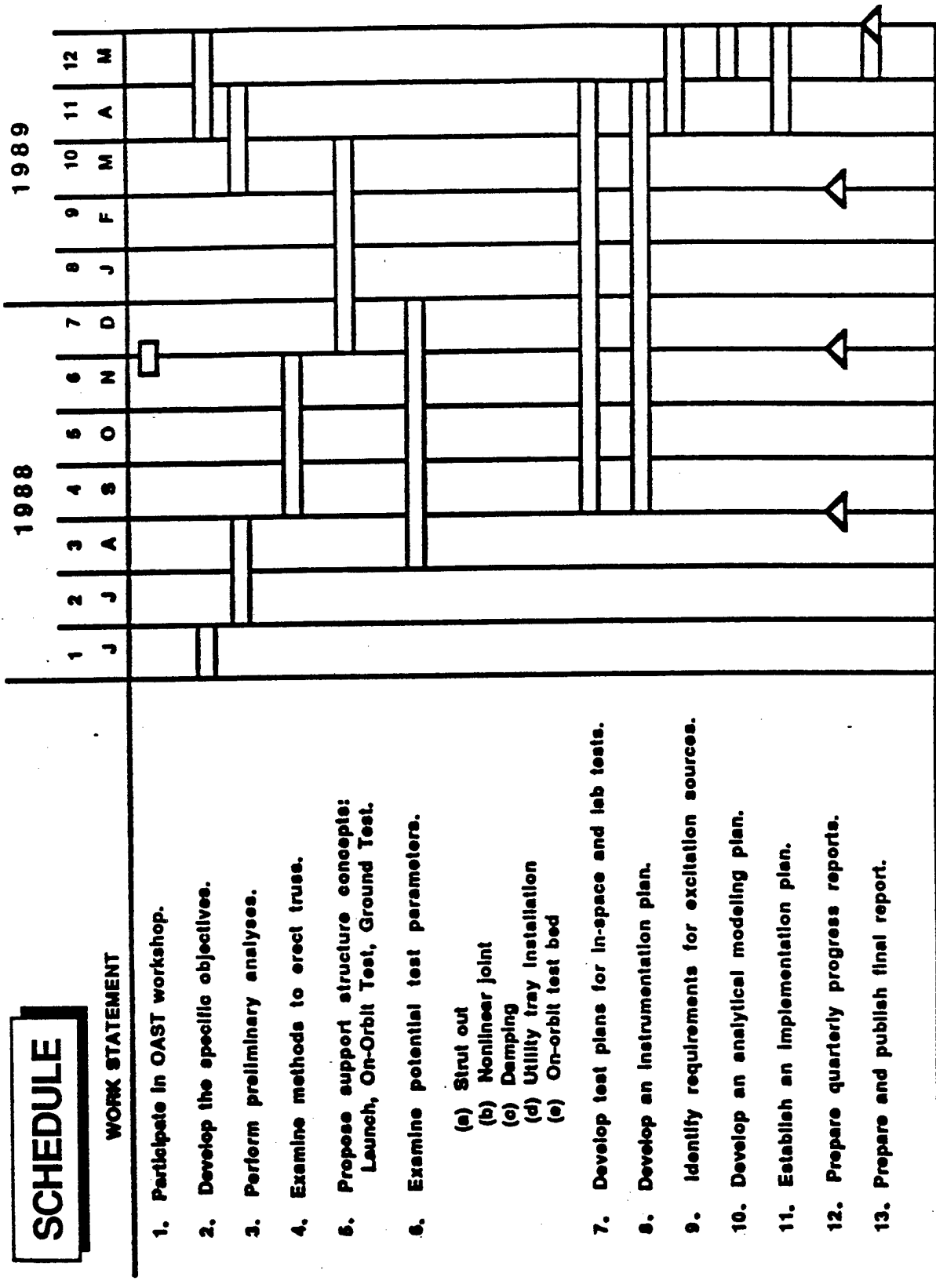
EXPERIMENT DESCRIPTION

- 1g ground test multi-bay erectable truss with short struts and full-size joints (Hybrid Scaled)
- 0g flight test truss and correlate with ground test results
- Validate analytical predictive techniques for nonlinear response and damping
- Investigate other technology issues
 - Instrumentation performance
 - Disturbance propagation
 - Damaged or damped members
 - Utilities/payload integration
 - EVA time lines
 - Long-term exposure test bed

EXPERIMENT DESCRIPTION



OUTREACH	IN-SPACE STRUCTURAL DYNAMICS EVALUATION OF A SKEWED SCALE TRUSS	MDAC



SPACE STRUCTURES	IN-SPACE TECHNOLOGY EXPERIMENTS WORKSHOP DECEMBER 6-9, 1988	STRUCTURES

MIDDECK 0-GRAVITY DYNAMICS EXPERIMENT (MODE)

PROF. EDWARD F. CRAWLEY
DR. DAVID W. MILLER

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MASSACHUSETTS INSTITUTE OF TECHNOLOGY

CONTACT # NAS1-18690
LANGLEY RESEARCH CENTER
DR. GARNETT HORNER

OUTREACH	MIDDECK 0-GRAVITY DYNAMICS EXPERIMENT (MODE)	SERC MIT

OBJECTIVES OF MODE

- INVESTIGATE DYNAMICS OF TWO ASPECTS OF NONLINEAR SPACECRAFT DYNAMIC SYSTEMS WHICH ARE GRAVITY DEPENDENT
 - MODE I
 - Dynamics of a partially filled fluid tank as it interacts with flexible vehicle motions.
 - Needed to verify modeling of large mass fraction fluid storage system.
 - MODE II
 - Nonlinear contribution of joints of statically indeterminate truss structure to damping and modal structure.
 - Needed to verify structural modeling techniques for use with precision/active structure.

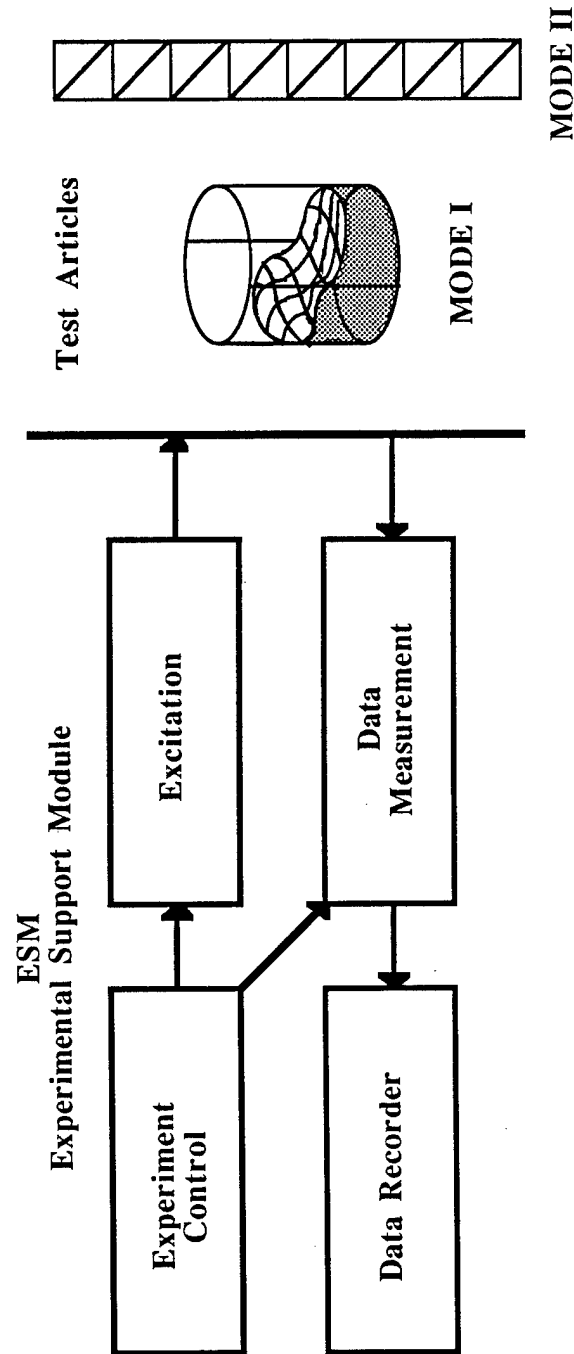
OUTREACH	MIDDECK 0-GRAVITY DYNAMICS EXPERIMENT (MODE)	SERC MIT

BACKGROUND TO MODE

- MODE I - FLUID/STRUCTURE INTERACTION
 - Linearized and nonlinear fluid models already developed consider large motion of highly curved free surface.
 - Extensive 1-g testing at M.I.T.
 - Extensive short term 0-g testing on KC-135.
 - Twenty seconds of +/- 0.02 g environment not sufficient.
- MODE II - NONLINEAR TRUSS STRUCTURE
 - Linearized and nonlinear models already developed include contribution of material damping and joint nonlinearity
 - Extensive 1-g and vacuum testing at M.I.T.
 - Short term 0-g testing in M.I.T. ASTROVAC
 - Require zero gravity pre-load/long duration to study lightly damped/on-orbit behavior

OUTREACH	MIDDECK 0-GRAVITY DYNAMICS EXPERIMENT (MODE)	SERC MIT

MIDDECK EXPERIMENT

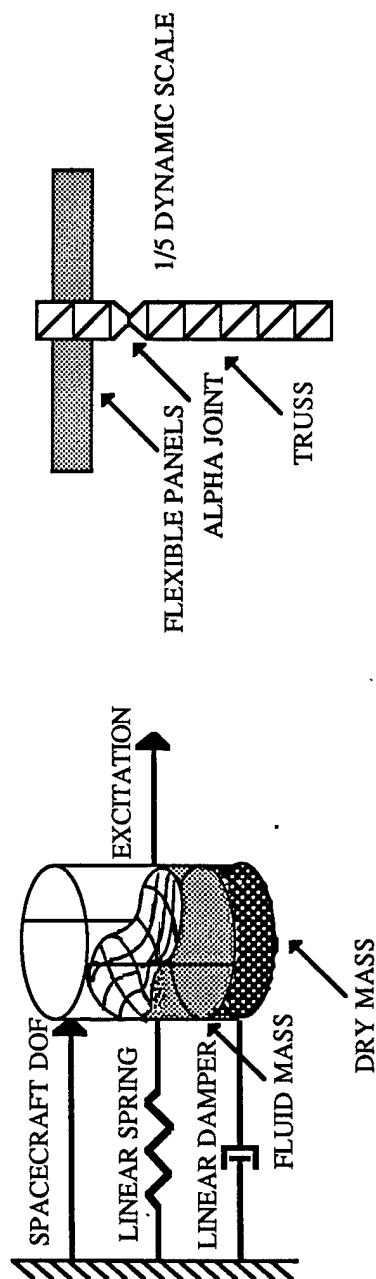


• EXPERIMENTAL HARDWARE

- ESM: Experimental support module provides capabilities typical of a dynamic test facility in single middeck locker
- Two test articles, MODE I & II, deployed and tested in Middeck.

OUTREACH	MIDDECK 0-GRAVITY DYNAMICS EXPERIMENT (MODE)	SERC MIT

TEST ARTICLES



MODE I

Cylindrical tank
coupled to a one DOF
dynamic system

MODE II

Hybrid scale model
erectable truss

OUTREACH	MIDDECK 0-GRAVITY DYNAMICS EXPERIMENT (MODE)	SERC MIT

TIMELINE

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
'88												START
'89					PFER	PDR/ FER				CDR		
'90									CREW TRAIN			
'91		PPDR			DE- LIVER		FLIGHT					
'92	FINAL REPORT	PMER										

PFER: Preliminary Flight Experiment Review
 FER: Flight Experiment Review
 PPDR: Payload Pre-Delivery Review
 PMER: Post Mission Experiment Review

OUTREACH	MIDDECK 0-GRAVITY DYNAMICS EXPERIMENT (MODE)	SERC MIT

SUMMARY

- Since each of the phenomena under study is fundamentally influenced by gravity, experiments must be done in zero gravity
- All available Earth based simulations of zero gravity have already been exploited
- These experiments compliment programs of near term interest to NASA.
- Involvement of corporate participants, Boeing Aerospace and McDonnell Douglas, assures relevance of experiment and dissemination of technology

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Space Structures	IN-SPACE TECHNOLOGY EXPERIMENTS WORKSHOP DECEMBER 6-9, 1988	Structures

Experiment Definition Phase for Measurement and Modeling of Joint Damping in Space Structures

S. L. Folkman and F. J. Redd
Center for Space Engineering
Utah State University

Contract No. NAS1-18682
NASA Langley
Center Contact: Mark Lake

OUTREACH	Measurement and Modeling of Joint Damping in Space Structures	Utah State University

Experiment Objective

The objective is to build an experiment which will measure the influence of gravity on structural damping of a truss structure.

- A three-bay subscale truss will be constructed.
- The truss and the joints used will be similar to those proposed for the Space Station.
- Ground-based testing will measure damping with 1-g loads.
- Fly as Get Away Special experiment to get micro-gravity damping.
- Results will provide qualitative data on the influence of gravity on damping.

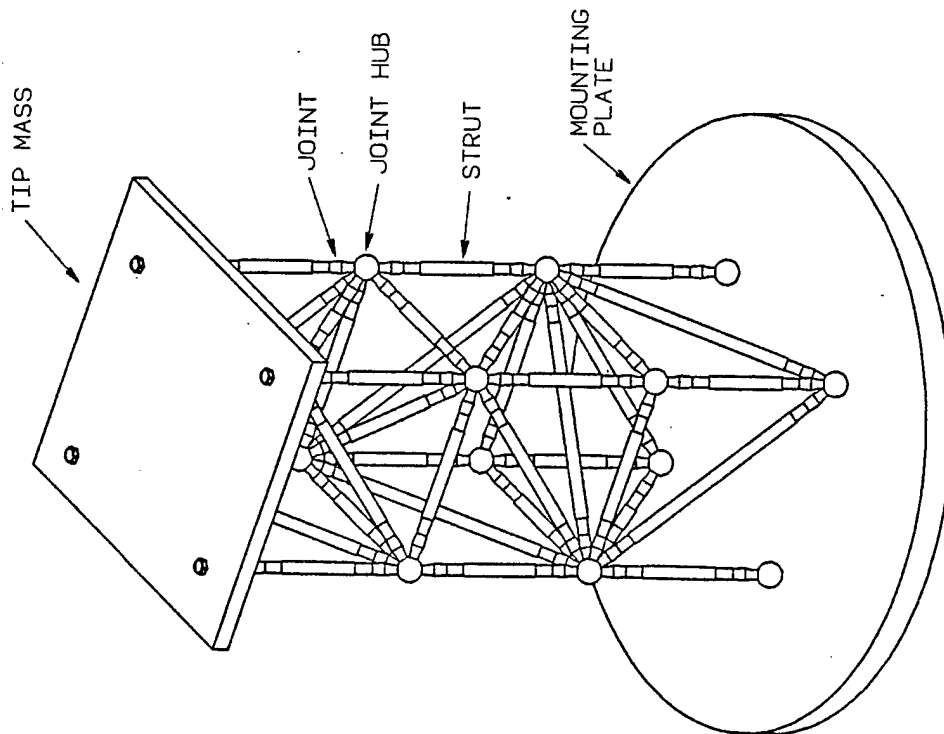
OUTREACH	Measurement and Modeling of Joint Damping in Space Structures	Utah State University

Background/Technology Need

Predicting the amount of damping expected in large space structures is expected to be difficult.

- Joints holding the structure together will produce some damping.
- The amount of damping produced by joints is dependent on several variables.
- Damping can be gravity dependent in a truss with pinned joints.
- On-ground damping measurements may be in error due to gravity loads.
- A data base of in-orbit and on-ground tests is needed to permit better predictions of damping for other structures.

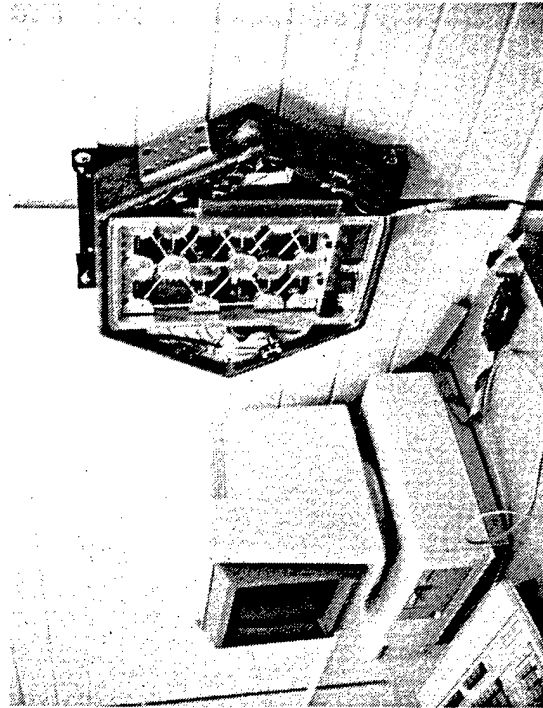
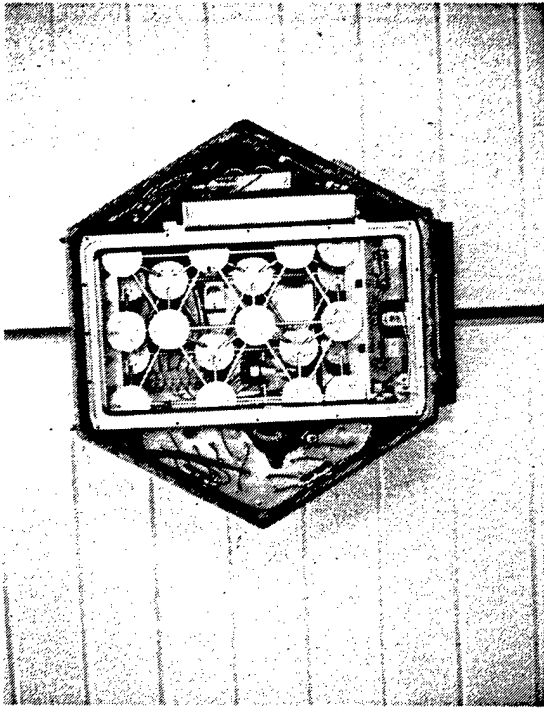
OUTREACH	Measurement and Modeling of Joint Damping in Space Structures	Utah State University



Experiment Description

The experiment consists of a three-bay truss and associated hardware for truss excitation and measurement of oscillations.

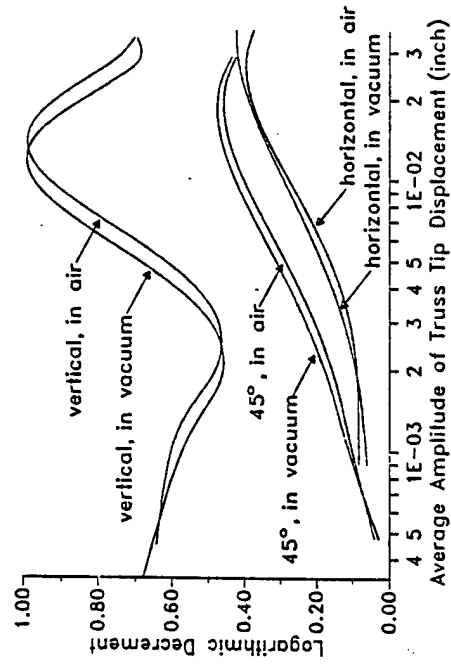
- The experiment fits inside a 5 cubic foot Get Away Special Cannister.
- Cantilevered truss with a tip mass to reduce the resonant frequency.
- Cannister vented to space to eliminate air damping.
- Truss excitation will induce bending modes in two directions or a torsional mode.
- Means for tip mass support during launch and reentry will be provided.



Previous Experiments

An experiment has been constructed to measure damping of a tetrahedral truss with pinned joints.

- One of 6 experiments to fly as a GAS Payload.
- Very small project budget.
- Damping is gravity dependent

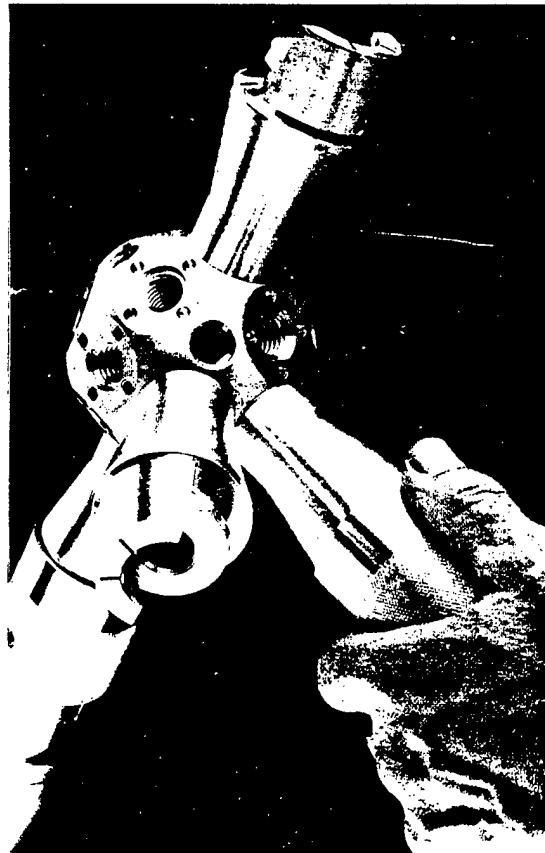


OUTREACH	Measurement and Modeling of Joint Damping in Space Structures	Utah State University

Prototype truss design

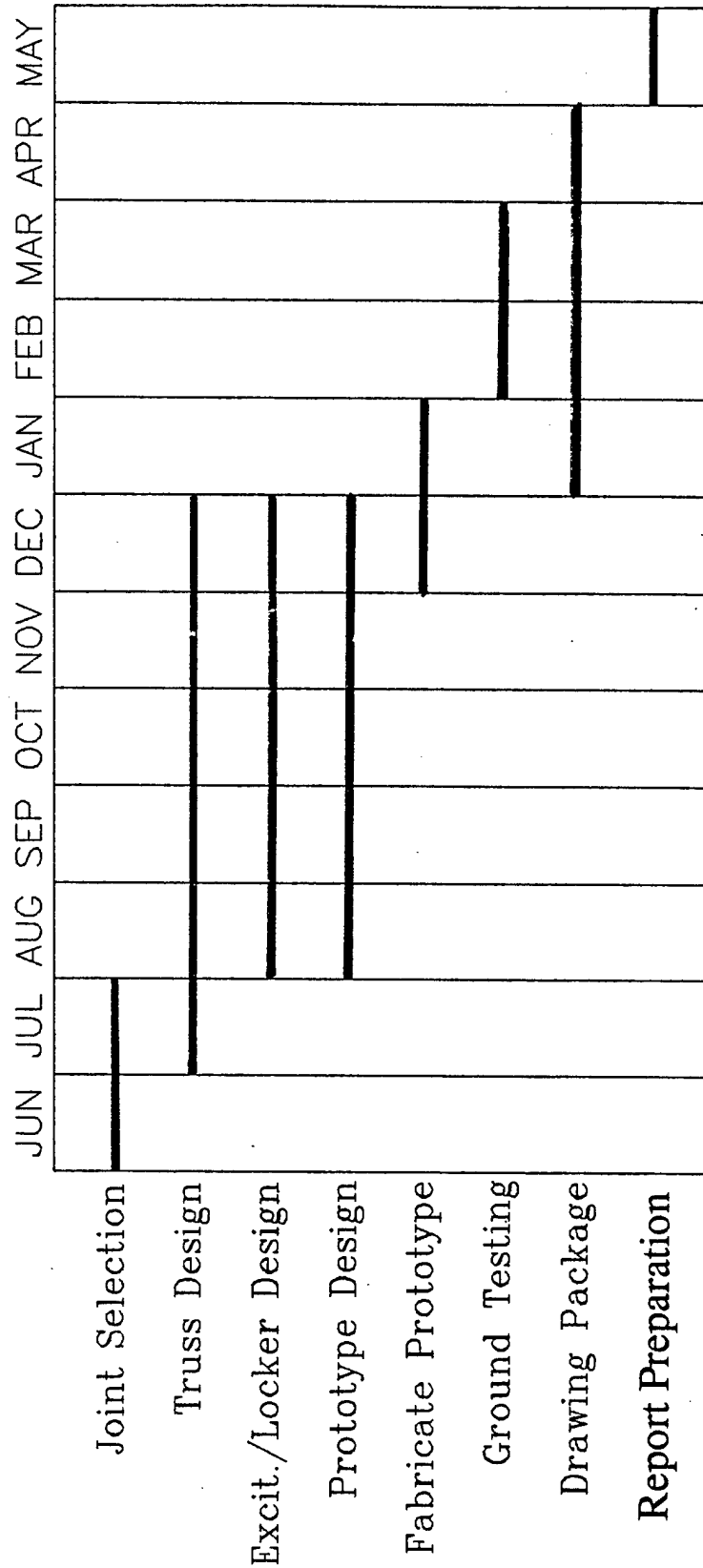
As part of the Experiment Definition Phase we are constructing a truss for ground testing.

- 3 Bay truss.
- First bay uses 1/4 scale joints made by Star*Net Structures.
- An inexpensive bolted joint is used elsewhere.
- Ground tests will examine the influence of gravity on damping.



OUTREACH	Measurement and Modeling of Joint Damping in Space Structures	Utah State University

1988-89 Schedule



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Space Structures	In-Space Technology Experiments Workshop December 6-9, 1988	Control/Structure Interaction

PAYLOAD VIBRATION ISOLATION IN MICROGRAVITY ENVIRONMENT

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Richard M. Alexander
Mechanical Engineering Department
Texas A&M University

Contract No. NAS 9-17972
Johnson Space Center
Contact: A. R. Rocha
Loads and Dynamics Branch

Outreach	Payload Vibration Isolation in Microgravity Environment	Mech. Eng. Dept. Texas A&M University

EXPERIMENT OBJECTIVE:

- Develop both passive and active techniques to isolate sensitive payloads from shock and vibration.
- Demonstrate candidate methodologies in low-gravity simulator.

Outreach	Payload Vibration Isolation in Microgravity Environment	Mech. Eng. Dept. Texas A&M University

BACKGROUND/TECHNOLOGY NEED

Experiments and processes in laboratory module require microgravity. Vibration excited by adjacent experiments or crew activity can contaminate the low-gravity environment and degrade the usefulness of the experiment or process.

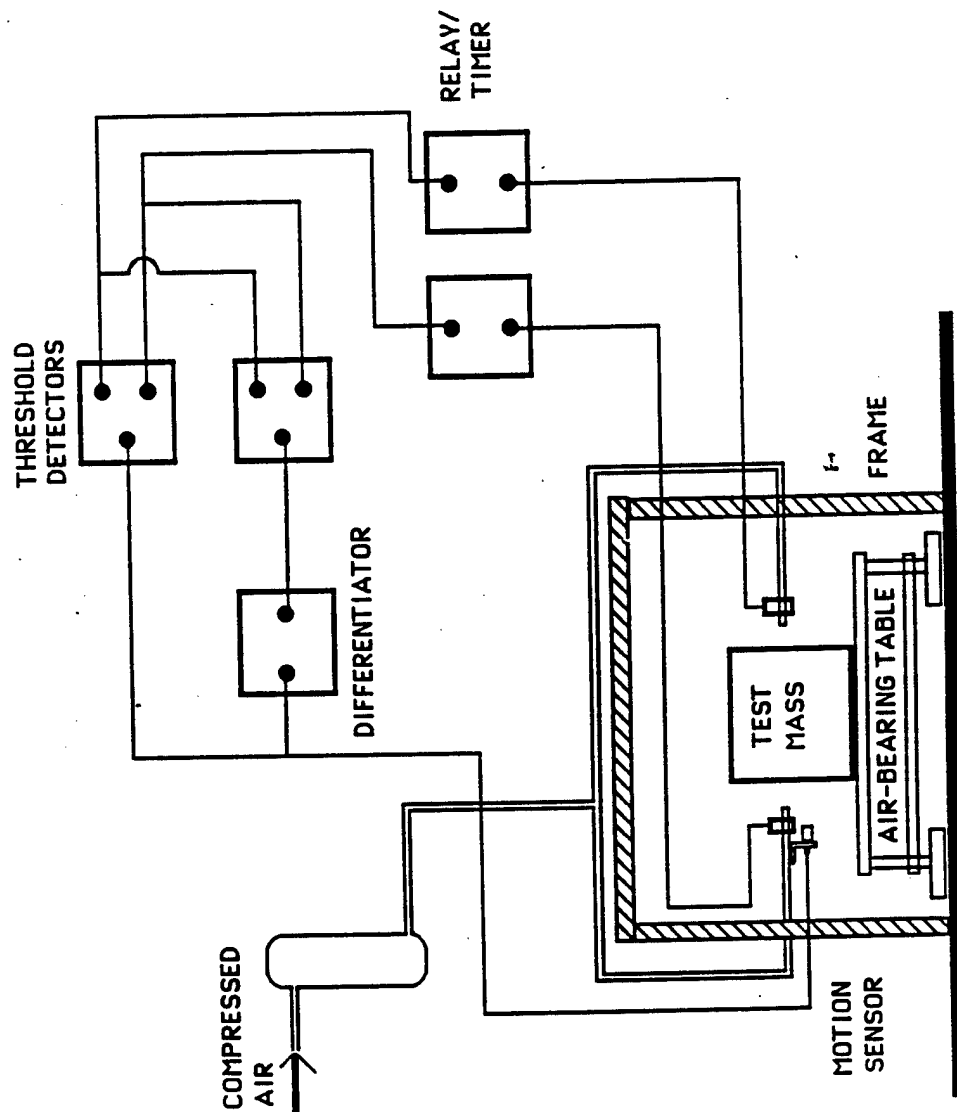
- Study will identify vibration isolation techniques for rigid body payload.
- Can verify methodology concept in one-"g" environment.
- Working model design verification requires shuttle flight.

Outreach	Payload Vibration Isolation in Microgravity Environment	Mech. Eng. Dept. Texas A&M University

EXPERIMENT DESCRIPTION:

- Low-gravity is simulated in the horizontal plane with a cart supported on air-bearing pads.
 - The cart rides on a film of air above a smooth, flat marble surface.
 - Motion of the test payload is measured using an ultrasonic sensor.
- Candidate isolation techniques are evaluated in terms of transmission ratio for harmonic and impulsive excitations.
 - Passive isolation
 - Utilize existing theory
 - Design for isolation = 99.9975%
 - Active Method
 - Payload floats in enclosure
 - Control system keeps payload centered

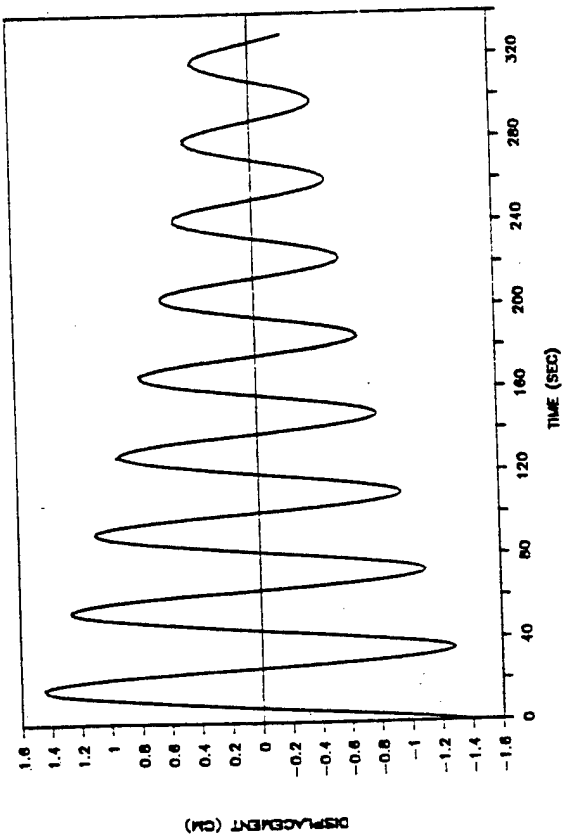
Outreach	Payload Vibration Isolation in Microgravity Environment	Mech. Eng. Dept. Texas A&M University



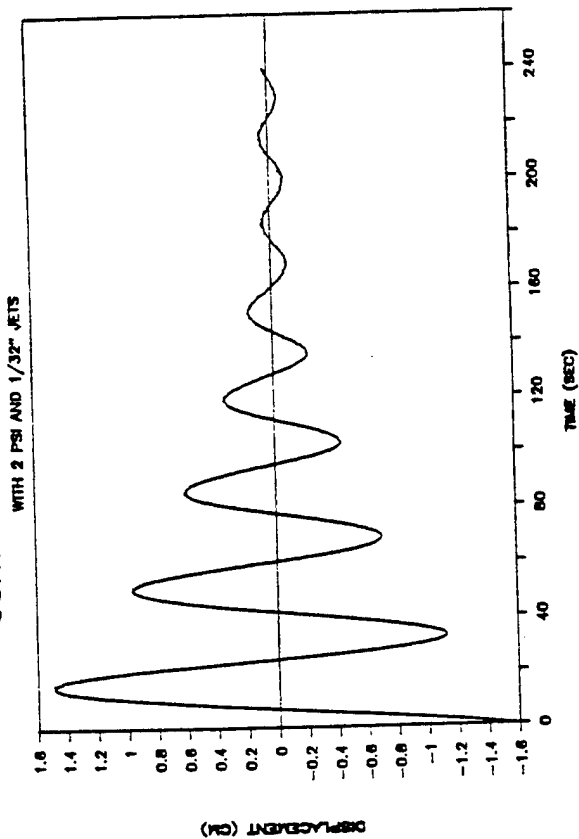
Air Jet Controller System Experiment Set-up

Space Structures	In-Space Technology Experiments Workshop December 6-9, 1988	Control/Structure Interaction

FREE VIBRATION OF CART

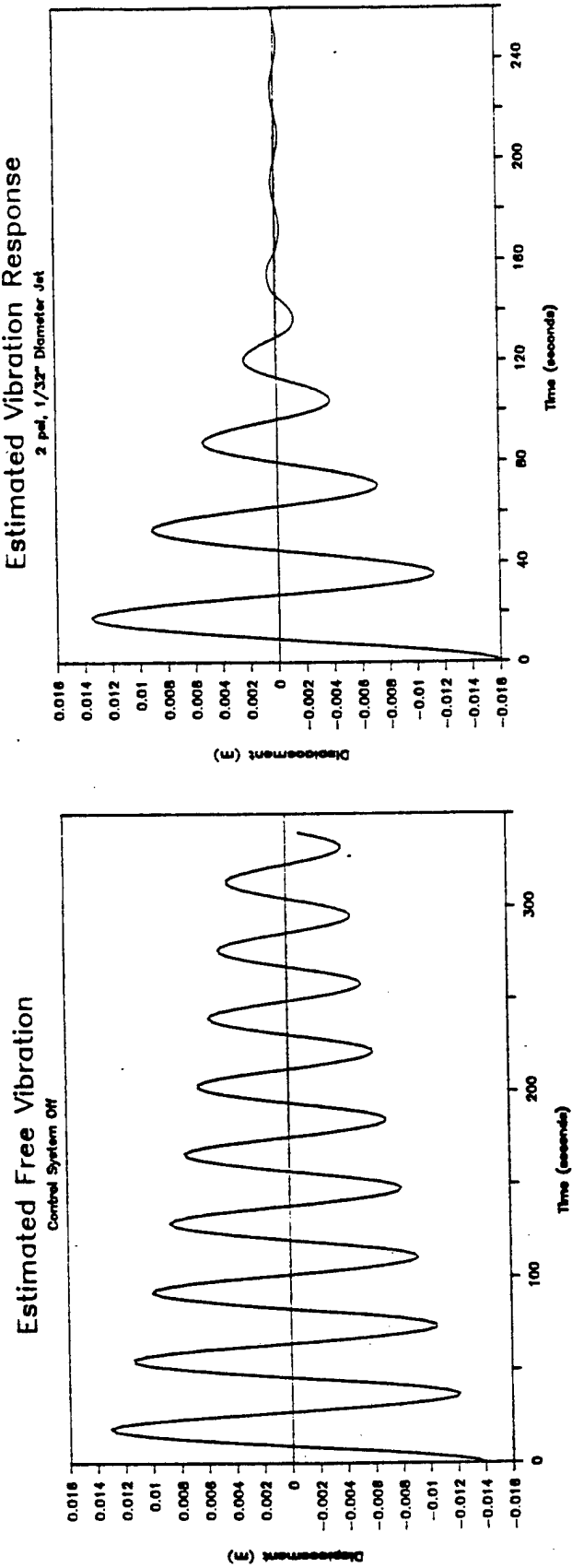


CONTROLLED CART VIBRATION



MEASURED VIBRATION RESPONSE

Space Structures	In-Space Technology Experiments Workshop December 6-9, 1988	Control/Structure Interaction



RESPONSE ESTIMATED BY ANALYTICAL MODEL

Outreach	Payload Vibration Isolation in Microgravity Environment	Mech. Eng. Dept. Texas A&M University

CONCLUSIONS:

- Vibration control demonstrated
 - System has one degree of freedom
 - Passive system can meet impulse criterion
 - Digital controller developed for active system
- Analytical model developed
 - Verified by experiment
 - Will be used to develop control system parameters

Outreach	Payload Vibration Isolation in Microgravity Environment	Mech. Eng. Dept. Texas A&M University

SCHEDULE

	'88	'89
I. Background		
A. Develop/Refine Isolation Criteria	J J A S O N D J J F M A M	
II. Passive Methods		
A. Select Candidate Techniques		
B. Develop Design Parameters		
C. Fabricate Samples & Evaluate		
III. Active Methods		
A. Select Candidate Technique		
B. Develop Design Parameters		
C. Fabricate and Test		
IV. Experiment Facility		
A. Fabricate 1 DOF System		
B. Modify for Plane Motion		

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SPACE STRUCTURES	IN-SPACE TECHNOLOGY EXPERIMENTS WORKSHOP DECEMBER 6-9, 1988	CONTROLS/ STRUCTURE INTERACTION

GENERIC POINTING MOUNT

ROBERT W. BOSLEY

ALLIED/SIGNAL AEROSPACE CO.
AIRESEARCH LOS ANGELES DIV.

CONTRACT NAS1-18685
LANGLEY RESEARCH CENTER
SHARON S. LaFLEUR

OUTREACH	GENERIC POINTING MOUNT	ALLIED/ SIGNAL

EXPERIMENTAL OBJECTIVE

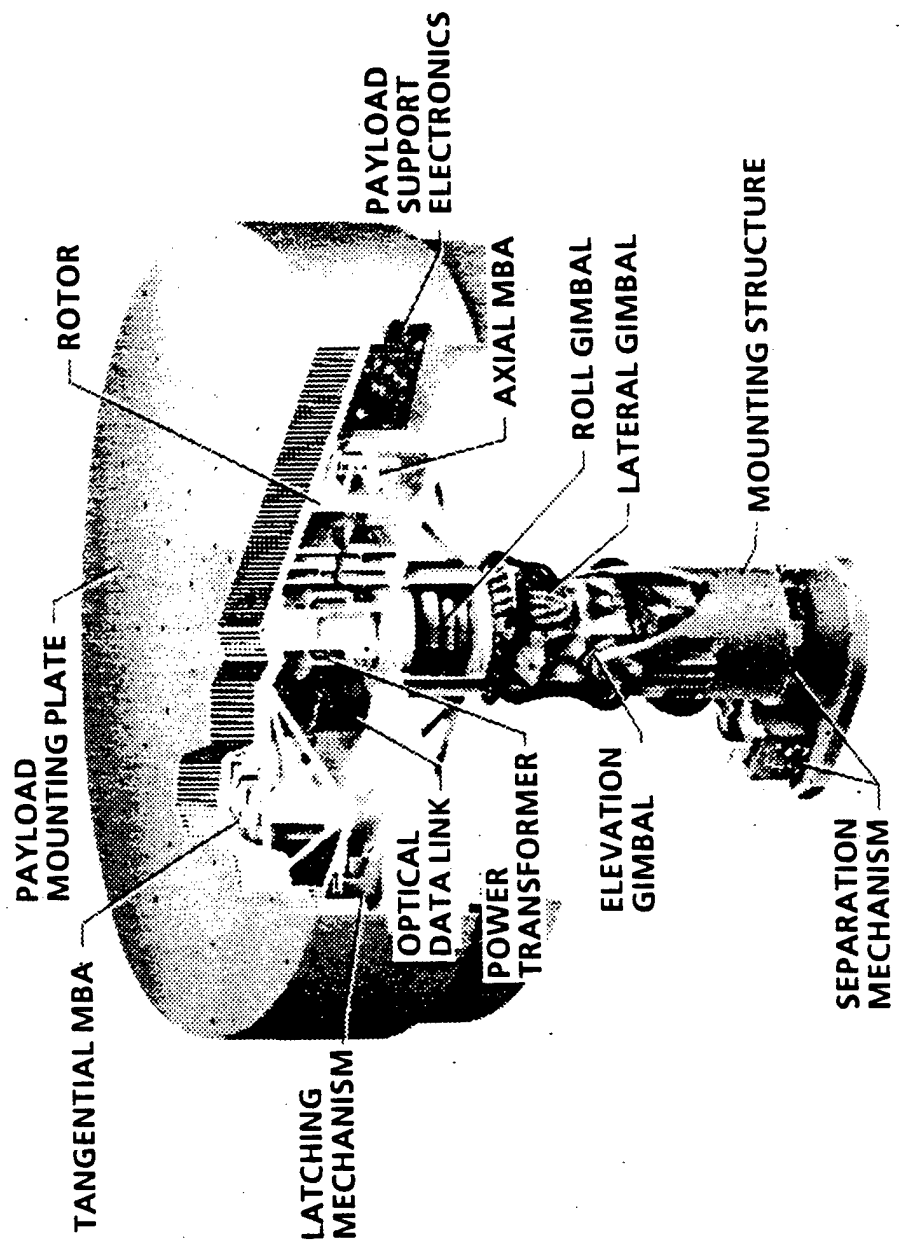
CHARACTERIZE THE PERFORMANCE CAPABILITIES OF A GENERIC POINTING MOUNT DESIGNED TO ISOLATE VIBRATION AND AIM INTERCHANGEABLE PAYLOADS OVER LARGE ARTICULATION ANGLES.

THIS EXPERIMENT WILL:

- VERIFY THE ABILITY OF ADVANCED MAGNETIC SUSPENSIONS TO:
 - ELIMINATE THE NEED FOR MECHANICAL GIMBALS
 - OPERATE OVER LARGE ARTICULATION ANGLES
 - IMPLEMENT ADAPTIVE CONTROL LAWS
 - UTILIZE ARTIFICIAL INTELLIGENCE SCHEMES
- ESTABLISH DESIGN/PERFORMANCE DATA BASE FOR THE NEXT GENERATION OF GENERIC POINTING MOUNTS

OUTREACH	GENERIC POINTING MOUNT	ALLIED/SIGNAL

CURRENT SPACE DEPLOYABLE POINTING TECHNOLOGY



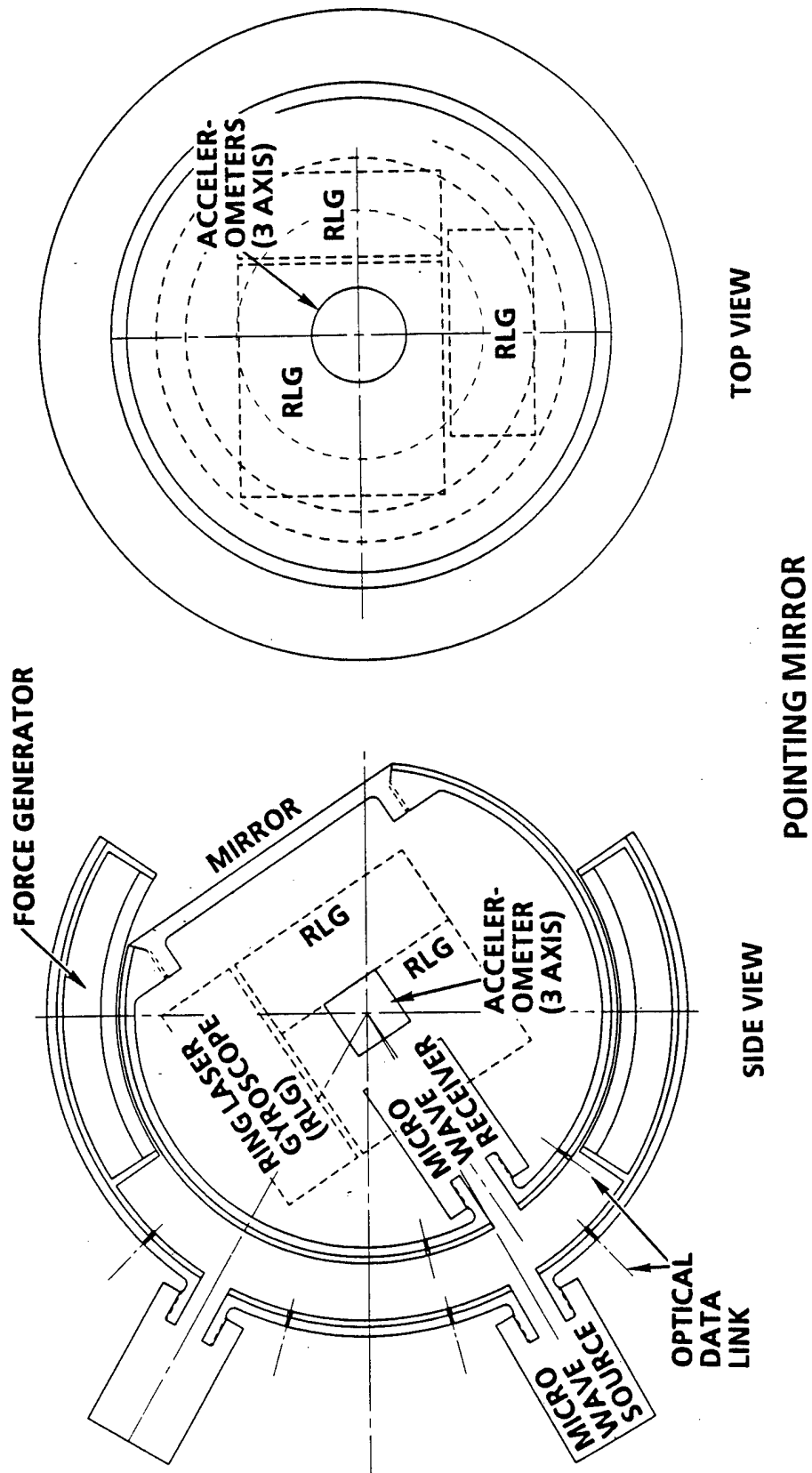
SPERRY/NASA ANNULAR SUSPENSION AND POINTING SYSTEM (ASPS)

OUTREACH	GENERIC POINTING MOUNT	ALLIED/ SIGNAL

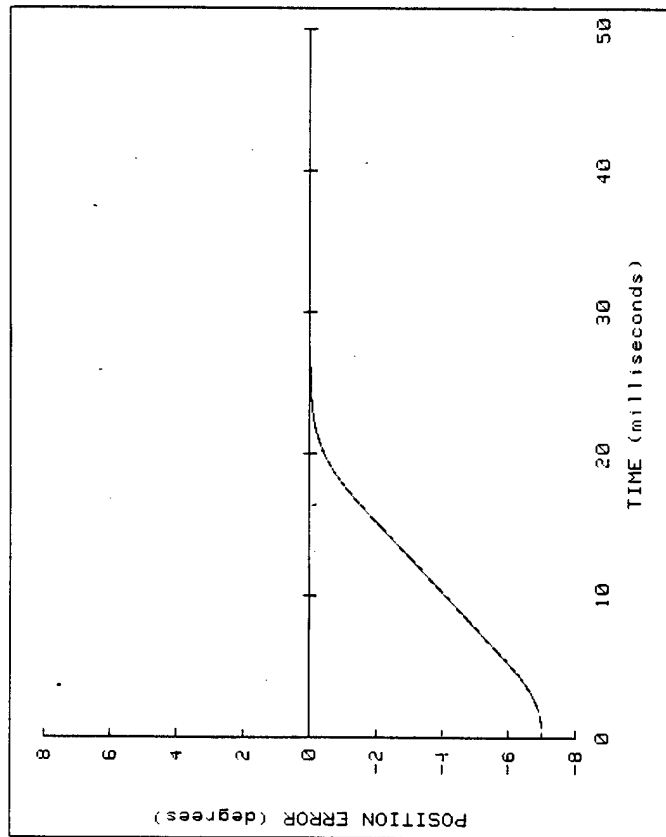
TECHNOLOGIES/FEATURES USED BY THE GENERIC POINTING MOUNT:

- UTILIZES ADVANCED MAGNETIC SUSPENSION/BEARING TECHNOLOGY IN LIEU OF MECHANICAL GIMBALS FOR ARTICULATION
- AUTOMATICALLY MEASURES THE MASS, MOMENTS OF INERTIA, RESONANT FREQUENCIES, RESONANT MODE SHAPES, AND VIBRATION DAMPING REQUIREMENTS OF EACH PAYLOAD
- AUTOMATICALLY OPTIMIZES THE MAGNETIC SUSPENSION AND POINTING/TRACKING SERVOSYSTEM CONTROL LAWS TO MATCH EACH PAYLOAD
- OPTIMIZES THE CONTROL LAWS IN REAL TIME FOR SIMULTANEOUS CONVERGENCE OF POSITION, VELOCITY, AND ACCELERATION ERRORS
- TRANSFERS POWER AND DATA ACROSS THE MAGNETIC SUSPENSION GAP WHILE EXPERIENCING LARGE ARTICULATION ANGLES

OUTREACH	GENERIC POINTING MOUNT	ALLIED/SIGNAL

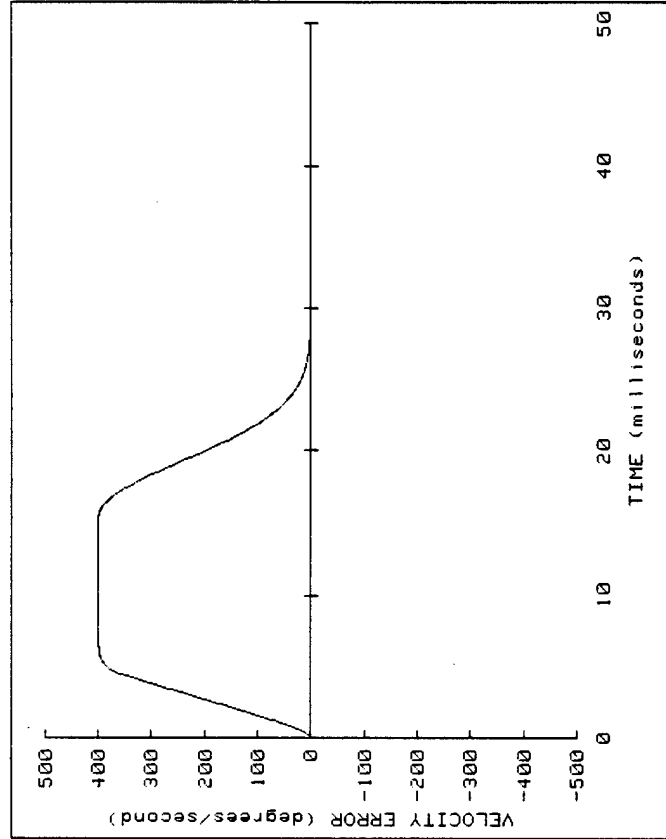


OUTREACH	GENERIC POINTING MOUNT	ALLIED/SIGNAL



DYNAMIC PERFORMANCE OF MAGNETICALLY SUSPENDED TIP/TILT MIRROR
 MIRROR DIAMETER IS 24 INCHES
 WEIGHT OF MIRROR IS 100 POUNDS
 ARTICULATION CAPABILITY IS PLUS OR MINUS 4 DEGREES
 MAXIMUM TORQUE THAT FORCE GENERATORS CAN DEVELOP IS 1200 LB-FT
 MAXIMUM RATE OF CHANGE OF TORQUE IS 1,200,000 LB-FT/SEC
 MAXIMUM VELOCITY CLAMP IS SET AT 400 DEGREES PER SECOND

X-12873



DYNAMIC PERFORMANCE OF MAGNETICALLY SUSPENDED TIP/TILT MIRROR
 MIRROR DIAMETER IS 24 INCHES
 WEIGHT OF MIRROR IS 100 POUNDS
 ARTICULATION CAPABILITY IS PLUS OR MINUS 4 DEGREES
 MAXIMUM TORQUE THAT FORCE GENERATORS CAN DEVELOP IS 1200 LB-FT
 MAXIMUM RATE OF CHANGE OF TORQUE IS 1,200,000 LB-FT/SEC
 MAXIMUM VELOCITY CLAMP IS SET AT 400 DEGREES PER SECOND

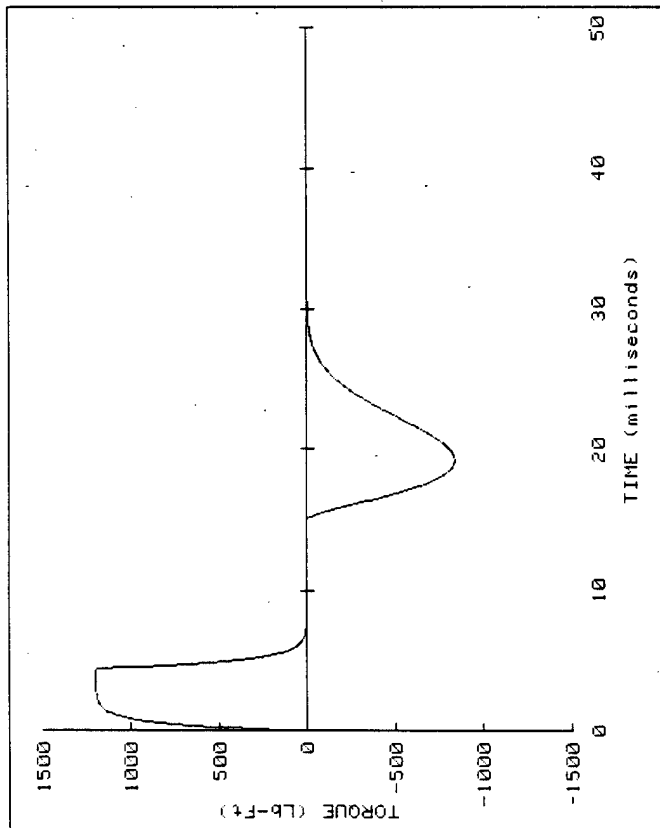
X-12874

SIX ORDERS OF MAGNITUDE ERROR REDUCTION WITH NO OVERSHOOT/UNDERSHOOT

OUTREACH

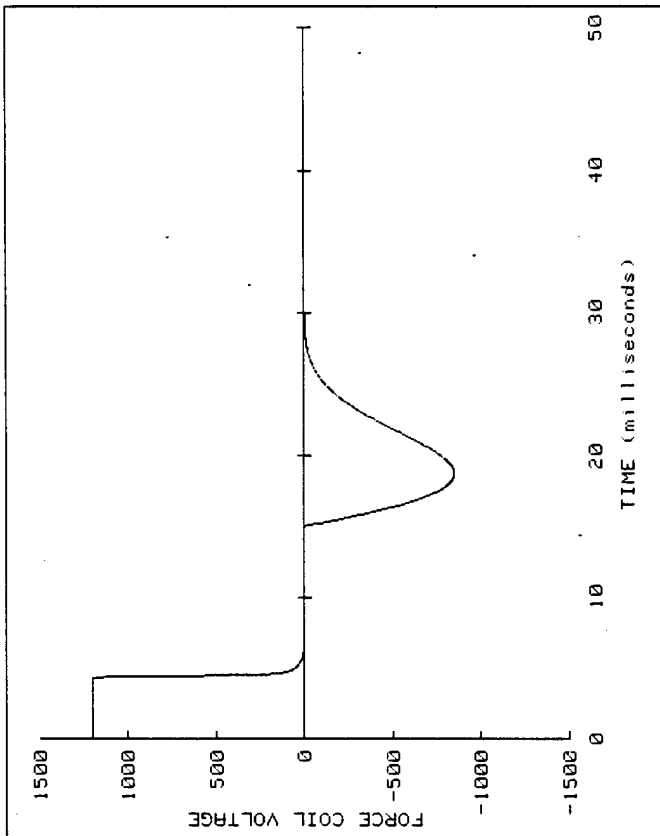
GENERIC POINTING MOUNT

ALLIED/SIGNAL



DYNAMIC PERFORMANCE OF MAGNETICALLY SUSPENDED TIP/TILT MIRROR
MIRROR DIAMETER IS 24 INCHES
HEIGHT OF MIRROR IS 100 POUNDS
ARTICULATION CAPABILITY IS PLUS OR MINUS 4 DEGREES
MAXIMUM TORQUE THAT FORCE GENERATORS CAN DEVELOP IS 1200 LB-FT
MAXIMUM RATE OF CHANGE OF TORQUE IS 1,200,000 LB-FT/SEC
MAXIMUM VELOCITY CLAMP IS SET AT 400 DEGREES PER SECOND

X-12876



DYNAMIC PERFORMANCE OF MAGNETICALLY SUSPENDED TIP/TILT MIRROR
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X-12875

SIX ORDERS OF MAGNITUDE ERROR REDUCTION WITH NO OVERSHOOT/UNDERSHOOT

OUTREACH	GENERIC POINTING MOUNT	ALLIED/ SIGNAL

EXPERIMENT DESCRIPTION:

- THE SPACE BASED POINTING MOUNT MODULE WILL BE COMPRISED OF:
 - THE MAGNETICALLY SUSPENDED AND CONTROLLED GENERIC POINTING MOUNT
 - A POINTING MIRROR ATTACHED TO AND ARTICULATED BY THE MOUNT
 - THREE OPTICAL AUTOCOLLIMATORS (one articulated)
 - A TELESCOPE WITH STAR PATTERN RECOGNITION CAPABILITIES AND STAR POSITION/POINTING ERROR SENSORS. THIS TELESCOPE WILL BE ALTERNATELY
 - ATTACHED TO AND ARTICULATED BY THE POINTING MOUNT.
 - ATTACHED TO A NON-ARTICULATED SURFACE IN THE MODULE SO AS TO RECEIVE OPTICAL SIGNALS/IMAGES REFLECTING OFF THE POINTING MIRROR
 - SIMULATED INSTRUMENTS/DEVICES WITH DIFFERENT MECHANICAL IMPEDANCES
 - AN INERTIAL MEASUREMENT UNIT (IMU) WITHIN THE ARTICULATED POINTING MOUNT
 - AN IMU WITHIN THE NON-ARTICULATED PORTION OF THE MODULE
 - POWER AND DATA LINKS BETWEEN THE MOUNTED TELESCOPE AND THE MODULE (across the magnetic suspension gap)
 - DATA LINKS:
 - TO THE SPACECRAFT IMU AND COMPUTERS
 - TO ONE OR MORE GROUND STATIONS

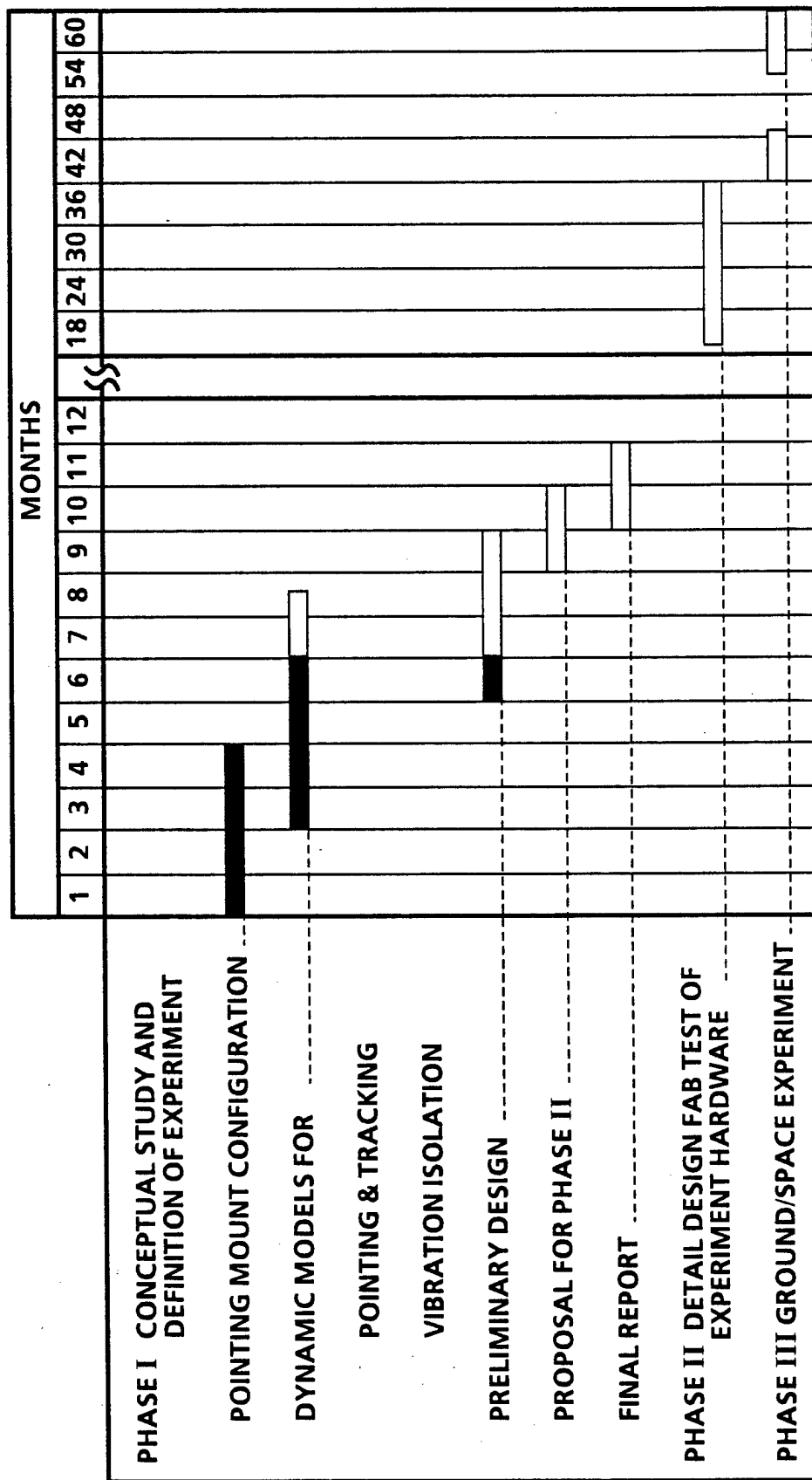
OUTREACH	GENERIC POINTING MOUNT	ALLIED/ SIGNAL

EXPERIMENT DESCRIPTION:

- THE EXPERIMENT WILL BE DIVIDED INTO FIVE SUB-EXPERIMENTS
- SUB-EXPERIMENT 1: CHARACTERIZE THE DYNAMIC SYSTEM PERFORMANCE WHEN SHIFTING LOCK FROM ONE AUTOCOLLIMATOR TO ANOTHER
- SUB-EXPERIMENT 2: CHARACTERIZE THE ABILITY OF THE SYSTEM TO ADAPT TO CHANGES IN THE MECHANICAL IMPEDANCES OF THE INSTRUMENTS/DEVICES BEING AIMED
- SUB-EXPERIMENT 3: CHARACTERIZE THE TRACKING STABILITY WHEN THE TELESCOPE IS ARTICULATED AND LOCKED TO A STAR OR EARTH STATION
- SUB-EXPERIMENT 4: CHARACTERIZE THE TRACKING STABILITY WHEN THE MIRROR/TELESCOPE IS LOCKED TO A STAR OR EARTH STATION AND THE UNARTICULATED TELESCOPE IS EXCITED BY EXTERNAL VIBRATIONS
- SUB-EXPERIMENT 5: CHARACTERIZE THE TRACKING STABILITY WHEN THE MIRROR IS RELAYING LASER BEAMS GENERATED BY EARTH STATIONS

OUTREACH	GENERIC POINTING MOUNT	ALLIED/ SIGNAL

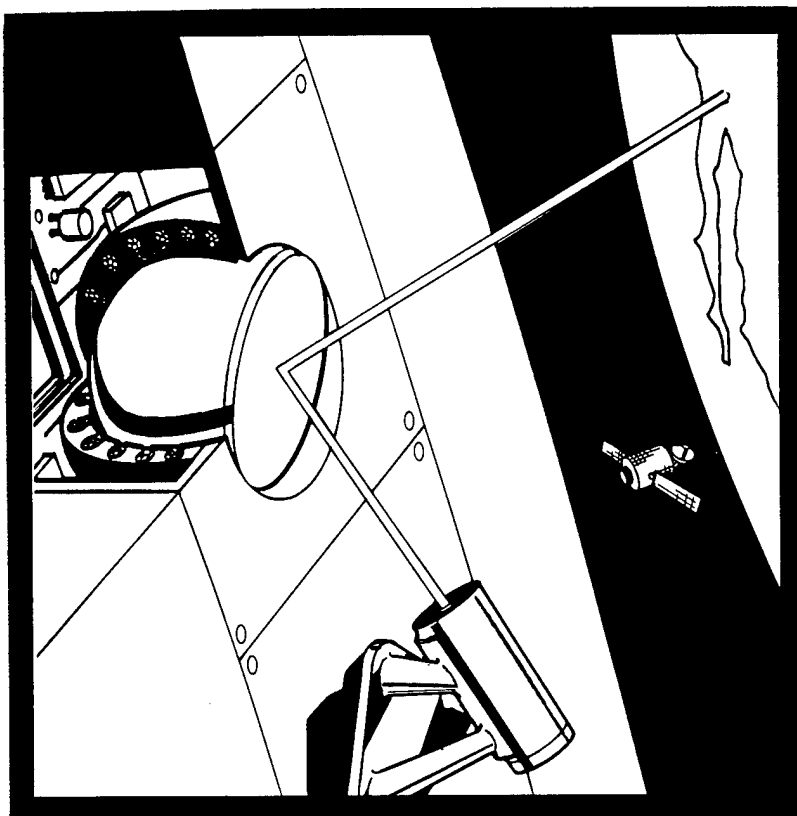
MASTER SCHEDULE (3 PHASES)



OUTREACH	GENERIC POINTING MOUNT	ALLIED/ SIGNAL

SUMMARY OF EXPERIMENT FEATURES:

- **GENERIC POINTING MOUNT FOR INTERCHANGEABLE PAYLOADS**
- **SYSTEM AUTOMATICALLY ADAPTS CONTROL LAWS TO EACH PAYLOAD**
- **POINTING CONTROL IN THREE AXES AROUND A SINGLE PIVOT POINT**
- **135° ARTICULATION ANGLES**



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SPACE STRUCTURES	IN-SPACE TECHNOLOGY EXPERIMENTS WORKSHOP DECEMBER 6-9, 1988	STRUCTURES

SPACE STATION STRUCTURAL CHARACTERIZATION EXPERIMENT

JAMES W. JOHNSON

AND

PAUL A. COOPER

NASA
LANGLEY RESEARCH CENTER

INREACH	SPACE STATION STRUCTURAL CHARACTERIZATION EXPERIMENT	LaRC

OBJECTIVE

THE DEVELOPMENT OF MODELING TECHNIQUES
FOR LARGE SPACE STRUCTURES USING ON-ORBIT
MEASUREMENTS OF SPACE STATION STRUCTURAL
DYNAMICS

INREACH	SPACE STATION STRUCTURAL CHARACTERIZATION EXPERIMENT	LaRC

TECHNOLOGY REQUIREMENT

LARGE SPACE STRUCTURES

- CANNOT BE INTEGRATED AND TESTED IN 1G
- REQUIRE ANALYTICAL PREDICTION AND / OR ON-ORBIT MEASUREMENT OF PERFORMANCE

DYNAMICS: MODELING TO PREDICT PERFORMANCE

CONTROL: ON-ORBIT CHARACTERIZATION FOR ACTIVE CONTROL

INREACH	SPACE STATION STRUCTURAL CHARACTERIZATION EXPERIMENT	LaRC

EXPERIMENT DESCRIPTION

- o SPACE STATION FREEDOM
 - PRESENTS AN EARLY OPPORTUNITY TO DEVELOP MODELING TECHNOLOGY
 - MAGNIFIES THE OPPORTUNITY WITH MULTIPLE ASSEMBLY CONFIGURATIONS

o FLIGHT EXPERIMENT CONCEPT

PHASE A

- MODAL TESTING OF SELECTED CONFIGURATIONS THRU ASSEMBLY COMPLETE
 - EXCITATION REBOOST TRANSIENTS
 MODULATED REBOOST
 - MEASUREMENTS ACCELERATION
 - MODAL IDENTIFICATION FREE DECAY

INREACH	SPACE STATION STRUCTURAL CHARACTERIZATION EXPERIMENT	LaRC

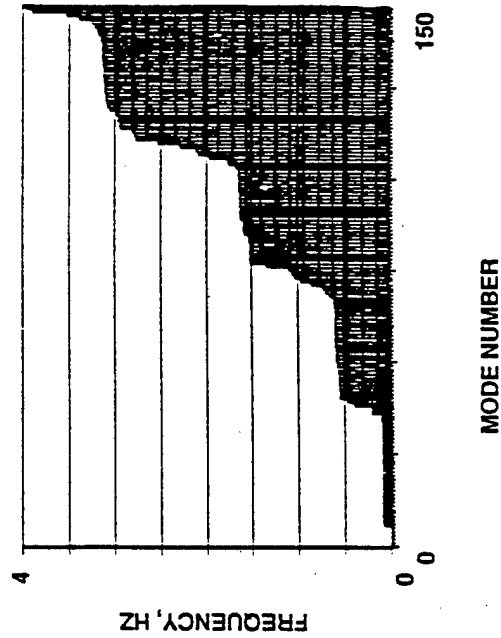
EXPERIMENT DESCRIPTION

(Cont.)

MODAL DENSITY

ASSEMBLY COMPLETE CONFIGURATION

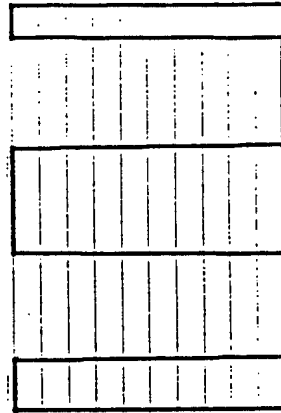
148 MODES / 0 - 4 HZ



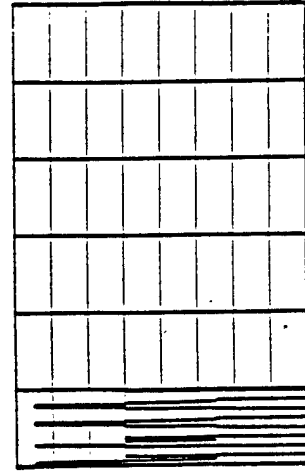
EXCITATION FUNCTIONS

STARBOARD X RCS JETS

REBOOST TRANSIENTS



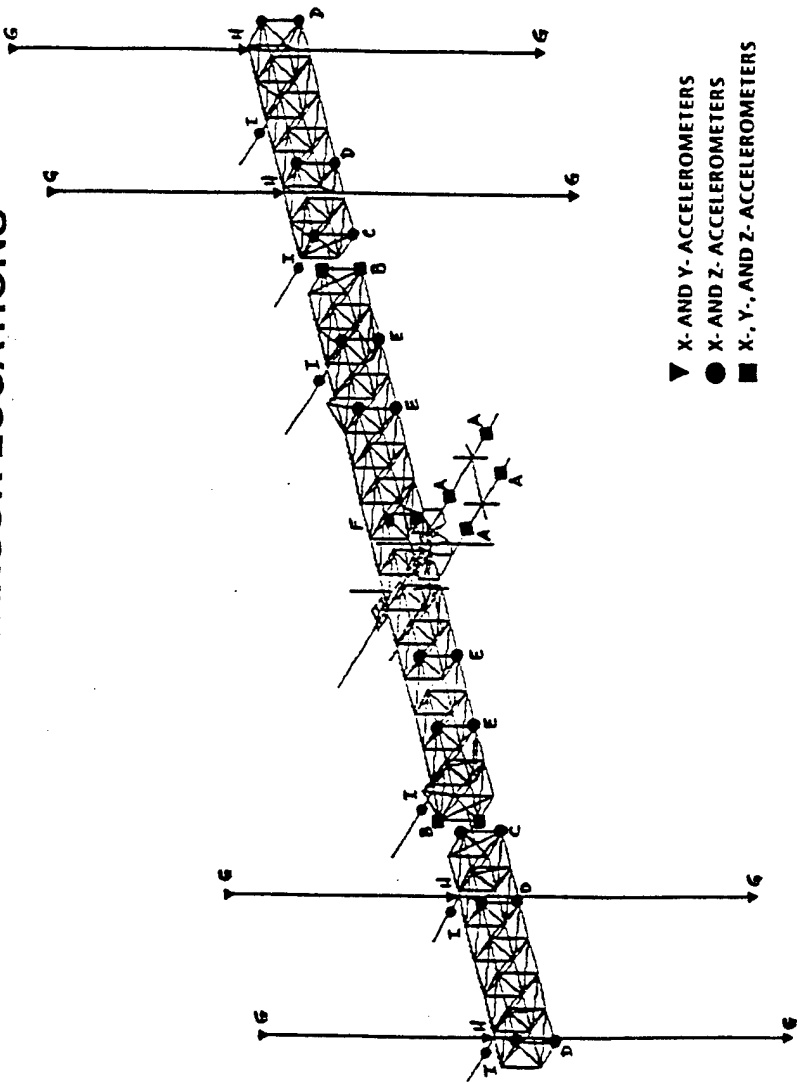
MODULATED REBOOST



TIME →

INREACH	SPACE STATION STRUCTURAL CHARACTERIZATION EXPERIMENT	LaRC

PRIMARY SENSOR LOCATIONS



- ▽ X- AND Y- ACCELEROMETERS
- X- AND Z- ACCELEROMETERS
- X-, Y-, AND Z- ACCELEROMETERS

INREACH	SPACE STATION STRUCTURAL CHARACTERIZATION EXPERIMENT	LaRC

SCHEDULE

CY	88	89	90	91	92	93	94	95	96	97	98



SPACE STATION FREEDOM

SPACE STATION STRUCTURAL CHARACTERIZATION EXPERIMENT

PHASE A STUDY



PHASE B STUDIES



DESIGN, DEVELOPMENT AND INTEGRATION



FLIGHT EXPERIMENTS



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SPACE STRUCTURES	IN-SPACE TECHNOLOGY EXPERIMENTS WORKSHOP DECEMBER 6-9, 1988	STRUCTURES

INFLATABLE SOLAR CONCENTRATOR EXPERIMENT DEFINITION PROGRAM

COSTA CASSAPAKIS
GEOFF WILLIAMS

L'GARDE, INC.

CONTRACT NAS1-18681
LANGLEY RESEARCH CENTER
TOM CAMPBELL

OUTREACH	INFLATABLE SOLAR CONCENTRATOR EXPERIMENT	L'GARDE, INC.

STUDY OBJECTIVE

ASSESS IN-SPACE THE TWO MOST CRITICAL ISSUES PERTAINING TO THE PERFORMANCE OF INFLATABLE STRUCTURES IN SPACE:

- * ASSESS THE EFFECTS OF SPACE ENVIRONMENT ON THE STRUCTURAL INTEGRITY AND SERVICE LIFE:

- METEOROIDS
- UV RADIATION
- ATOMIC OXYGEN

- * DEMONSTRATE THAT INFLATABLE SYSTEMS CAN BE DESIGNED TO PROVIDE HIGH LEVELS OF STRUCTURAL DAMPING.

- BYPRODUCT: VALIDATION OF EXISTING ANALYTICAL TOOLS THAT PREDICT STRUCTURAL DAMPING.

OUTREACH	INFLATABLE SOLAR CONCENTRATOR EXPERIMENT	L'GARDE, INC.

BACKGROUND / TECHNOLOGY NEED

* INFLATABLE STRUCTURES IN SPACE HAVE BEEN VERY SUCCESSFUL AND THEIR ADVANTAGES HAVE BEEN DEMONSTRATED IN SHORT MISSIONS

- SMALL PACKAGED VOLUMES
- LOW WEIGHT
- LESS EXPENSIVE TO BUILD AND TEST THAN COMPETING MECHANICALLY ERECTED SYSTEMS

* FOR LONG TERM SPACE MISSIONS, AS IN THE CASE OF ANTENNAS AND SOLAR CONCENTRATORS, IT IS NECESSARY TO DEMONSTRATE THAT:

- INDUCED DAMAGE DUE TO ENVIRONMENT (METEORIDS, UV RADIATION AND ATOMIC OXYGEN AT LOW EARTH ORBITS) CAN BE HANDLED BY ON-BOARD GAS SUPPLY, AND/OR OTHER MEANS.
- INDUCED DYNAMICS ARE DAMPED OUT QUICKLY, SO THAT STRUCTURAL ACCURACY IS MAINTAINED.

* THIS EXPERIMENT MUST BE CONDUCTED IN-SPACE, BECAUSE ZERO GRAVITY, VACUUM, METEORIDS, UV AND ATOMIC OXYGEN ARE ALL SIMULTANEOUSLY PRESENT.

OUTREACH	INFLATABLE SOLAR CONCENTRATOR EXPERIMENT	L'GARDE, INC.

STUDY DESCRIPTION

1. TRADE STUDIES WILL BE CONDUCTED ON THE:
 - * DESIRABLE ORBIT TYPE
 - HEO
 - LEO
 - * INFLATABLE STRUCTURE
 - TYPE (E.G. SPHERICAL OR PARABOLOID)
 - MATERIALS (E.G. KAPTON, MYLAR TEFLON, ETC.)
 - RESPONSE INSTRUMENTATION (METEOROLIDS, UV, O)
 - DYNAMICS INSTRUMENTATION (ACCELEROMETERS AND/OR VIDEO FOR INSTANCE)

OUTREACH	INFLATABLE SOLAR CONCENTRATOR EXPERIMENT	L'GARDE, INC.

STUDY DESCRIPTION

1. (Continued)

* CARRIER VEHICLE

- TYPE:

- FREE FLYER, NON-RETRIEVABLE
- FREE FLYER, RETRIEVABLE
- SPACE STATION

- TELEMETRY (MAY NOT BE REQUIRED FOR SPACE STATION MEASUREMENTS)

- CONTROL

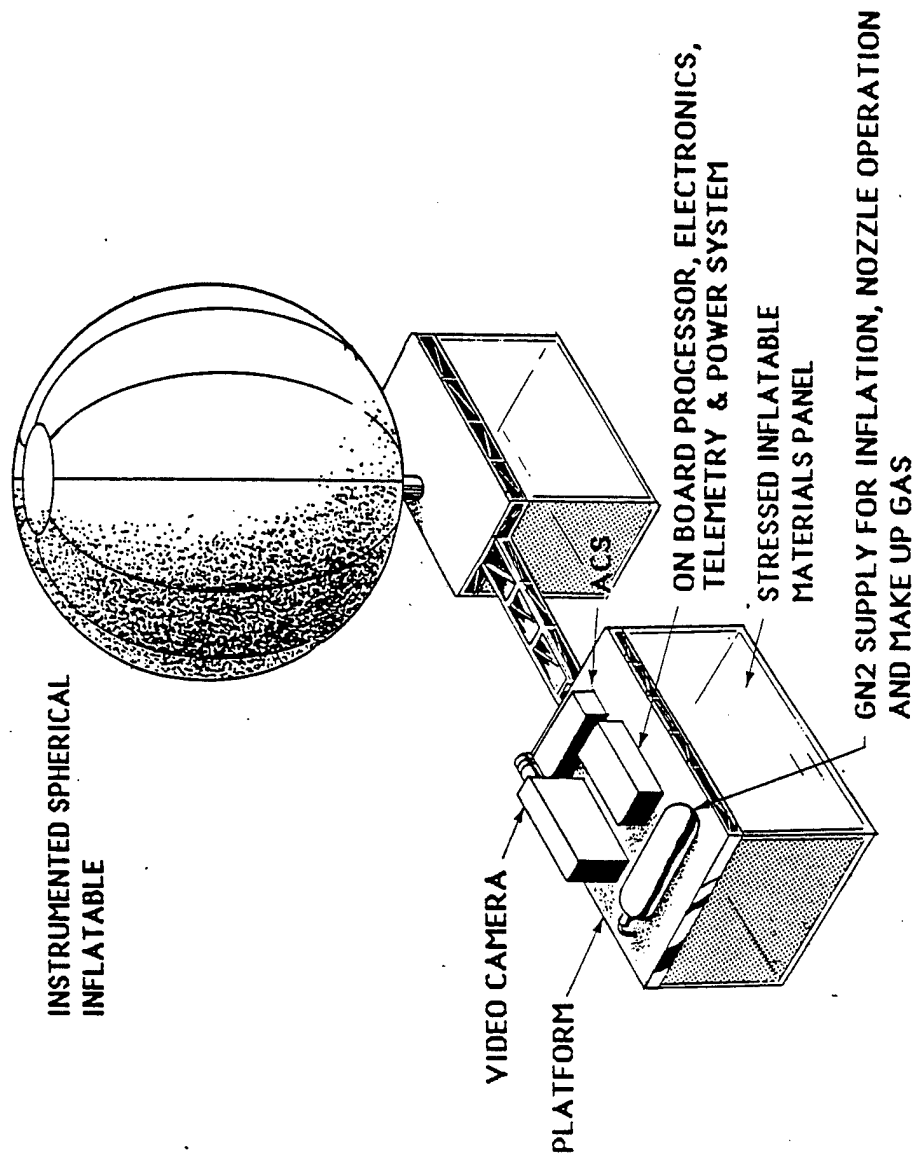
- ATTITUDE CONTROL?
- ON-BOARD MICROPROCESSOR TYPE
- INFLATION FEEDBACK LOOP
- INFLATABLE DYNAMICS INDUCTION TYPE

- POWER

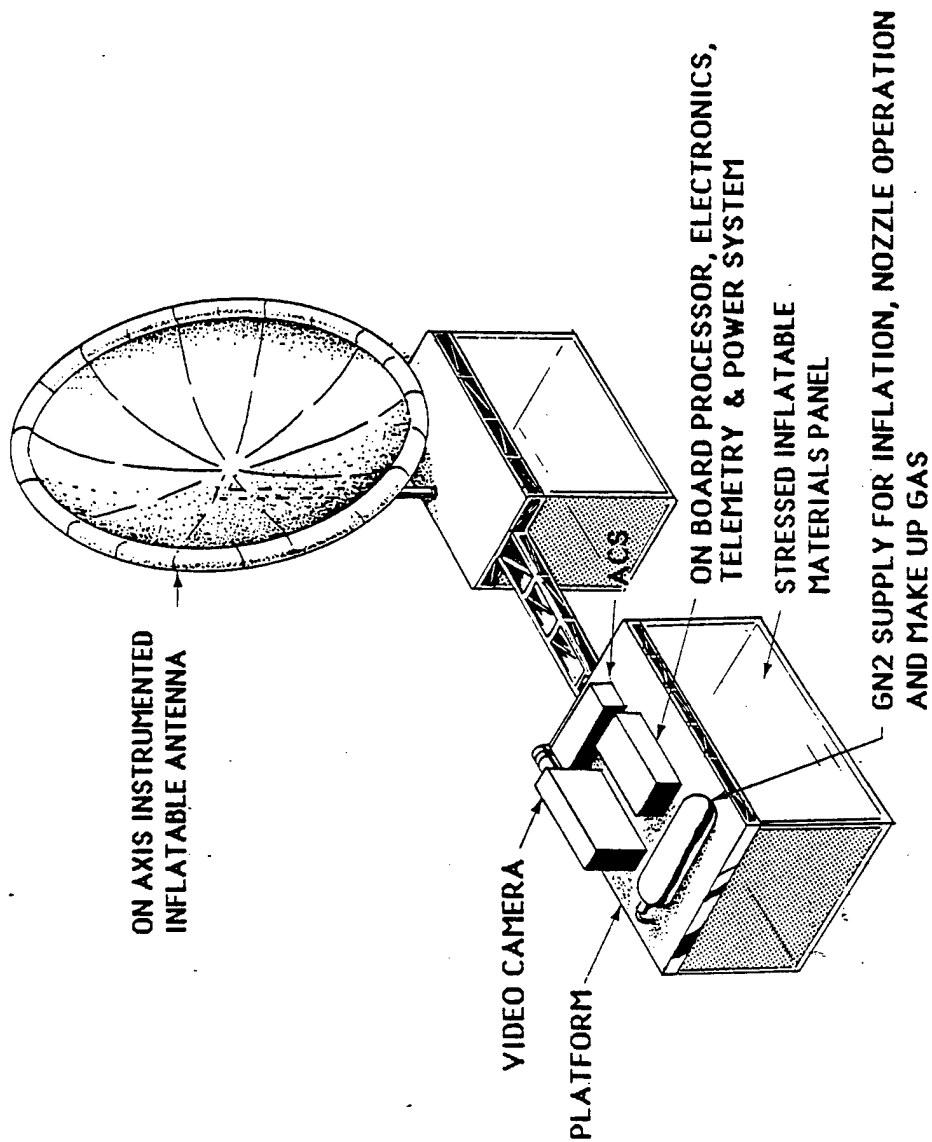
- REQUIREMENTS
- TYPE

2. RECOMMENDATIONS WILL BE MADE FOR THE MOST COST EFFECTIVE EXPERIMENTAL CONFIGURATION CONCEPT

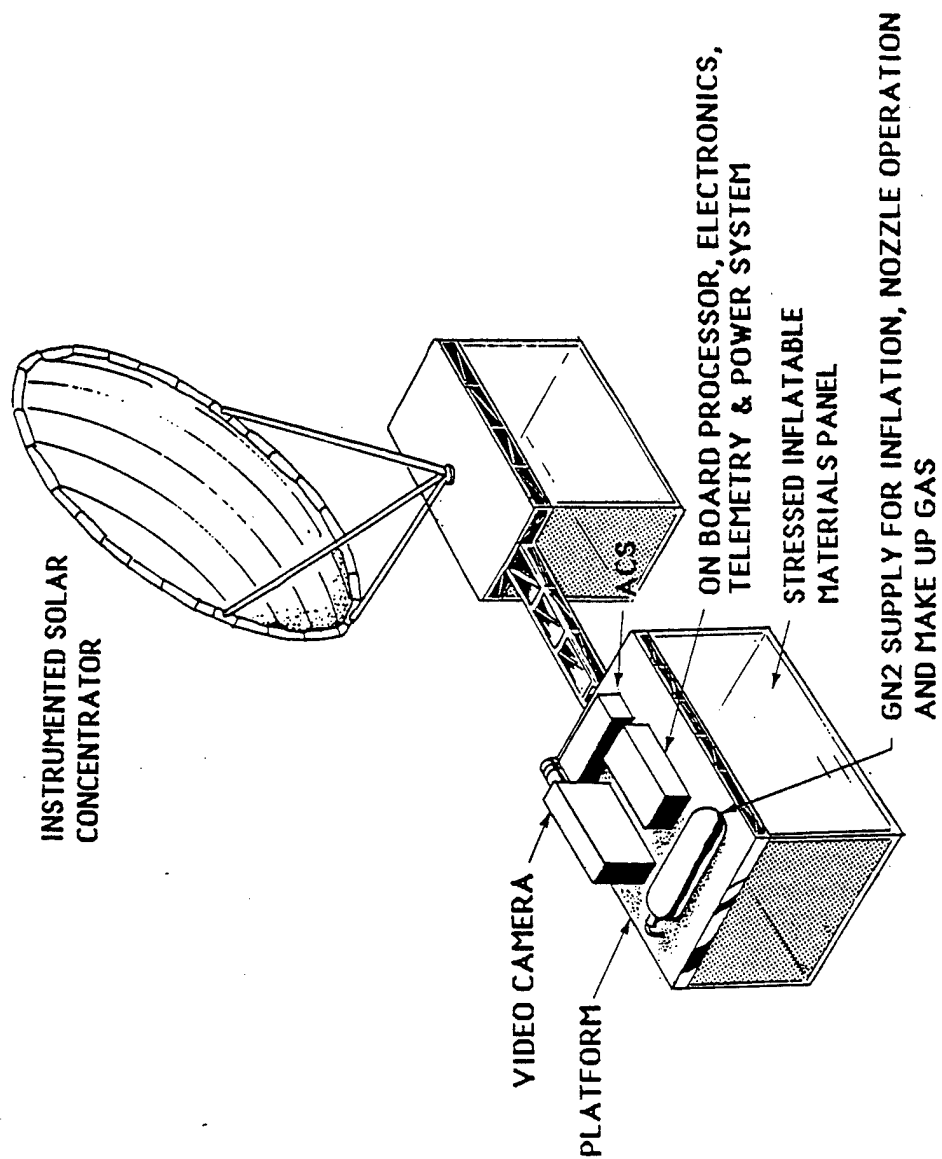
OUTREACH	INFLATABLE SOLAR CONCENTRATOR EXPERIMENT	L'GARDE, INC.



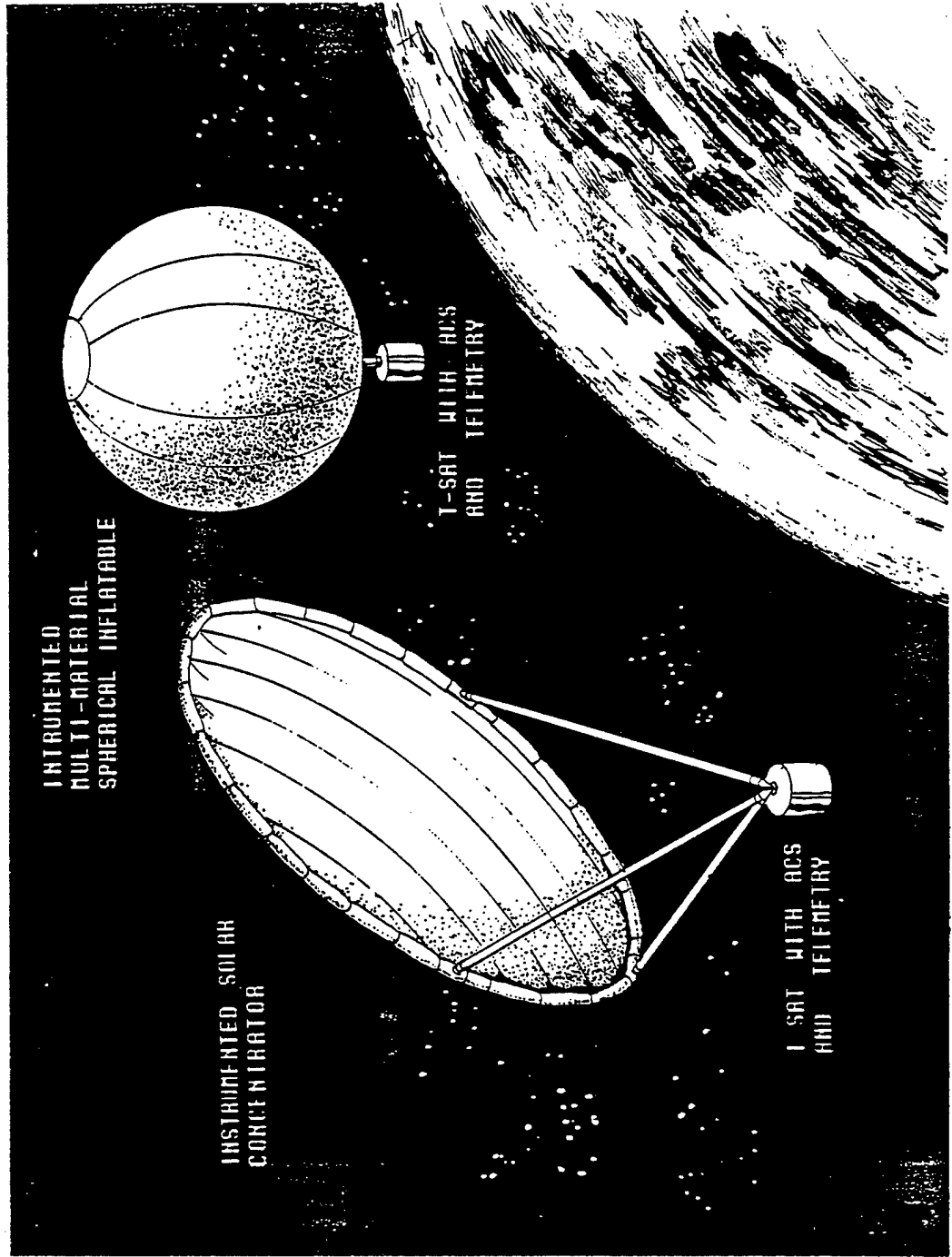
OUTREACH	INFLATABLE SOLAR CONCENTRATOR EXPERIMENT	L'GARDE, INC.



OUTREACH	INFLATABLE SOLAR CONCENTRATOR EXPERIMENT	L'GARDE, INC.

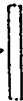


OUTREACH	INFLATABLE SOLAR CONCENTRATOR EXPERIMENT	L'GARDE, INC.

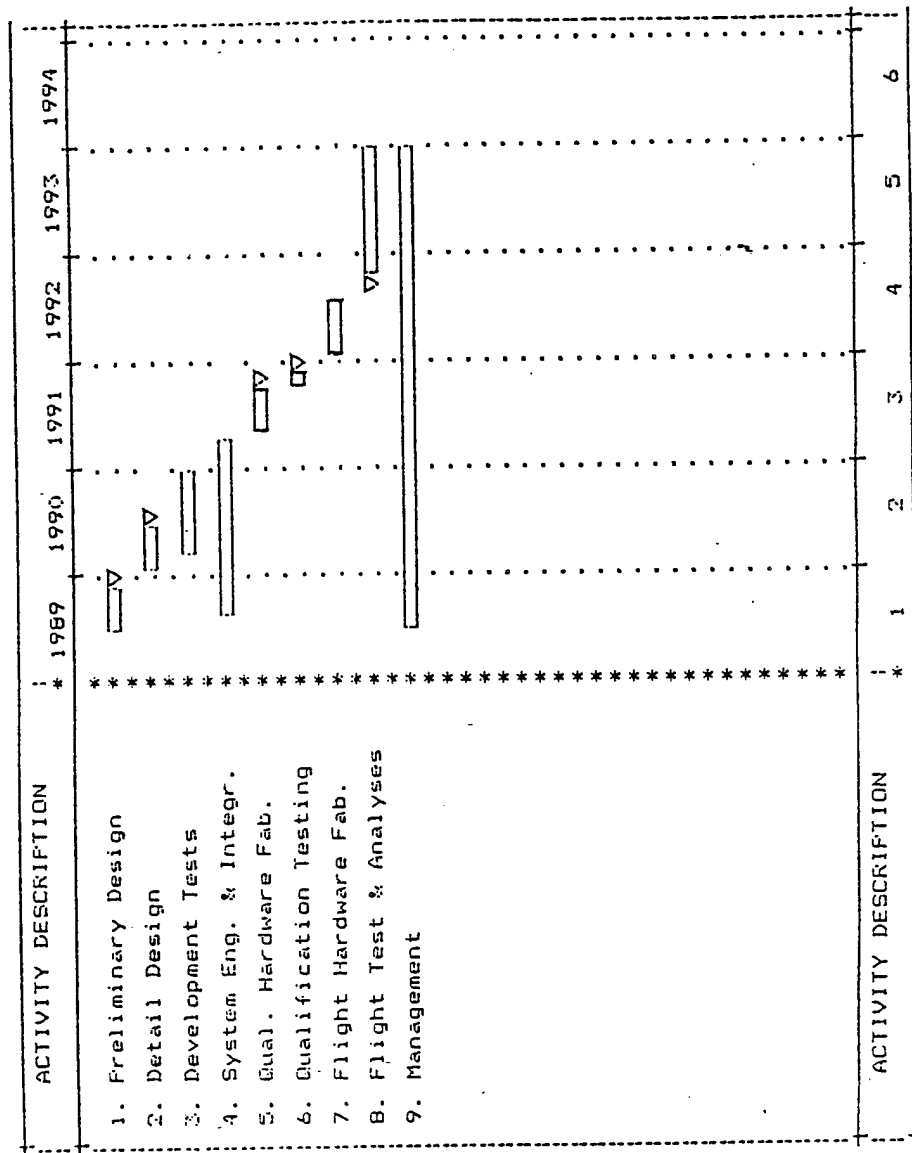


OUTREACH	INFLATABLE SOLAR CONCENTRATOR EXPERIMENT	L'GARDE, INC.

PROJECTED EXPERIMENT SCHEDULE

LEGEND: Major Milestone  Task Duration 

Issue Date 10/24/88



2. SPACE ENVIRONMENTAL EFFECTS

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SPACE ENVIRONMENTAL EFFECTS	IN-SPACE TECHNOLOGY EXPERIMENTS WORKSHOP DECEMBER 6-9, 1988	ATMOSPHERIC EFFECTS AND CONTAMINATION

MEASUREMENT OF SURFACE REACTIONS IN THE SPACE ENVIRONMENT

L.R. MEGILL

GLOBESAT INC.

CONTRACT NAS1-18684
LANGLEY RESEARCH CENTER
LENWOOD G. CLARK
JET PROPULSION LAB
DR. DAVID A. BRINZA

Experiment objectives

Measure in space effective reaction

rates for degradation of materials

- Selected space materials
- In-space analysis
- Inexpensive, small satellite

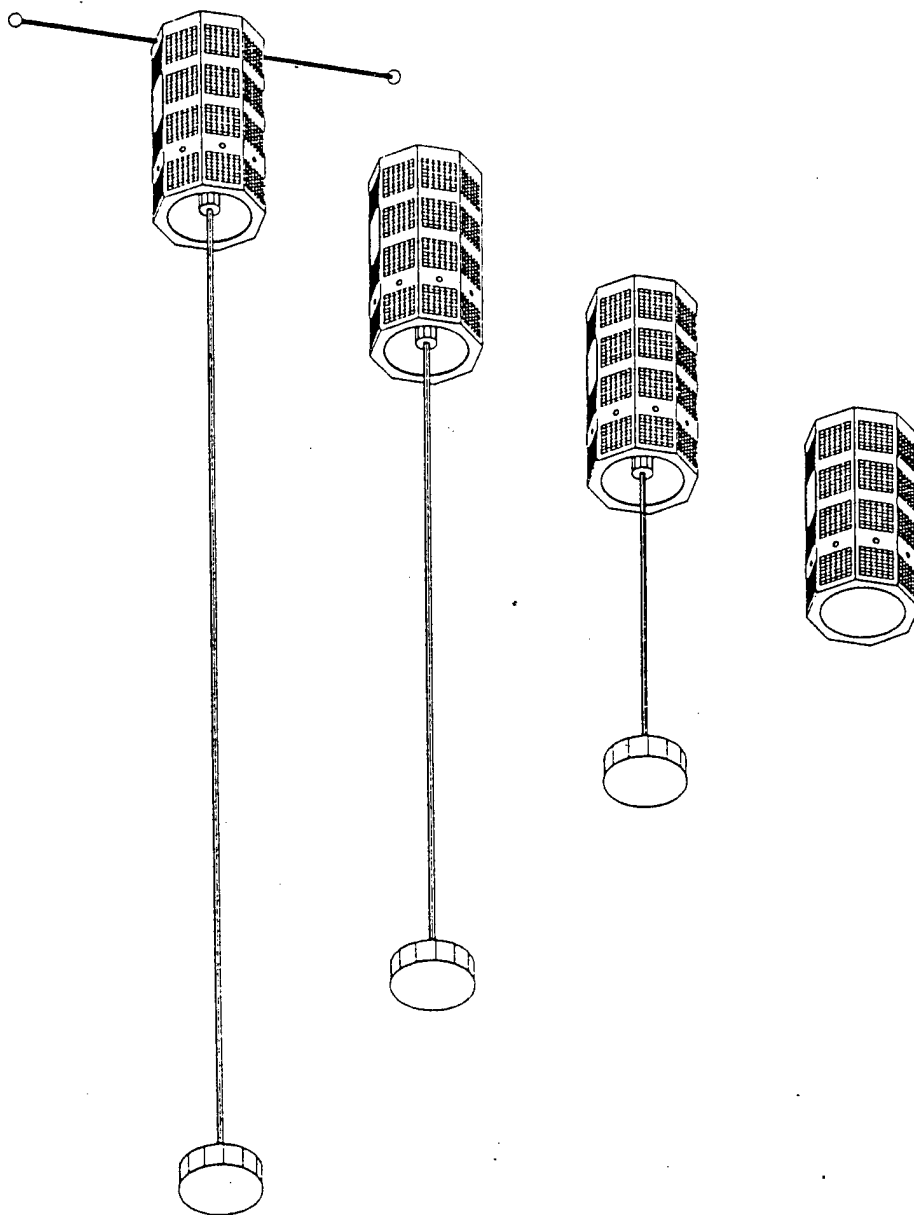
Background

- Observations of returned specimens indicate severe degradation
- Future structures will make use of composite materials
- Laboratory sources of 5ev atomic oxygen are difficult to obtain

- Gravity Gradient/Magnetic Torque
Stabilized satellite
- Several in-space measurements
to be used
- Results telemetered to the ground

**Measurement of Surface reactions
in the Space environment**

OUTREACH

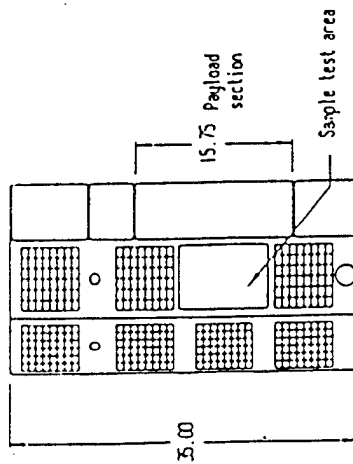
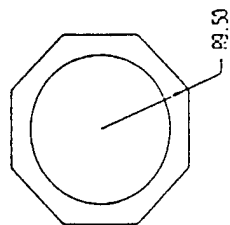
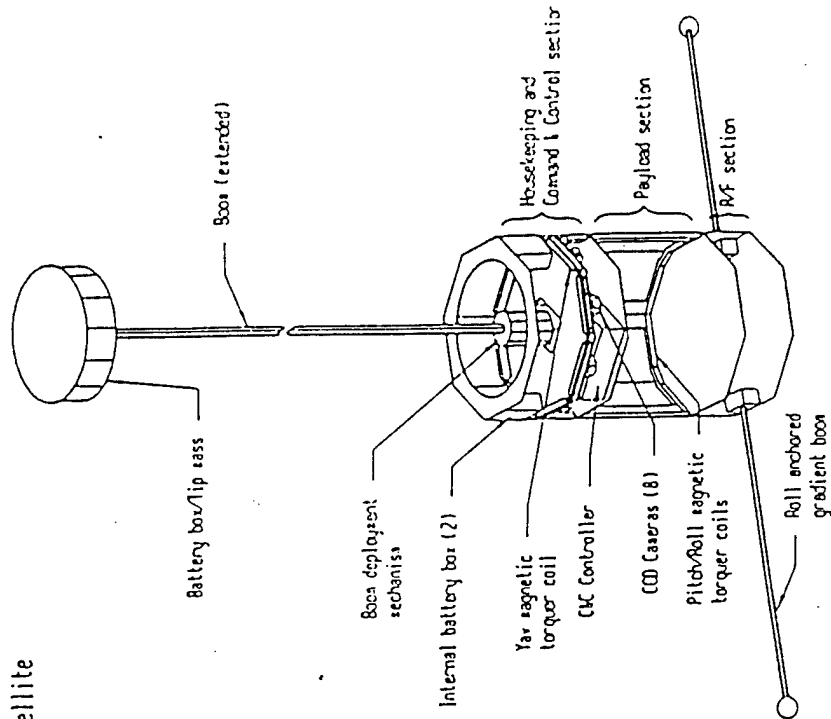


Measurement of Surface reactions in the Space environment

OUTREACH

NASA IITC Satellite

GS-100



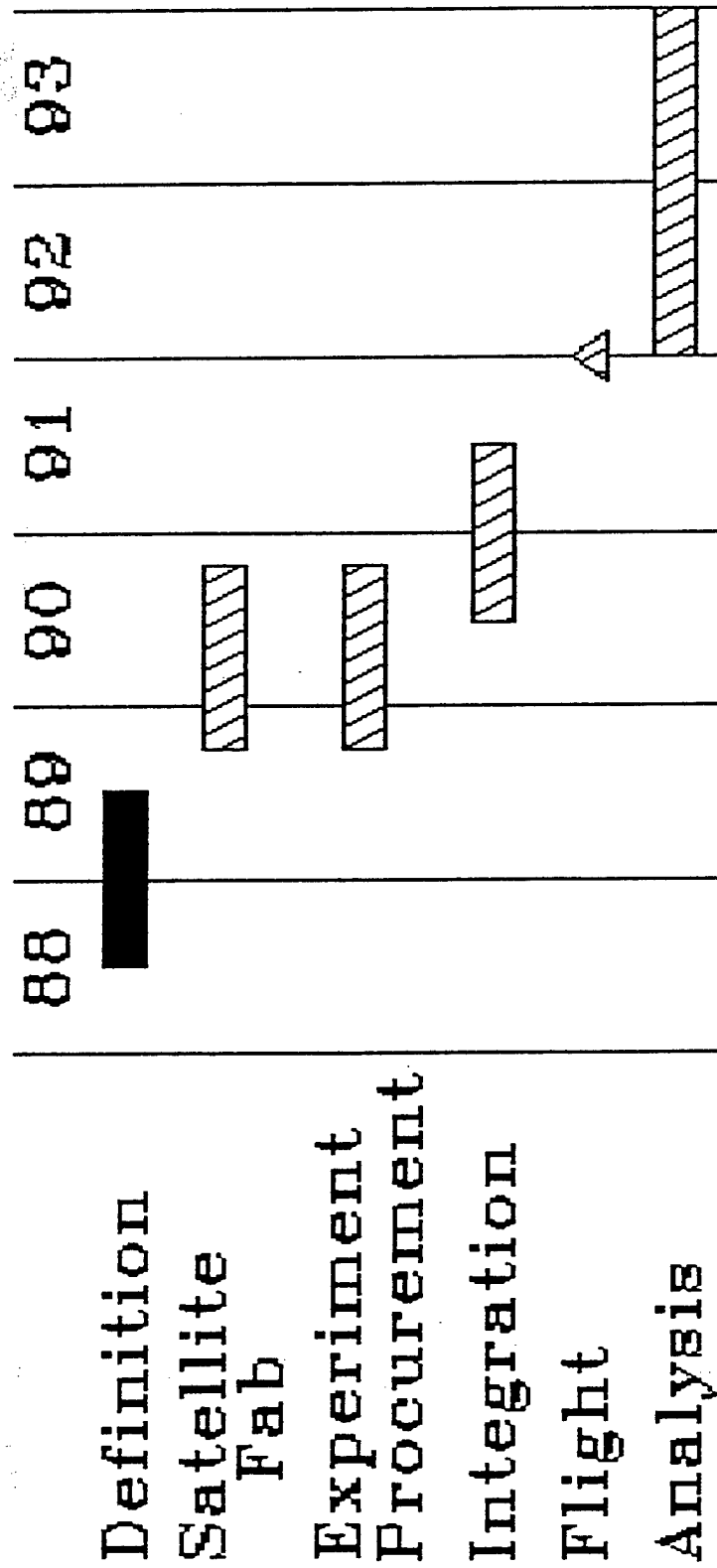
Measurement Techniques Under Consideration

- Mass Spectrometer
- Q C M
- Osmium Detectors
- Surface erosion measurements

Optical

S E M

Scattering



OPTICAL PROPERTIES MONITOR (OPM) EXPERIMENT

Donald R. Wilkes
John M. Cockerham & Associates

Contract No: NAS8-37755
NASA Marshall Space Flight Center
Jim Zwiener

18-2778-1188

OUTREACH EXPERIMENT DEFINITION STUDY	Optical Properties Monitor (OPM) Experiment	John M. Cockerham & Associates
<u>EXPERIMENT OBJECTIVE</u> To study the effects of the space environment, both natural and induced, on optical materials and thermal surfaces. • Develop a multifunction, reusable flight instrument for in-space optical studies • Determine the effects and damage mechanisms of the space environment on optical materials and thermal surfaces • Provide flight testing of critical spacecraft and optical materials • Validate ground test facilities and techniques		
18-2778-1188		

BACKGROUND

- The natural and induced space environment can damage spacecraft materials
- Space environmental effects and damage mechanisms are not well understood
- The space environment cannot be fully simulated
- There have been only limited in-space optical measurements of material properties

TECHNOLOGY NEED

- Longer duration, and more complex missions, such as Space Station, require better materials and better materials performance characterization
- A better understanding of space environmental damage mechanisms will lead to:
 - Better, more stable materials and coatings
 - Better, more accurate ground simulation testing
- Improved materials and better material performance characterization will lead to better, more cost effective, lower weight space systems designs
- A multifunction, reusable flight instrument is needed for in-space optical studies

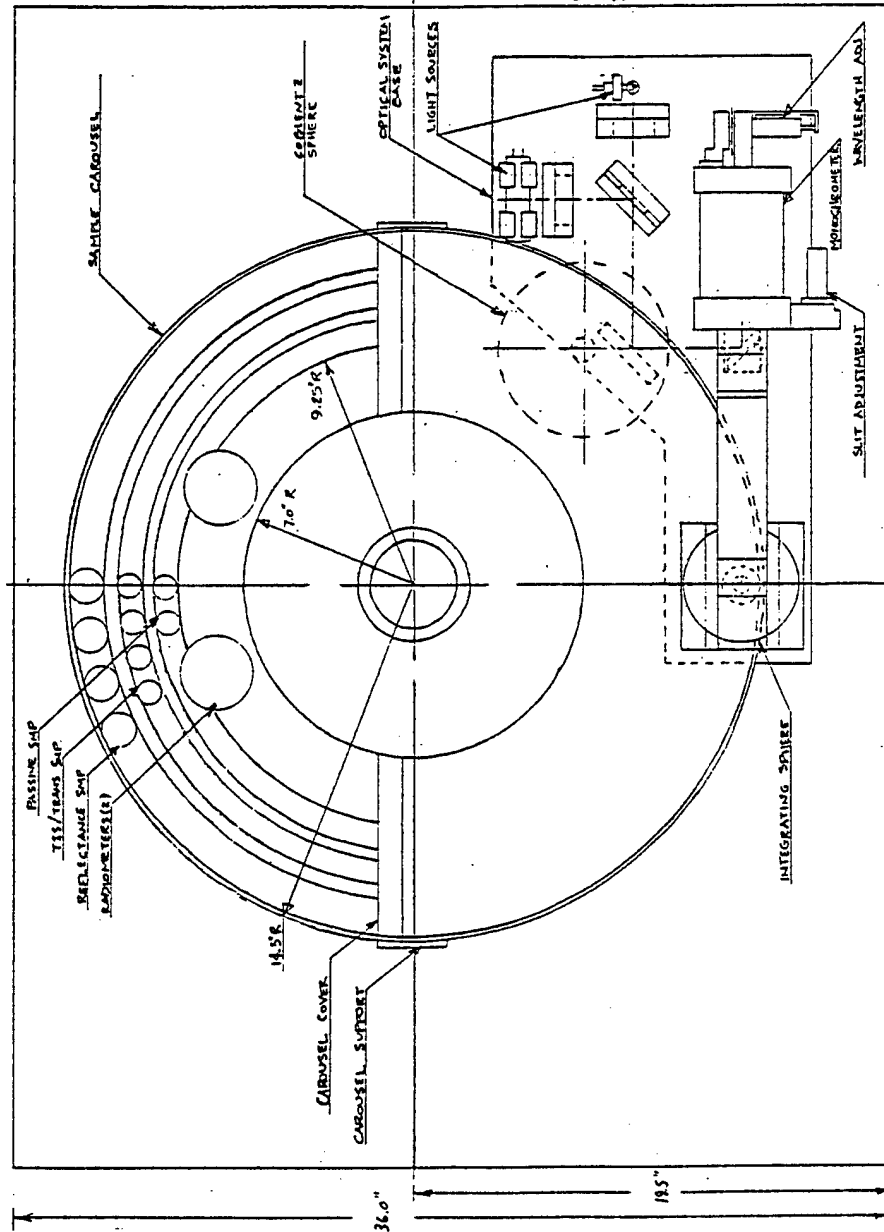
EXPERIMENT DESCRIPTION

Selected materials will be exposed to the near earth space environment and the effects measured through in-situ and post flight analysis.

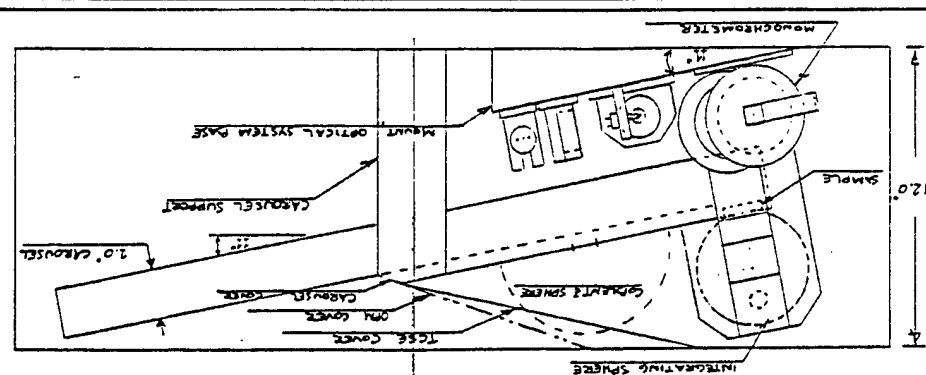
- Active sample optical and thermal properties are measured by the in-situ measurement subsystem
 - Spectral total hemispherical reflectance - Integrating Sphere
 - Total integrated scatter - Coblentz Sphere
 - Spectral Transmittance
 - Total emittance/solar absorptance - Calorimetric Method
- Environmental monitors measure the sample exposure environment
 - Solar/earth irradiance - Radiometers
 - Molecular contamination - Temperature controlled quartz crystal microbalance
 - Atomic oxygen
- Passive sample optical and thermal properties, surface degradation, and surface contamination are determined by post-flight analysis.

OPM SKETCH

Plan



Elevation



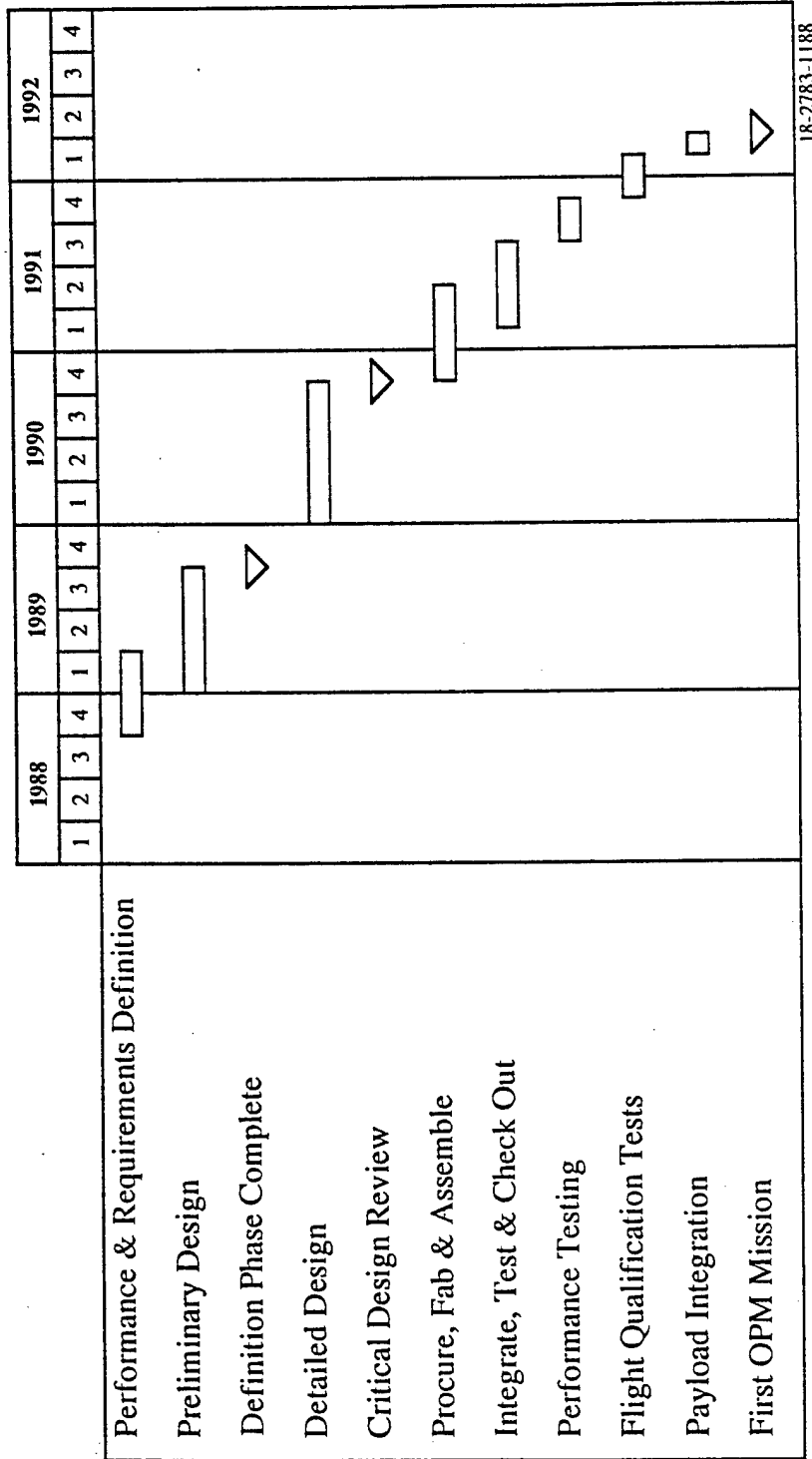
18-2778-1188

**OUTREACH
EXPERIMENT
DEFINITION STUDY**

**Optical Properties Monitor (OPM)
Experiment**

John M. Cockerham
& Associates

OPM SCHEDULE



18-2783-1188

18-2778-1188

OPM SUMMARY

- Definition phase effort is underway (September 16, 1988)
- Basic flight hardware concept proven on the LDEF Thermal Control Surfaces Experiment (TCSE)
- Total Integrated Scatter (TIS) and transmission measurements are added to the TCSE design
- Environmental monitors for molecular contaminants and atomic oxygen are added to the TCSE design
- The TIS measurement system design will be verified by laboratory breadboard testing
- 1978 TCSE design will be modernized to current technology
- OPM mission opportunities are being researched
- An OPM advisory committee is being formed

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SPACE ENVIRONMENTAL EFFECTS	IN-SPACE TECHNOLOGY EXPERIMENTS WORKSHOP DECEMBER 6-9, 1988	ATMOSPHERIC EFFECTS AND CONTAMINATION

EXPERIMENTAL INVESTIGATION OF SPACECRAFT GLOW

GARY SWENSON

LOCKHEED PALO ALTO RESEARCH LABORATORY *
LOCKHEED MISSILES & SPACE COMPANY, INC.
PALO ALTO, CALIFORNIA

* TEAMED WITH LOCKHEED HOUSTON (LEMSCO) FOR STRUCTURE AND INTEGRATION

CONTRACT NAS9-17969
JOHNSON SPACE CENTER
JIM VISENTINE, ES5

OUTREACH	EXPERIMENTAL INVESTIGATION OF SPACECRAFT GLOW	

Experiment Objective

Develop understanding of the physical processes leading to spacecraft glow phenomena, with emphasis on surface temperature and altitude effects. This development can be used to:

- Characterize optical instrument backgrounds
- Provide guidelines for thermal insulations
- Characterize material selection for flight optics and associated spacecraft
- Affect flight-operation altitude selection for relevant missions

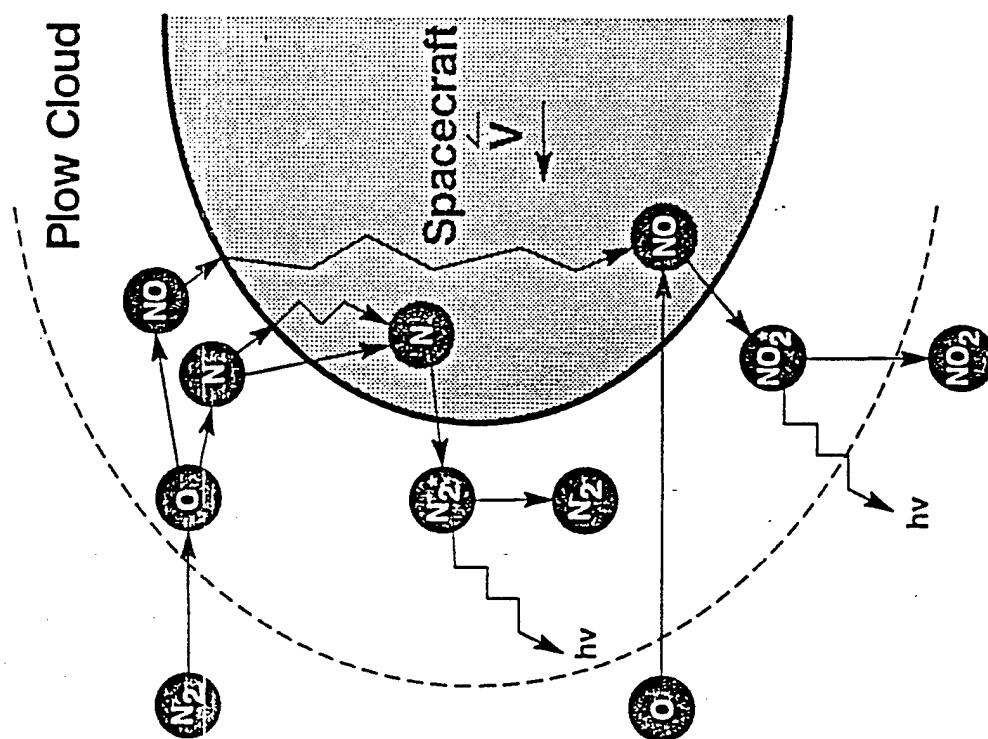
OUTREACH	EXPERIMENTAL INVESTIGATION OF SPACECRAFT GLOW	

Background/Technology Need

Experimental data from STS missions suggest that cold surfaces result in increased surface catalysis with atmospheric constituents, resulting in brighter glow.

Confirming spectral and intensity data are needed from a temperature-monitored surface in ram. Intensities at different altitudes are desired in order to understand the synergistic effect of multiple atmospheric species. Spectral and intensity data from ultraviolet and infrared wavelengths are also required.

Why a space experiment? Glow contamination results from large fluxes ($>10^{13} \text{ cm}^{-2}$) of fast atmospheric constituents (4–10 eV), catalytically reacting on surfaces to form excited-state molecules which emit glow. The combined fluxes and energies are not reproducible in ground facilities.

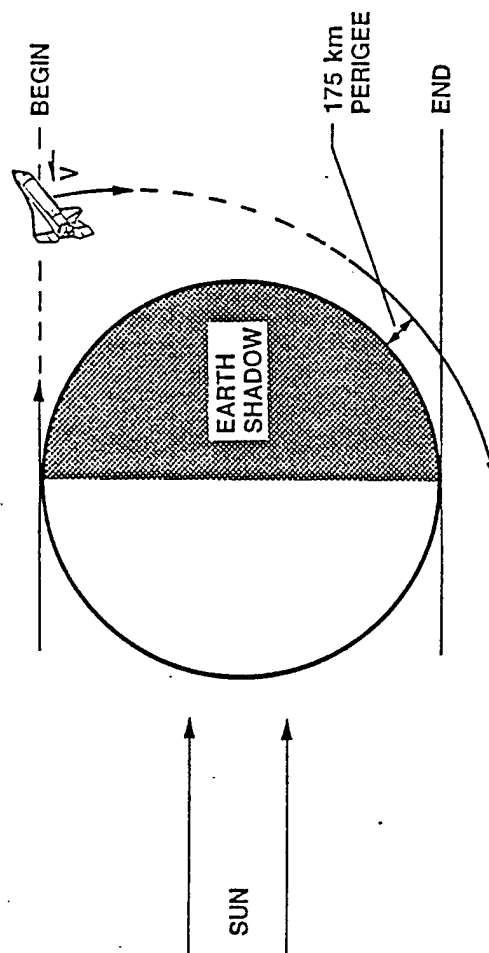


Spacecraft-Atmospheric Interaction

The top of the figure shows atmospheric N_2 interacting with rebounding O and atom exchanging to form N and NO . The N is shown to contact N which has been deposited on the surface, and to recombine to form N_2^+ . This excited state leads to N_2 LBH emission which is predicted to be responsible for the low-altitude glow seen on the S3-4 satellite. The bottom of the figure illustrates atmospheric O impinging on NO which is weakly bound to the surface. The surface recombination will lead to NO_2 and has been proposed as being responsible for the "red" shuttle glow.

Experiment Description

The experiment hardware will include a 1 x 1 m flat plate with a material sample. The plate will be directed into atmospheric ram direction on orbit. The instrumentation includes a visible imaging spectrometer (400-800 nm), an IR detector (1-3 μm), and a far-ultraviolet imaging spectrometer (110-300 nm). The instrumentation will be mounted on an MPESS structure. An uplink command will activate the experiment, and an onboard recorder will log the data. Operation during four "shadowed" orbit periods is desired, at low altitude. At least two orbits of 175-km perigee are desired (as part of the STS reentry sequence).

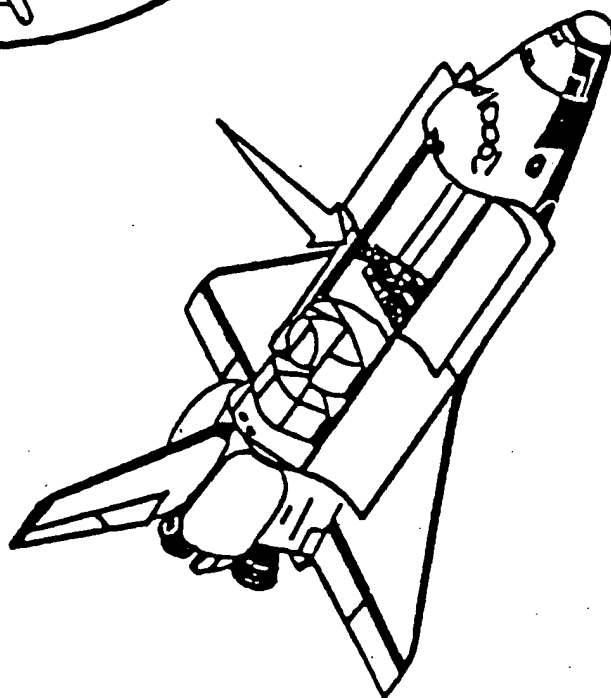
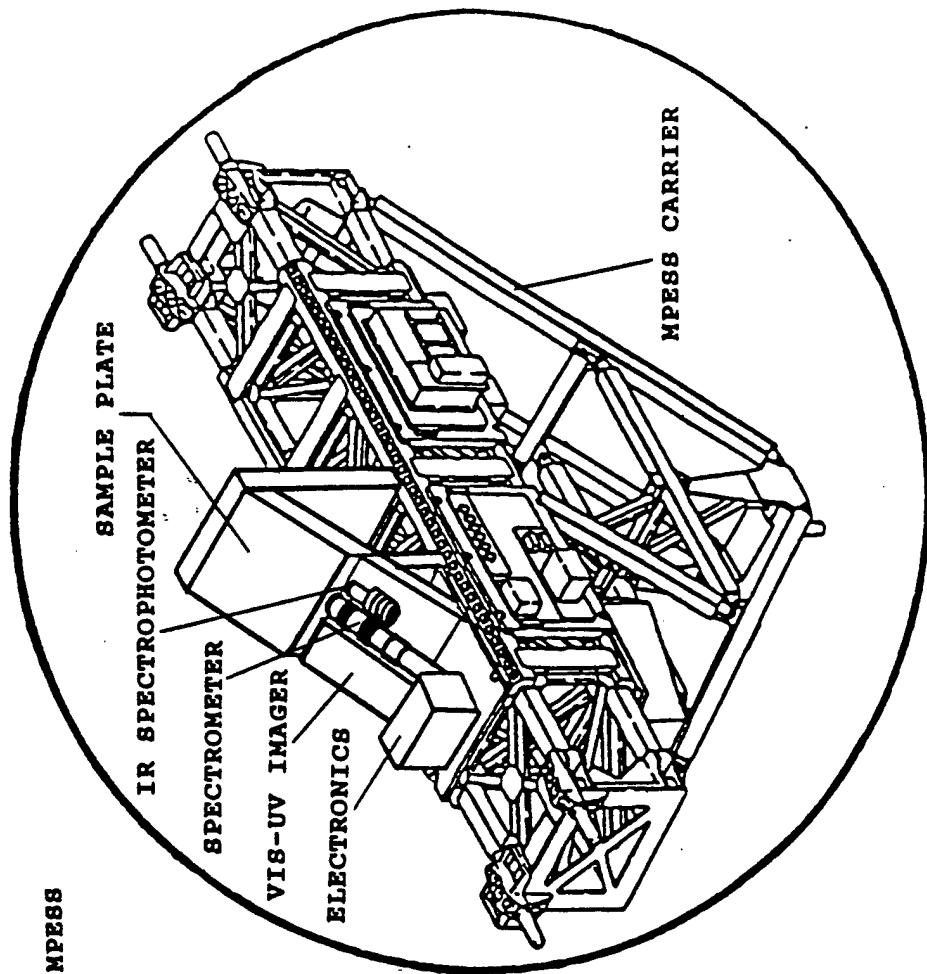


OUTREACH	EXPERIMENTAL INVESTIGATION OF SPACECRAFT GLOW	

Breadboard Tests for Functionality, Response, and Sensitivity

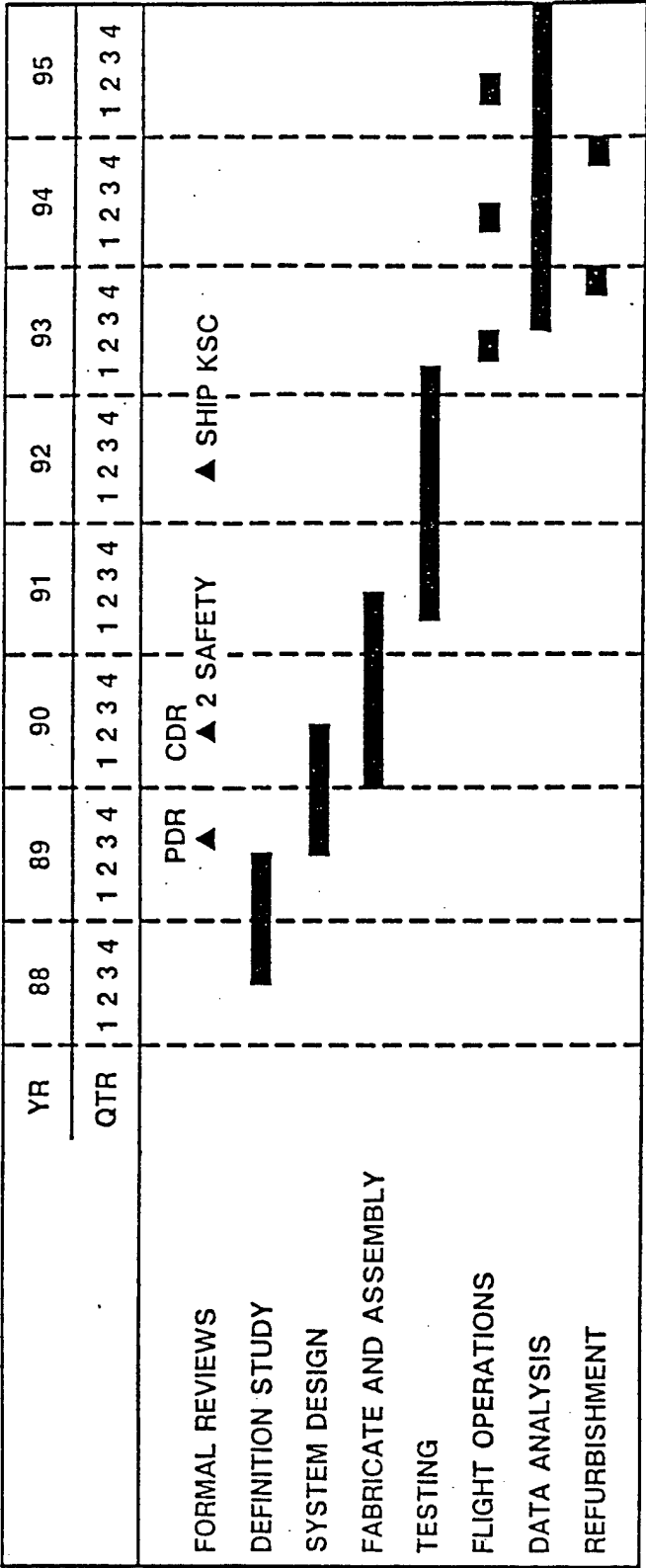
- Breadboard an image detector for the far-ultraviolet imaging spectrometer
 - Gated intensifier, plug coupled to a CCD
 - 110–300-nm response
 - RbTe photocathode
 - 25-mm diameter
 - 388×480 CCD array, thermoelectrically cooled to 230 K
 - Digital output
- Breadboard an IR detector
 - Dewar resident, single element
 - 1–5.5- μm response
 - InSb element
 - Joule-Thompson cooled to 77 K
 - High-gain analog output

- THE EXPERIMENT MAY ALSO BE FLOWN ON THE MPSS WITH THE HITCHHIKER-M SYSTEM.



GLOW EXPERIMENT SHOWN ON MPSS CARRIER WITH STANDARD MSL CONFIGURATION

MASTER SCHEDULE



SPACE ENVIRONMENTAL EFFECTS	IN-SPACE TECHNOLOGY EXPERIMENTS WORKSHOP DECEMBER 6-9, 1988	ATMOSPHERIC EFFECTS AND CONTAMINATION

RETURN FLUX EXPERIMENT (REFLEX)

**J.J. TRIOLO
R. MCINTOSH**

NASA GODDARD SPACE FLIGHT CENTER

IN-REACH	RETURN FLUX EXPERIMENT (REFLEX)	NASA / GSFC

EXPERIMENT OBJECTIVES

* CONTAMINATION MEASUREMENTS

- FULLY CHARACTERIZE THE S/C MOLECULAR CONTAMINATION ENVIRONMENT
- TOTAL CONTAMINATION ACCRETION FROM DIRECT FLUX AND RETURN FLUX
- INDIVIDUAL SPECIES ACCRETION FROM DIRECT FLUX AND RETURN FLUX
- VERIFICATION OF ALL AVAILABLE MASS TRANSFER CODES (NEWLY DEVELOPED AND CURRENT)
- VELOCITY/DIRECTION OF EACH SPECIE
- CHEMISTRY OF NATURAL + INDUCED SPECIES (GAS PHASE AND HETEROGENEOUS REACTIONS)

* NATURAL ENVIRONMENT CHARACTERIZATION

- DIRECT MEASUREMENT OF CONCENTRATION OF SPECIES IN THE NATURAL ENVIRONMENT (ATOMIC OXYGEN, ATOMIC NITROGEN, O₂, N₂, CO, NO, AR, ETC.)

IN-REACH	RETURN FLUX EXPERIMENT (REFLEX)	NASA / GSFC

BACKGROUND/TECHNOLOGY NEED

- AVAILABLE DATA ON SPACECRAFT INDUCED ENVIRONMENT IS VERY SPARSE. NO SYSTEMATIC EFFORT TO MEASURE THE CONTAMINATION ENVIRONMENT AS A FUNCTION OF MISSION PARAMETERS HAS BEEN MADE TO DATE.
- EXISTING CONTAMINATION MODELS ARE NOT FLIGHT VERIFIED. THE MEAGER AMOUNT OF FLIGHT DATA SEEMS TO INDICATE GROSS INACCURACIES IN SOME AREAS (PARTICULARLY FOR THE RETURN FLUX COMPONENT OF THE MOLECULAR ENVIRONMENT).
- FLIGHT EXPERIMENTS ARE URGENTLY NEEDED TO GATHER DATA IN AN ORGANIZED MANNER.
- RELIABLE PREDICTIONS WILL ALLOW GREAT ECONOMICAL ADVANTAGE IN THE SIZING OF THE CONTAMINATION CONTROL ACTIVITIES FOR A LARGE NUMBER OF NASA PROGRAMS.

IN-REACH	RETURN FLUX EXPERIMENT (REFLEX)	NASA / GSFC

EXPERIMENT DESCRIPTION

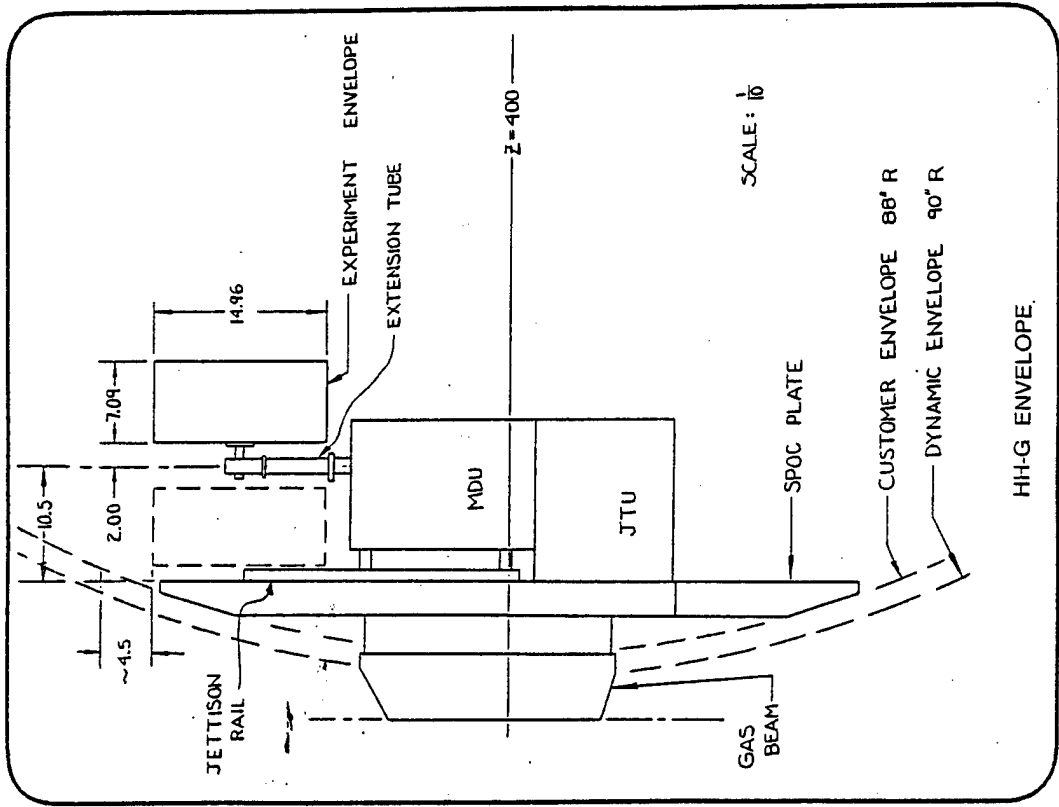
- MAJOR EXPERIMENT COMPONENTS:

- 1) - SENSOR: MASS SPECTROMETER
- 2) - MOLECULAR SOURCE: NOBLE GAS
- 3) - CARRIER: TBD

- COMPONENT FUNCTION:

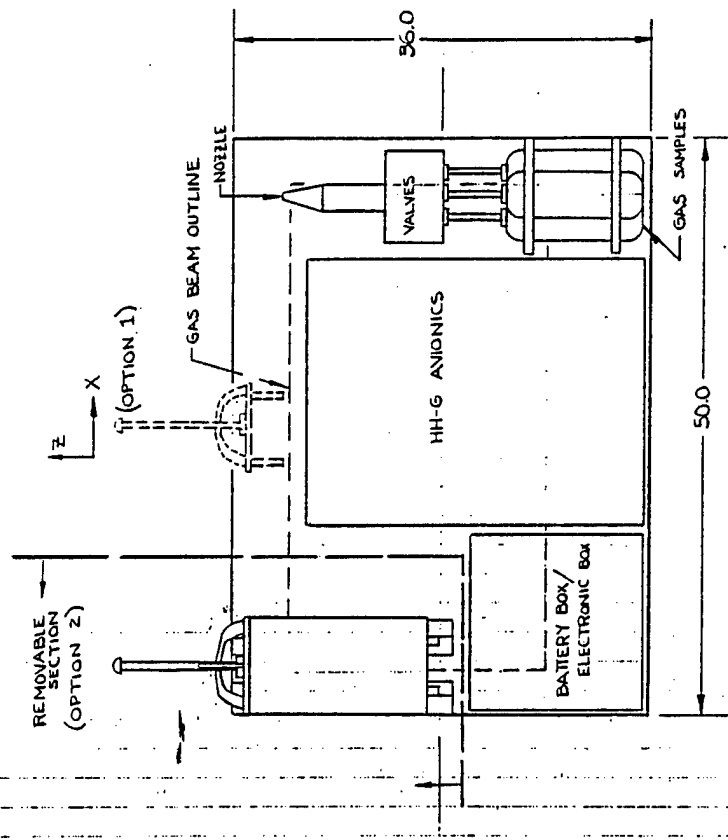
- 1) - SENSOR: DETECTION OF ALL MOLECULAR SPECIES OF INTEREST IN BOTH NATURAL AND SPACECRAFT INDUCED ENVIRONMENTS. CHEMICAL NATURE AND VELOCITY ARE OBTAINED AS A FUNCTION OF TIME.
- 2) - MOLECULAR SOURCE: PROVIDES A KNOWN INPUT TO THE S/C ENVIRONMENT FOR RETURN FLUX MEASUREMENTS.
- 3) - CARRIER: ALLOWS POSITIONING OF THE EXPERIMENT PACKAGE TO LOW/ZERO BACKGROUND LOCATIONS FOR EXTREMELY ACCURATE MEASUREMENTS OF LOW INTENSITY PHENOMENA (RETURN FLUX).

IN-REACH	RETURN FLUX EXPERIMENT (REFLEX)	NASA / GSFC



IN-REACH	RETURN FLUX EXPERIMENT (REFLEX)	NASA / GSFC

SCALE ~ 1/10



RMS CONFIGURATION
(FRONT VIEW)

IN-REACH	RETURN FLUX EXPERIMENT (REFLEX)	NASA / GSFC

SCHEDULE

- COMPLETE PHASE A: NOV 88
- PHASE B START: JAN 89
- PHASE C/D START: JAN 90

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SPACE ENVIRONMENTAL EFFECTS	IN-SPACE TECHNOLOGY EXPERIMENTS WORKSHOP DECEMBER 6-9, 1988	METEROIDS AND DEBRIS

DEBRIS COLLISION WARNING SENSORS

FAITH VILAS
DAVID THOMPSON

SOLAR SYSTEM EXPLORATION DIVISION
JOHNSON SPACE CENTER

IN REACH	DEBRIS COLLISION WARNING SENSORS	JOHNSON SPACE CENTER

EXPERIMENT OBJECTIVE:

CHARACTERIZE STATISTICALLY THE LEO DEBRIS ENVIRONMENT, CONCENTRATING ON OBSERVING DEBRIS OF SIZES DOWN TO 1 mm DIAMETER; OBTAINING BOTH VISIBLE PHOTOMETRY (~0.56 μ m) AND THERMAL RADIOMETRY (5 μ m). TEST DETECTOR EFFECTIVENESS FOR SPACECRAFT DEBRIS COLLISION WARNING SYSTEM. DATA ACQUIRED WILL USED TO:

- MODEL EFFECTS (NOISE SOURCES, FALSE SIGNALS) WHICH SMALL DEBRIS PIECES COULD HAVE ON DEBRIS COLLISION WARNING SYSTEM OPERATION.
- OPTIMIZE DETECTOR SELECTION FOR DCW BY UNDERSTANDING ALBEDO VALUES AND THERMAL HEATING PROPERTIES OF LEO DEBRIS.
- CALCULATE DEBRIS FRAGMENT SIZES WITH ACCURATE ALBEDO MEASUREMENT.

IN REACH	DEBRIS COLLISION WARNING SENSORS	JOHNSON SPACE CENTER

BACKGROUND/TECHNOLOGY NEED

- LEO DEBRIS POPULATION INCREASING, PRODUCING INCREASED HAZARD TO SPACECRAFT.
- NEW CONCEPTS FOR PROTECTING SPACECRAFT MUST BE DEVELOPED.
 - ON-BOARD DETECTION WILL PROBABLY PLAY A KEY ROLE.
 - REQUIRES SCIENTIFIC TECHNIQUE AND TECHNOLOGY DEVELOPMENT.
- DATA AMOUNT AND QUALITY ARE WORST IN SIZE (1mm-10cm), SPECTRAL RANGES (0.56 μ m, 5 μ m) WHERE INFORMATION IS MOST CRITICAL TO DEBRIS COLLISION WARNING SYSTEM DESIGN.

IN REACH	DEBRIS COLLISION WARNING SENSORS	JOHNSON SPACE CENTER

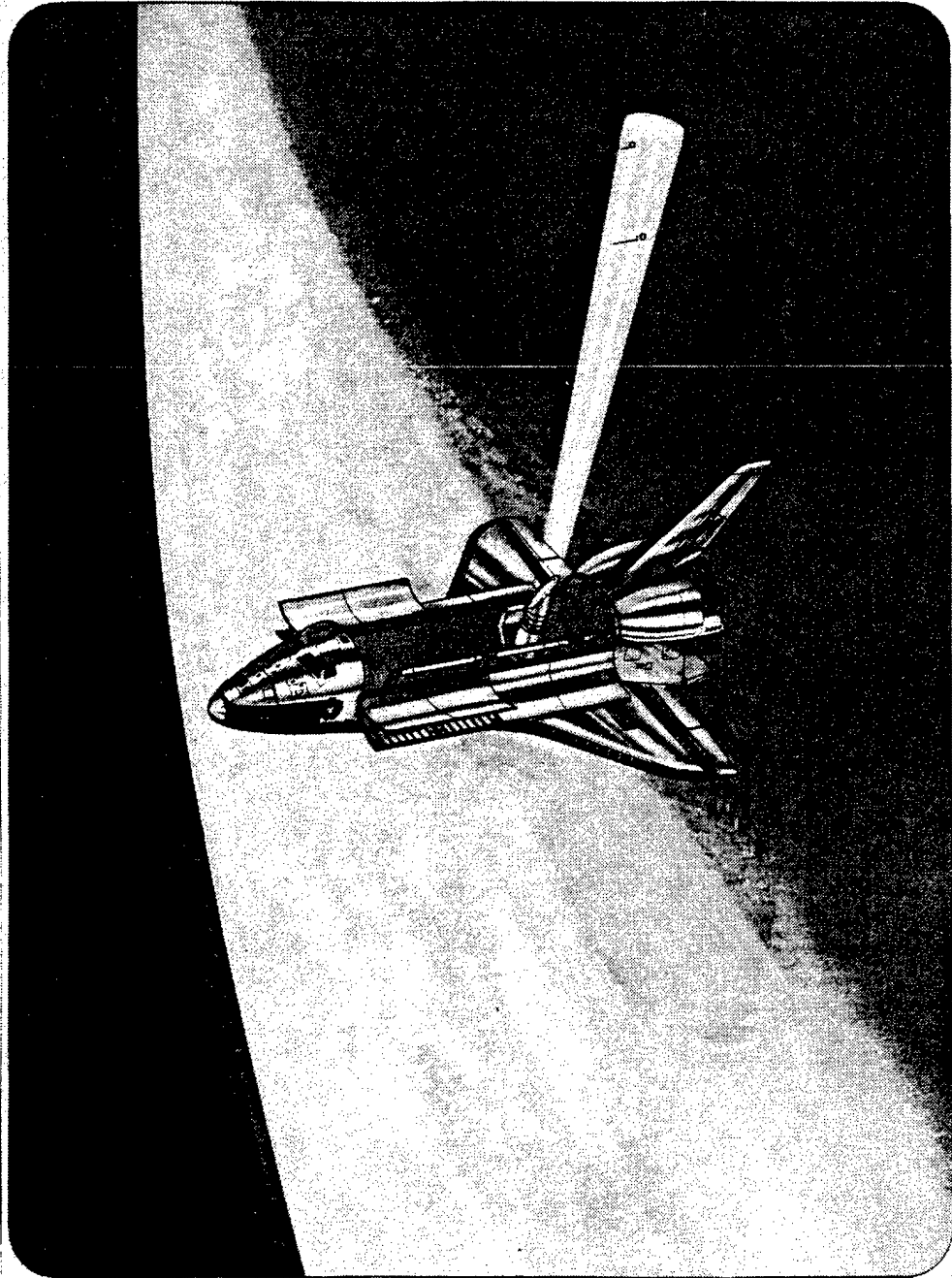
EXPERIMENT DESCRIPTION

THE APPARATUS WILL CONSIST OF ONE 60-IN. F/1.2 TELESCOPE HAVING ALL-REFLECTING OPTICS WITH A 3.7° FIELD OF VIEW. A TEKTRONIX 2048x2048 PIXEL CCD RINGED BY SINGLE-ELEMENT 5-μm DETECTORS, OPERATING AT A READOUT RATE OF ONE FRAME EVERY 1/10 SEC, IS LOCATED IN THE FOCAL PLANE. VISIBLE PHOTOMETRY, THERMAL RADIOMETRY, AND VELOCITY DATA CAN BE ACQUIRED ON DEBRIS PIECES PASSING THROUGH THE TELESCOPE'S FOV. EXPERIMENT MODES INCLUDE A BLIND SEARCH FOR DEBRIS DOWN TO 1mm DIAMETER, OBSERVATIONS OF KNOWN DEBRIS PIECES TRACKED BY USSPACECOM.

IN REACH

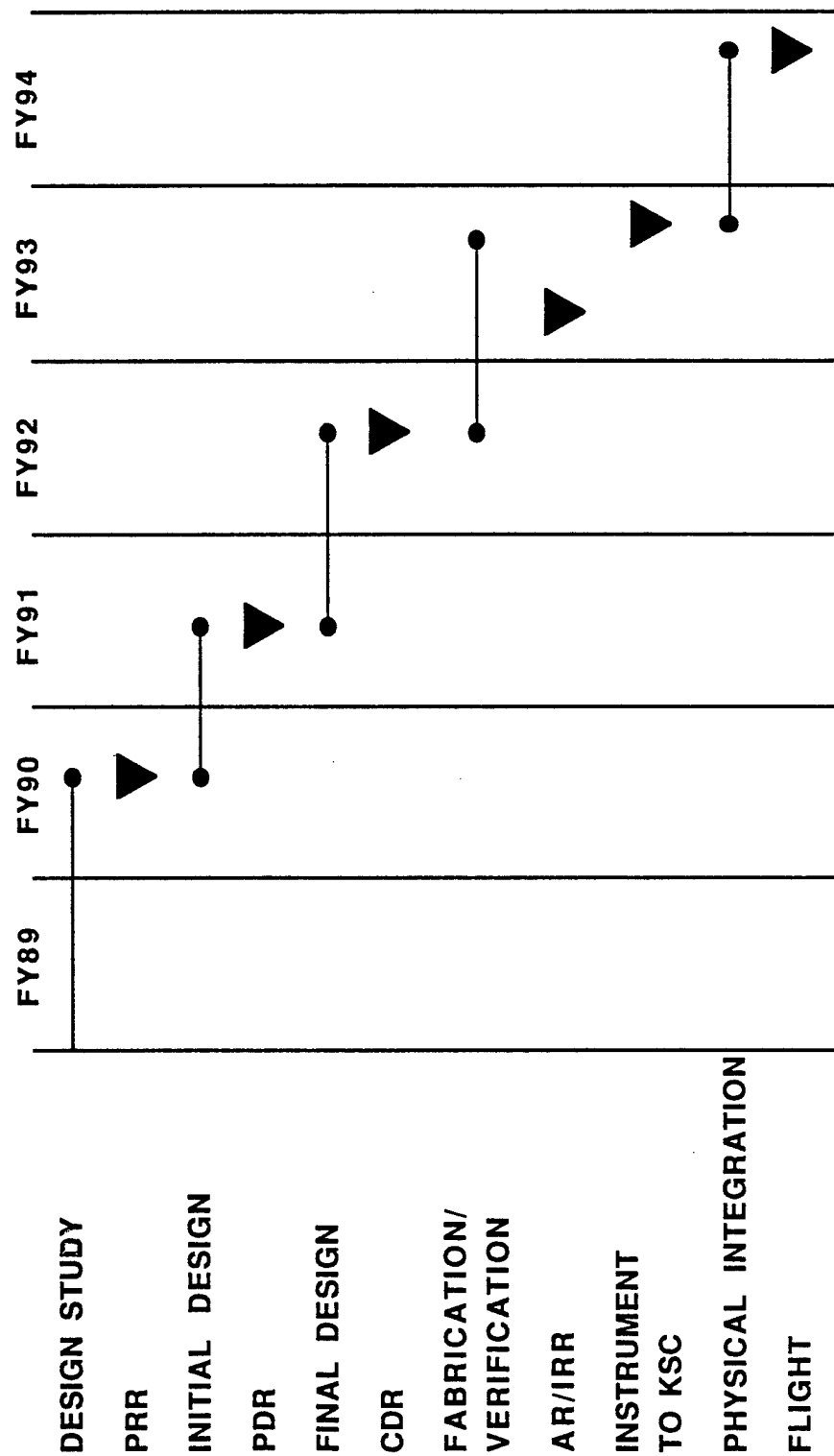
DEBRIS COLLISION WARNING SENSORS

JOHNSON
SPACE
CENTER



IN REACH	DEBRIS COLLISION WARNING SENSORS	JOHNSON SPACE CENTER

PRELIMINARY SCHEDULE FOR PROPOSED
FLIGHT EXPERIMENT



SPACE ENVIRONMENTAL EFFECTS	IN-SPACE TECHNOLOGY EXPERIMENTS WORKSHOP DECEMBER 6-9, 1988	ATMOSPHERIC EFFECTS AND CONTAMINATION

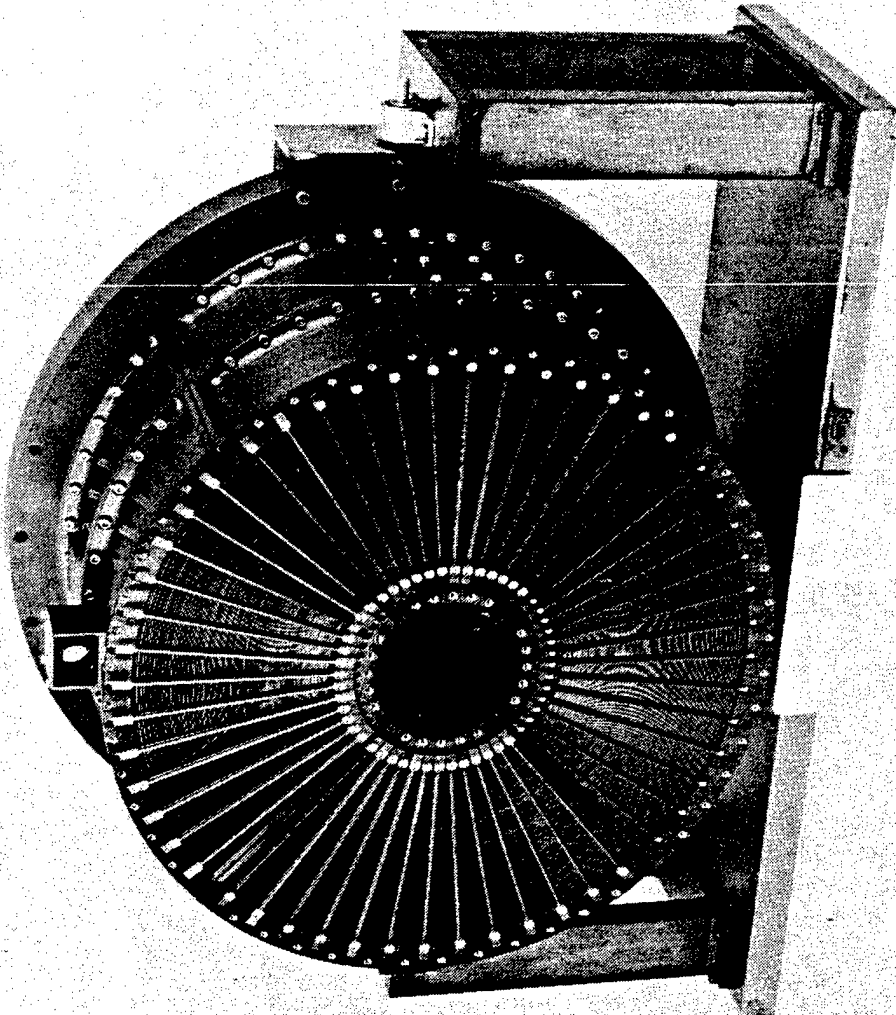
THIN FOIL X-RAY OPTICS SPACE ENVIRONMENT CONTAMINATION EXPERIMENT

**R. PETRE
P.J. SERLEMITOS
C.A. GLASSER**

NASA / GODDARD SPACE FLIGHT CENTER

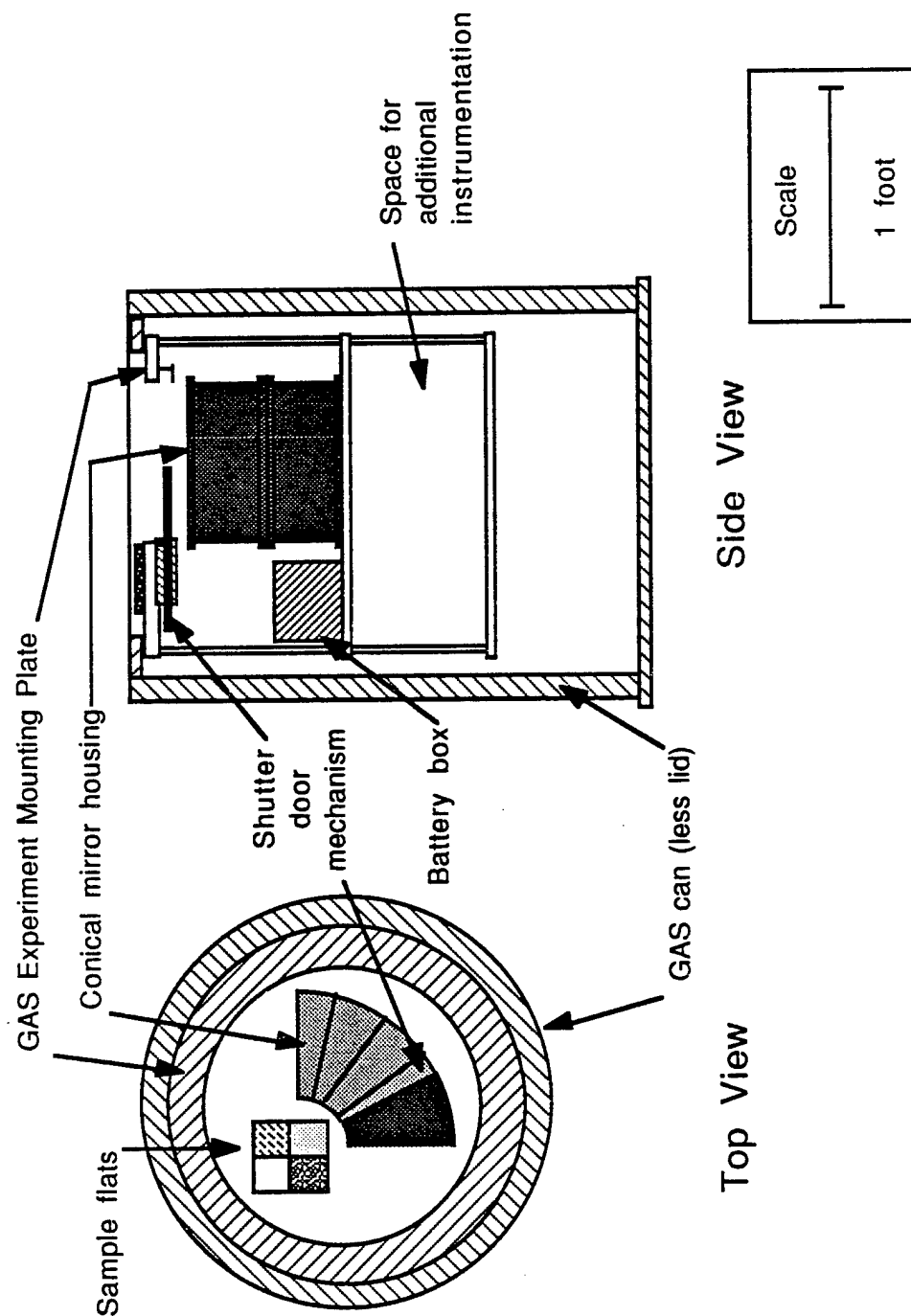
In-Reach	Thin Foil X-Ray Optics Space Environment Contamination Experiment	NASA/GSFC
Experiment Objective: Expose thin-foil, lacquer-coated, grazing incidence X-ray reflectors to low earth orbit environment in order to: 1. Measure the degradation of X-ray reflection efficiency of candidate mirror surfaces due to interaction with atomic oxygen 2. Determine the effectiveness of protective measures		

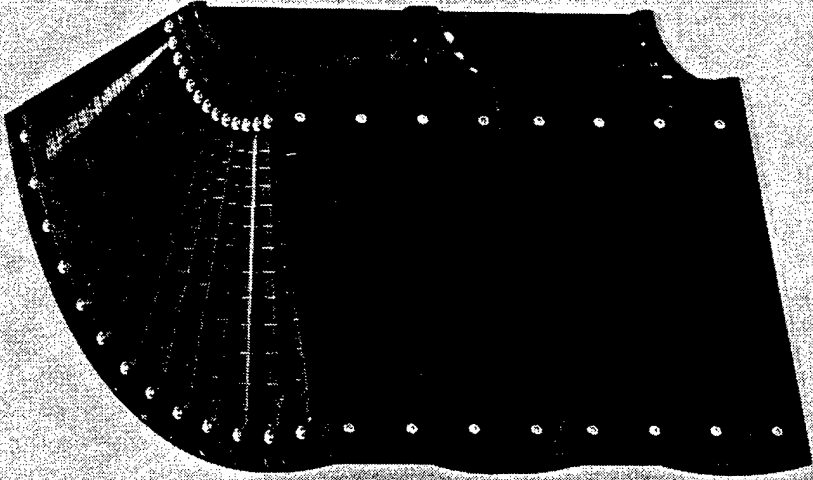
In-Reach	Thin Foil X-Ray Optics Space Environment Contamination Experiment	NASA/GSFC
Background: • Thin-foil, conical imaging X-ray mirrors represent new technology X-ray astronomy instrumentation • Mirror technology developed entirely within NASA (GSFC) • Grazing incidence reflecting surfaces consist of lacquer-coated, high reflectivity aluminum foil, with evaporated 500 Angstrom gold layer • Initial implementation on Broad Band X-Ray Telescope (STS-35, March 1990) • Will be used or being studied for use on several long term X-ray astronomy missions: - ASTRO-D, 1993 (Japan/USA) - Spectrum-X , 1994 (USSR/Denmark/USA) - Spektrosat, 1994 (W. Germany/USA) • Lacquer coating technology has direct applications for other kinds of X-ray mirrors and for far and extreme ultraviolet optics • Unclear how previous contamination studies relate to grazing incidence or lacquer coated surfaces, or to X-ray reflectivity		

In-Reach	Thin Foil X-Ray Optics Space Environment Contamination Experiment	NASA/GSFC
NASA National Aeronautics and Space Administration Goddard Space Flight Center Greenbelt, Maryland 20771 D-88-4367		Thin-foil conical imaging X-ray mirror for the Broad Band X-Ray Telescope instrument

In-Reach	Thin Foil X-Ray Optics Space Environment Contamination Experiment	NASA/GSFC
Experiment Description Baseline approach - low cost, minimal STS interface Strategy - use GAS carrier, develop hardware quickly to allow possibility of manifesting with larger experiments with similar mission requirements (e.g., EOIM-3, IFCE) Key Components - Conical mirror quadrant - holds reflector samples at proper incidence angles Sample tray - holds thin foil mirror samples at normal incidence Shutter mechanism - shuts slowly over duration of experiment to allow determination of degradation vs. exposure time Carrier - GAS can with Motorized Door Assembly		

Thin Foil Mirror Contamination Experiment



In-Reach	Thin Foil X-Ray Optics Space Environment Contamination Experiment	NASA/GSFC
 Thin-foil conical mirror quadrant to be used for holding samples for contamination experiment		

3. POWER SYSTEMS AND THERMAL MANAGEMENT

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SODIUM - SULFUR BATTERY FLIGHT EXPERIMENT DEFINITION

117

CONTRACT NO. NAS3 - 25355
MR. H. F. LEIBECKI
NASA LEWIS RESEARCH CENTER
CLEVELAND, OHIO 44135

PRESENTED BY:

BECKY CHANG
FORD AEROSPACE CORPORATION
SPACE SYSTEMS DIVISION
3825 FABIAN WAY
PALO ALTO, CA 94303

OUTREACH	SODIUM-SULFUR BATTERY FLIGHT EXPERIMENT DEFINITION	FORD AEROSPACE SPACE SYSTEMS DIVISION PALO ALTO, CA

NaS BATTERY TECHNOLOGY BENEFITS -

- \$ 1.1-1.7 M\$/KW SAVING IN LAUNCH FOR GEO MISSION OVER NIH2 BATTERY
- \$ 0.2-0.4 M\$/KW SAVING IN LAUNCH FOR LEO MISSION OVER NIH2 BATTERY

EXPERIMENT OBJECTIVE

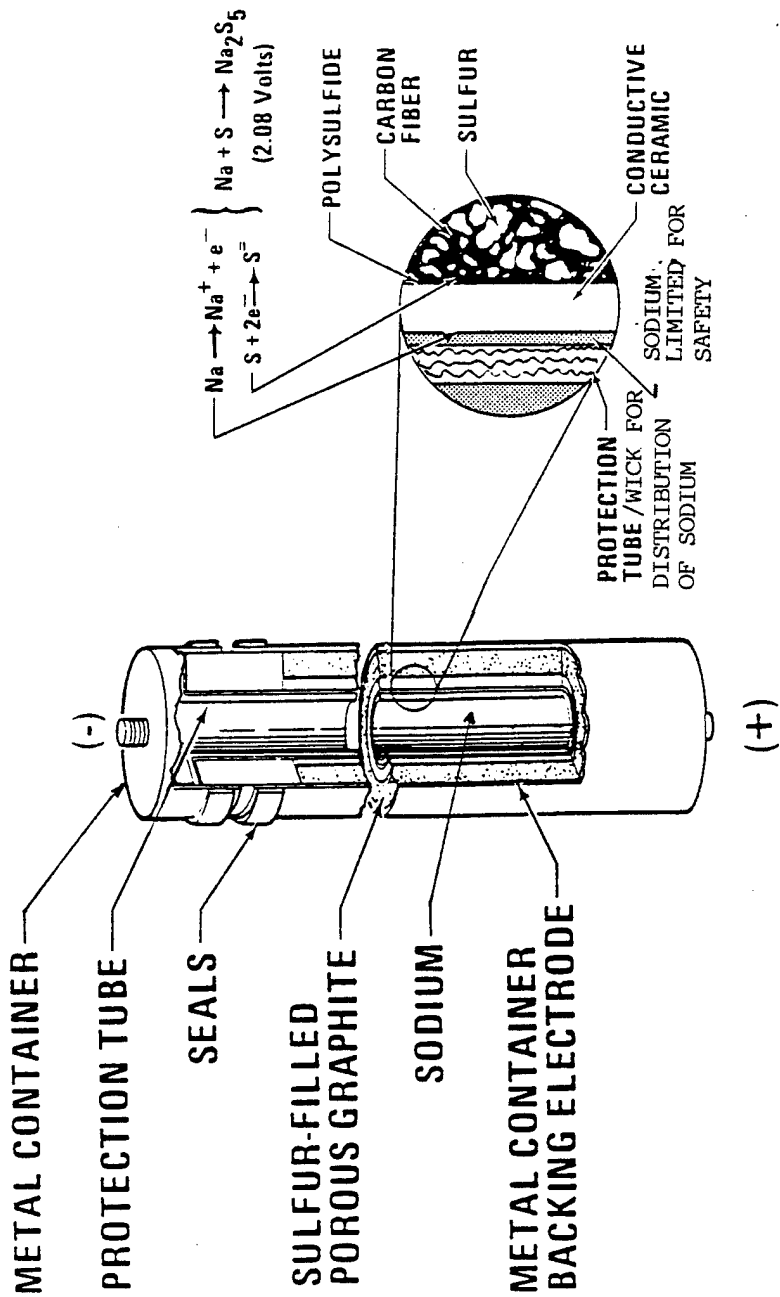
TO DESIGN AN EXPERIMENT THAT WILL DEMONSTRATE OPERATION OF SODIUM-SULFUR BATTERY/CELLS UNDER SPACE ENVIRONMENTS WITH PARTICULAR EMPHASIS ON EVALUATION ON MICROGRAVITY EFFECTS.

- O TO EVALUATE CHARGE AND DISCHARGE CHARACTERISTICS AS AFFECTED BY FLUID REACTANT DISTRIBUTIONS
- O TO DETERMINE REACTANT DISTRIBUTIONS UNDER MICROGRAVITY CONDITION
- O TO UNDERSTAND CURRENT & THERMAL DISTRIBUTION WITHIN CELLS
- O TO EVALUATE FREEZE THAW EFFECTS
- O TO EVALUATE COLD VS WARM LAUNCH
- O TO EVALUATE MULTICELL OPERATION

SODIUM-SULFUR BATTERY FLIGHT EXPERIMENT DEFINITION

Ford FORD AEROSPACE
SPACE SYSTEMS DIVISION
PALO ALTO, CA 94303

BACKGROUND /TECHNOLOGY



OUTREACH

**SODIUM-SULFUR BATTERY
FLIGHT EXPERIMENT DEFINITION**

 **FORD AEROSPACE
SPACE SYSTEMS DIVISION
PALO ALTO, CA 94303**

EXPERIMENTAL APPROACH

- O SELECT ONLY THOSE TESTS THAT ARE CRITICAL AND EXPECTED TO DIFFER UNDER MICROGRAVITY CONDITION.
- O 'SPINNERS' CAN BE DUPLICATED ON EARTH.
- O CORRELATE CELL CHARACTERISTICS BEFORE/DURING/FOLLOWING SPACE FLIGHT TO ELIMINATE EXTRANEOUS VARIABLES
- O INCORPORATE ADDITIONAL CONTROL CELLS

EXPERIMENT DESCRIPTION

I. CELL CHARACTERIZATION TEST

- O RATED 40 AH BASELINE CELLS
- O 8 CELLS FOR SPACE; 4 CELLS FOR GROUND CONTROL
- O COLD LAUNCH
- O TWO OPERATING TEMPERATURES : 275- 300; 350 -375 °C
- O CHARGE RATES: C/5,C/2,3/4C,C PLUS TAPER
- O DISCHARGE RATES C/2; C ; 1.5C, 2C PLUS PULSES TO ~4C
- O CELL IMPEDANCE & EFFICIENCY

II. REACTANT DISTRIBUTION DESTRUCTIVE PHYSICAL ANALYSIS

- O 8 CELLS REUSED AFTER NO.1

OUTREACH

**SODIUM-SULFUR BATTERY
FLIGHT EXPERIMENT DEFINITION**

 **FORD AEROSPACE
SPACE SYSTEMS DIVISION
PALO ALTO, CA 94303**

EXPERIMENT DESCRIPTION (CONTINUED)

III. REACTANT DISTRIBUTION TEST

- O SPECIAL INSTRUMENTED 40 AH CELLS
- O 2 CELLS IN SPACE, 1 CELL ON GROUND
- O TO DETERMINE CURRENT DENSITY VS. AXIAL POSITION
DURING DISCHARGE/CHARGE AND OPEN CIRCUIT

IV. FREEZE/THAW TEST

- O RATED 40 AH BASELINE CELLS
- O 4 CELLS FOR SPACE; 2 CELLS ON GROUND

V. WARM LAUNCH TEST

- O RATED 40 AH BASELINE CELLS
- O 4 CELLS FOR SPACE
- O 200°C PRELAUNCH/LAUNCH

VI. CELL CYCLE TEST

- O MULTI-CELL OPERATION
- O EARLY-LIFE LEO CHARACTERISTICS

SODIUM-SULFUR BATTERY FLIGHT EXPERIMENT DEFINITION



Ford FORD AEROSPACE
SPACE SYSTEMS DIVISION
PALO ALTO, CA 94303

NA-S BATTERY FLIGHT EXPERIMENT DEFINITION MASTER SCHEDULE

[illegible]

OUTREACH

**SODIUM-SULFUR BATTERY
FLIGHT EXPERIMENT DEFINITION**

 **FORD AEROSPACE
SPACE SYSTEMS DIVISION
PALO ALTO, CA 94303**

SUMMARY

- NA-S BATTERY TECHNOLOGY OFFERS SIGNIFICANT PAYOFF FOR SPACE APPLICATIONS, BUT OPERATION IN SPACE ENVIRONMENT IS UNKNOWN.
- FURTHER ENHANCEMENT OF NA-S EXCELLENT PERFORMANCE AND CYCLE LIFE COULD OCCUR DUE TO MORE UNIFORM CONDITION WITHIN CELL DUE TO MICROGRAVITY CONDITIONS.
- SOME HYPOTHESES PREDICT PERFORMANCE LIMITATIONS WITH IMPACT ON CELL LIFE IN LOW-GRAVITY ENVIRONMENTS.
- FLIGHT EXPERIMENTS HAVE BEEN SELECTED TO DOCUMENT AND CORRELATE CRITICAL CELL CHARACTERISTICS UNDER SPACE ENVIRONMENTS WITH KNOWN RESPONSE ON EARTH.
- RESULTING DATA BASE WILL MINIMIZE COSTS OF SUBSEQUENT LARGER-SCALE APPLICATION-SPECIFIC EXPERIMENTS.
- CYCLE LIFE EFFORTS CAN NOT BE ADDRESSED IN SIMPLE STS FLIGHT WOULD REQUIRE-EXTENDED ORBIT EXPERIMENT.

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POWER SYSTEMS AND THERMAL MANAGEMENT	IN-SPACE TECHNOLOGY EXPERIMENTS WORKSHOP DECEMBER 6-9, 1988	CONVENTIONAL POWER SYSTEMS

UNITIZED REGENERATIVE SPE[®] FUEL CELL

TIMOTHY A. NALETTE

SPE[®] is a registered trademark of United Technologies Corp., Hamilton Standard Division



CONTRACT NAS9-18001
JOHNSON SPACE CENTER
MIKE PHAM
LEWIS RESEARCH CENTER
RICK BALDWIN

Experiment Objective:

- Evaluate zero gravity operation of a passive Unitized Regenerative SPE Fuel Cell (URFC) electrical energy storage system
 - Cell module
 - Reversible SPE Fuel Cell / electrolyzer operation
 - Passive phase separation
 - Static vapor feed
 - System
 - Passive fluid management
 - Passive thermal control

Background:

- Existing spacecraft energy storage and fluid management systems are heavy and/or complex
- SPE fuel cells and SPE electrolyzers are mature technologies
- Unitized regenerative fuel cells offer potential reductions in system complexity, weight, and volume

Technology need:

- Reliability is enhanced through the use of passive fluid and thermal management technologies
- Applications include electrical energy storage for Space Station, satellites, rechargeable rover vehicles, peak power requirements, and any orbiting system requiring electrical energy storage

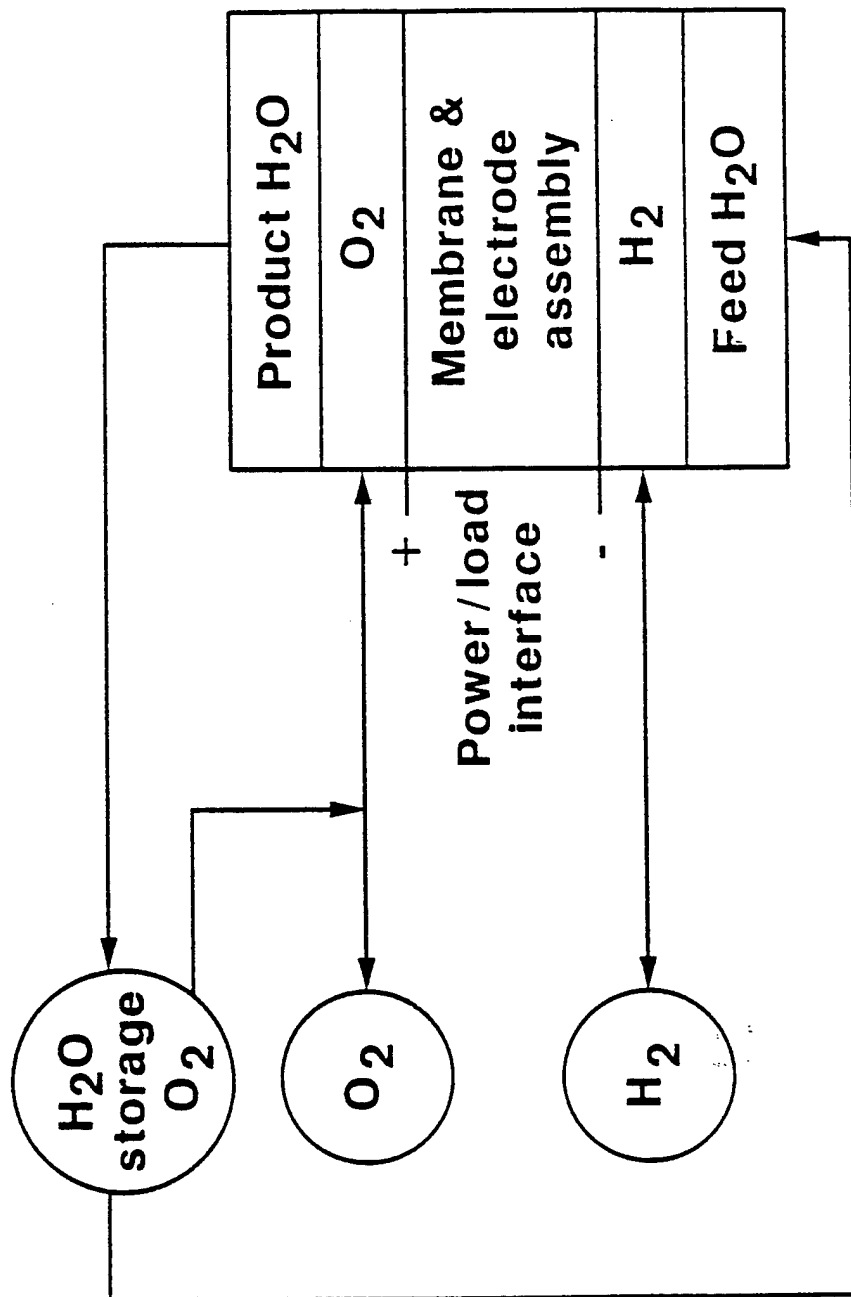
OUTREACH	UNITIZED REGENERATIVE SPE FUEL CELL (URFC)



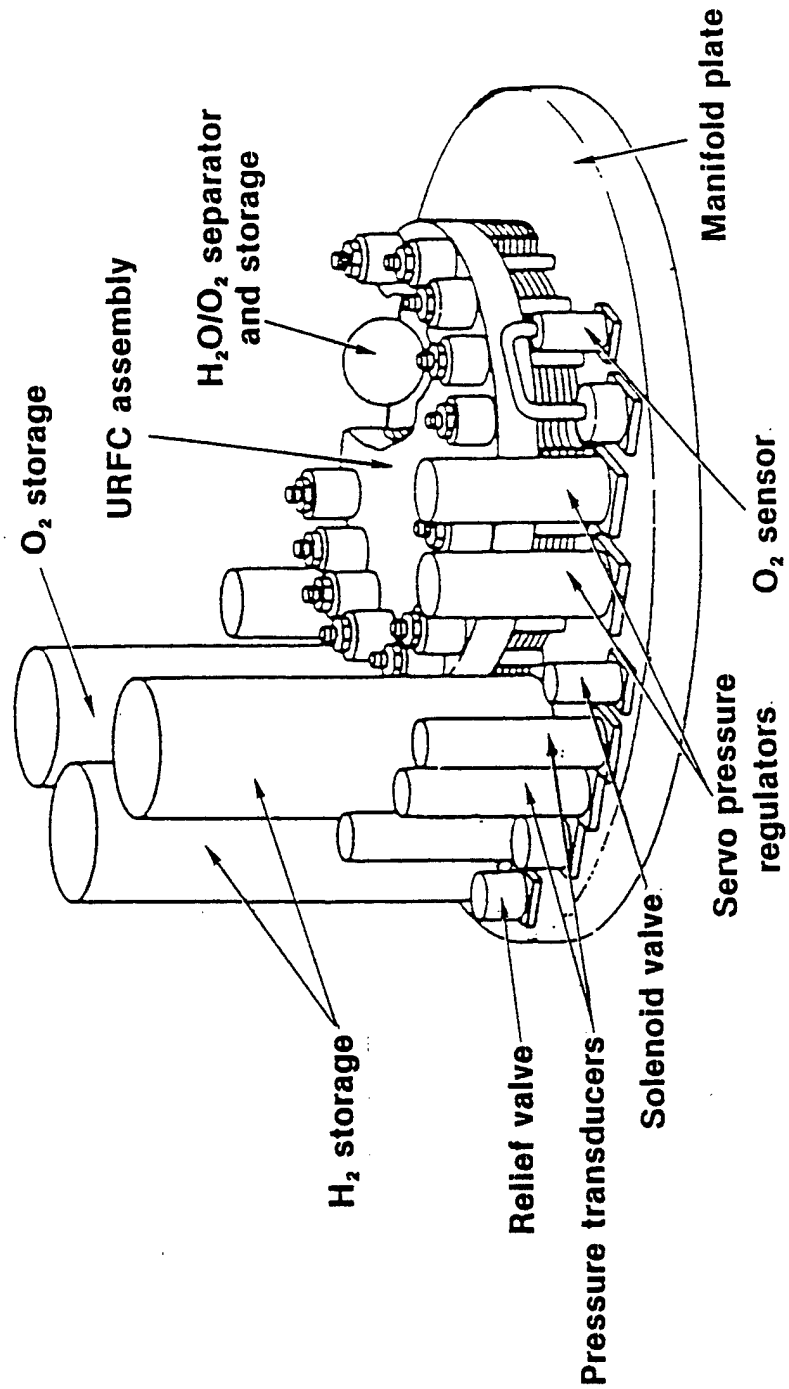
Experiment Description:

- URFC system will demonstrate a simple passive means of electrical energy storage for space applications employing passive fluid and thermal management technologies
- System parameters such as temperatures, pressures, voltage, and current will be measured for purposes of control and analysis
- Packaging concept depicts the “Get Away Special” carrier option but is easily adapted to other options
- Experiment will be self-contained
- Component selection and safety consideration based on mature flight designs

Simplified URFC system schematic

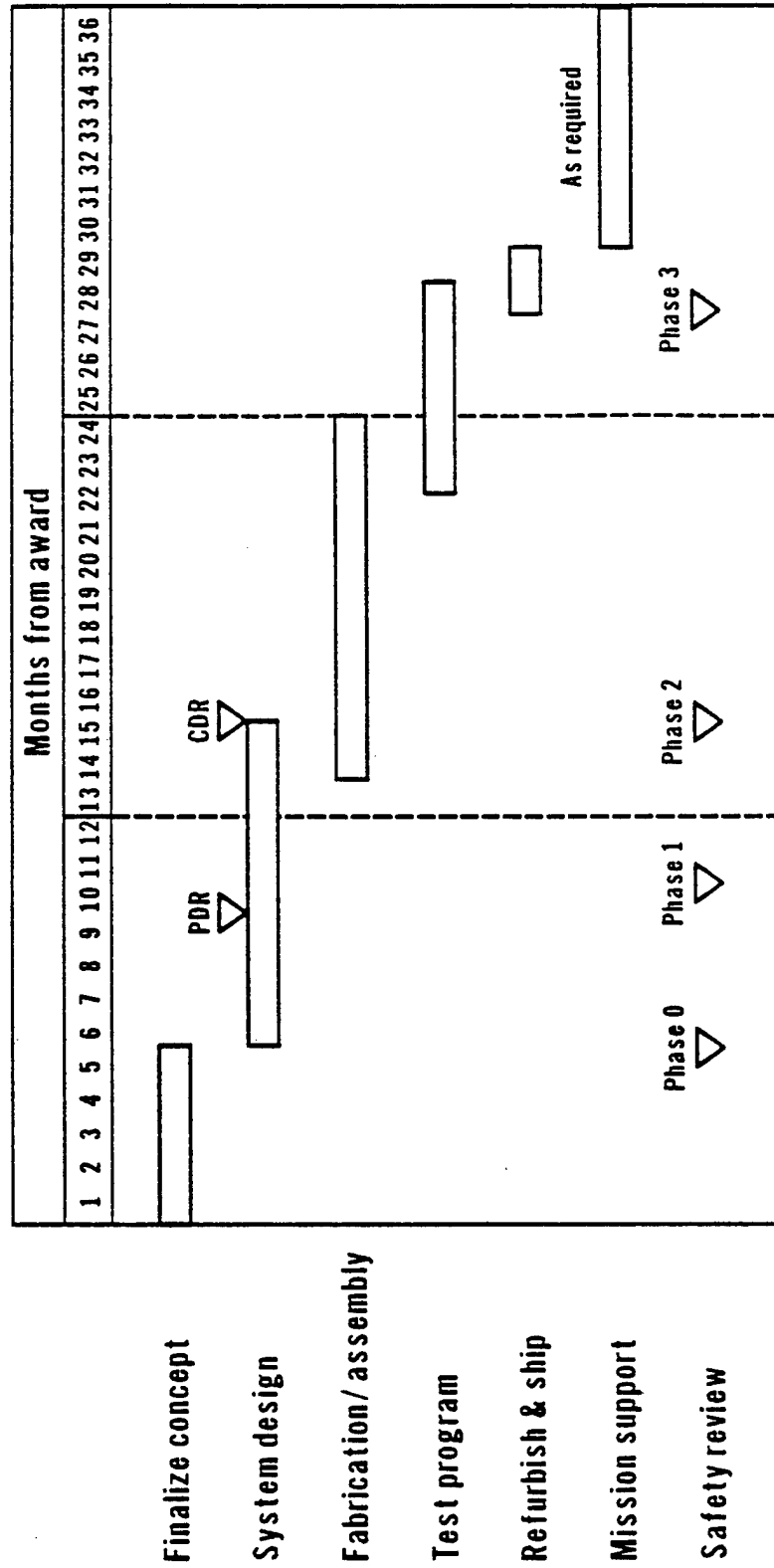


Packaging Concept



OUTREACH

UNITIZED REGENERATIVE SPE FUEL CELL (URFC)



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POWER SYSTEMS AND THERMAL MANAGEMENT	IN-SPACE TECHNOLOGY EXPERIMENTS WORKSHOP DECEMBER 6-9, 1988	DYNAMIC AND NUCLEAR POWER SYSTEMS

THERMAL ENERGY STORAGE FLIGHT EXPERIMENTS
FOR SOLAR DYNAMIC POWER SYSTEMS

SOLAR THERMAL SYSTEMS
EXPERIMENTS (STSE) DEFINITION

BOEING AEROSPACE

PROJECT MANAGER: STEVE JOHNSON
LeRC

PROGRAM MANAGER: BARBARA HEIZER

PRINCIPAL INVESTIGATOR:
TOM FOSTER

NASA CONTRACT: NAS3-25364

THERMAL ENERGY STORAGE
TECHNOLOGY (TEST)

NASA-LEWIS RESEARCH CENTER

PROJECT SCIENTIST: DAVID NAMKOONG

FLIGHT PROJECT MANAGER: JERRI LING

SUPPORT SERVICE CONTRACTOR:
SVERDRUP

IN-REACH	THERMAL ENERGY STORAGE FLIGHT EXPERIMENTS FOR SOLAR DYNAMIC POWER SYSTEMS	NASA LeRC

OBJECTIVE

EVALUATION OF PHASE CHANGE THERMAL ENERGY STORAGE (TES) SYSTEM AND MATERIALS IN MICROGRAVITY.

ISSUES

PROGRAMMATIC

- TES CRITICAL TO EFFICIENT OPERATION OF THE RECEIVER, SYSTEM.
- FLIGHT TESTS ARE REQUIRED TO ASSESS VOID BEHAVIOR OF ADVANCED TES MATERIALS UNDERGOING REPEATING PHASE CHANGE IN MICROGRAVITY.
- COMPREHENSIVE APPROACH REQUIRES ANALYTICAL UNDERSTANDING AND EXPERIMENTAL VERIFICATION - - NEEDED FOR ADVANCED HEAT RECEIVER DESIGN PROCESS.

TECHNICAL

- VOID SHAPE AND LOCATION
- EFFECT OF VOID ON HEAT TRANSFER MECHANISMS
- COMPARISON BETWEEN 1-g AND MICROGRAVITY PERFORMANCE
- EFFECT OF STORAGE MATERIAL THERMAL/PHYSICAL PROPERTIES ON SYSTEM PERFORMANCE
- LACK OF A VALIDATED COMPUTER MODEL TO PREDICT PERFORMANCE TES SYSTEMS IN MICROGRAVITY

IN-REACH	THERMAL ENERGY STORAGE FLIGHT EXPERIMENTS FOR SOLAR DYNAMIC POWER SYSTEMS	NASA LeRC

APPROACH

STSE DEFINITION

- DEFINE SPECIFIC EXPERIMENT OBJECTIVES AND REQUIREMENTS
- DEVELOP PRELIMINARY DESIGN OF EXPERIMENT TO ACCOMMODATE MULTIPLE TES CONCEPTS
- CONDUCT TRADE STUDIES, ANALYSES, AND GROUND TESTS
- PREPARE PROGRAM PLAN, SCHEDULE, AND COST

TEST

- DEVELOP AN ANALYTICAL AND COMPUTATIONAL BASIS TO PREDICT TRANSIENT BEHAVIOR OF TES MATERIALS, PARTICULARLY VOID SHAPE AND LOCATION, UNDER MICROGRAVITY
- CONDUCT MICROGRAVITY EXPERIMENTS TO ESTABLISH DATA BANK OF TES MATERIALS UNDER 1-g AND MICROGRAVITY
- VERIFY CAPABILITY OF DEVELOPED COMPUTER CODE TO PREDICT VOID LOCATION AND THERMAL HISTORY OF TES SYSTEM UNDERGOING PHASE CHANGE IN MICROGRAVITY

IN-REACH	THERMAL ENERGY STORAGE FLIGHT EXPERIMENTS FOR SOLAR DYNAMIC POWER SYSTEMS	NASA LeRC

TEST EXPERIMENT

• "GAS" CAN EXPERIMENTAL PACKAGE

• FOUR EXPERIMENTS:

LiF	1121 K
CaF/50 MgF	1250 K
*GERMANIUM	1210 K
*NiSi	1265 K

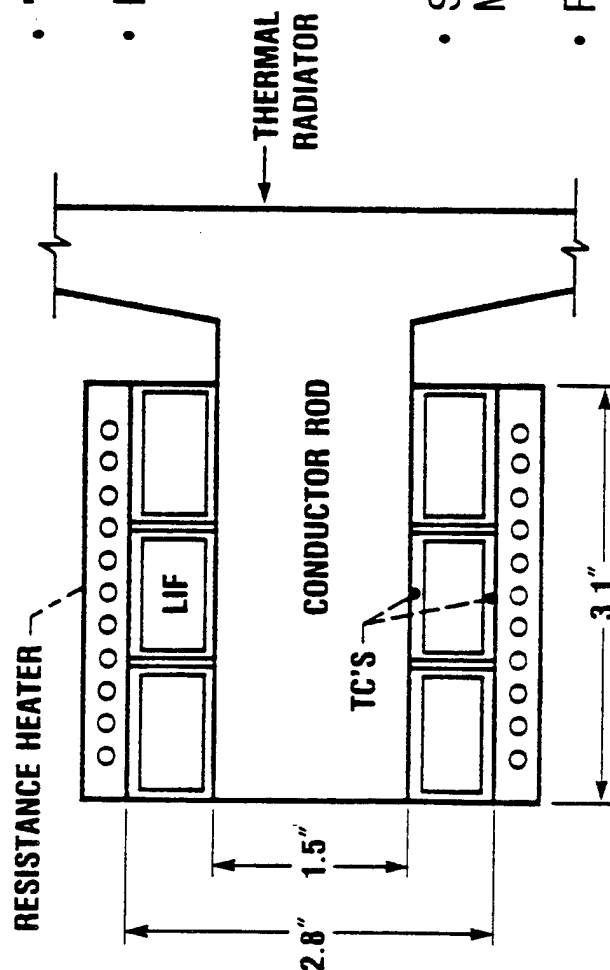
• SUN/SHADE PERIODS OF 60/34
MINUTES PER CYCLE; 5 CYCLES

• RESULTS:

TEMPERATURE MEASUREMENTS

POST-TEST EXAMINATION OF
VOID SHAPE, LOCATION

COMPARISON WITH ANALYTICAL
PREDICTION



TES EXPERIMENT NO. 1

IN-REACH	THERMAL ENERGY STORAGE FLIGHT EXPERIMENTS FOR SOLAR DYNAMIC POWER SYSTEMS	NASA LeRC

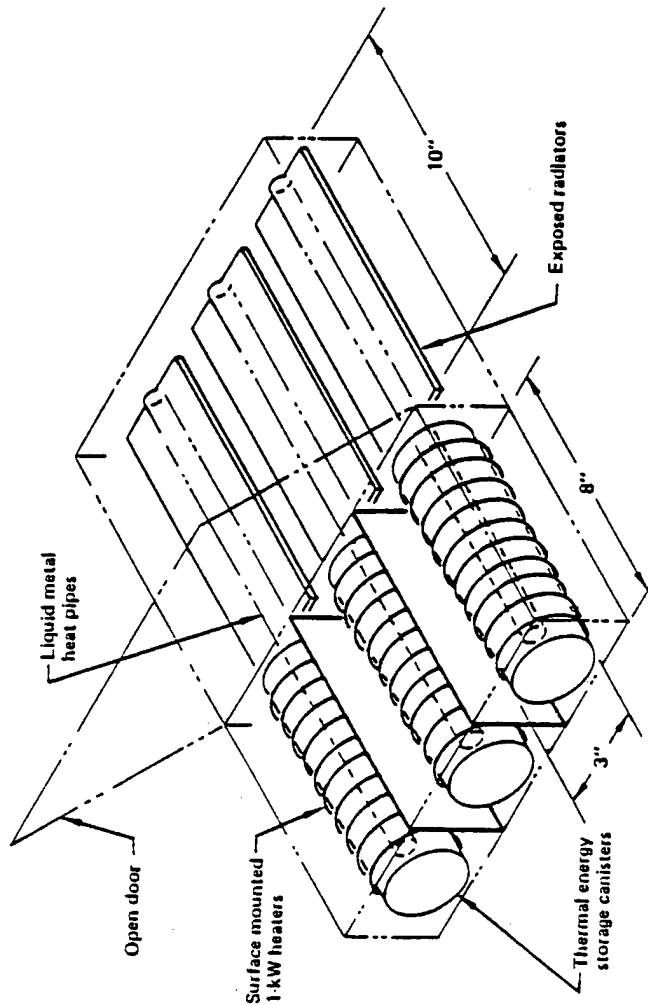
STSE EXPERIMENT

DESCRIPTION

- COMPATIBLE WITH HITCHHIKER
- DESIGNED FOR MODULARITY
- MULTIPLE CONCEPTS TESTED SIMULTANEOUSLY
- TEMPERATURE DISTRIBUTION AND HEAT FLUX MEASURED

OBJECTIVES

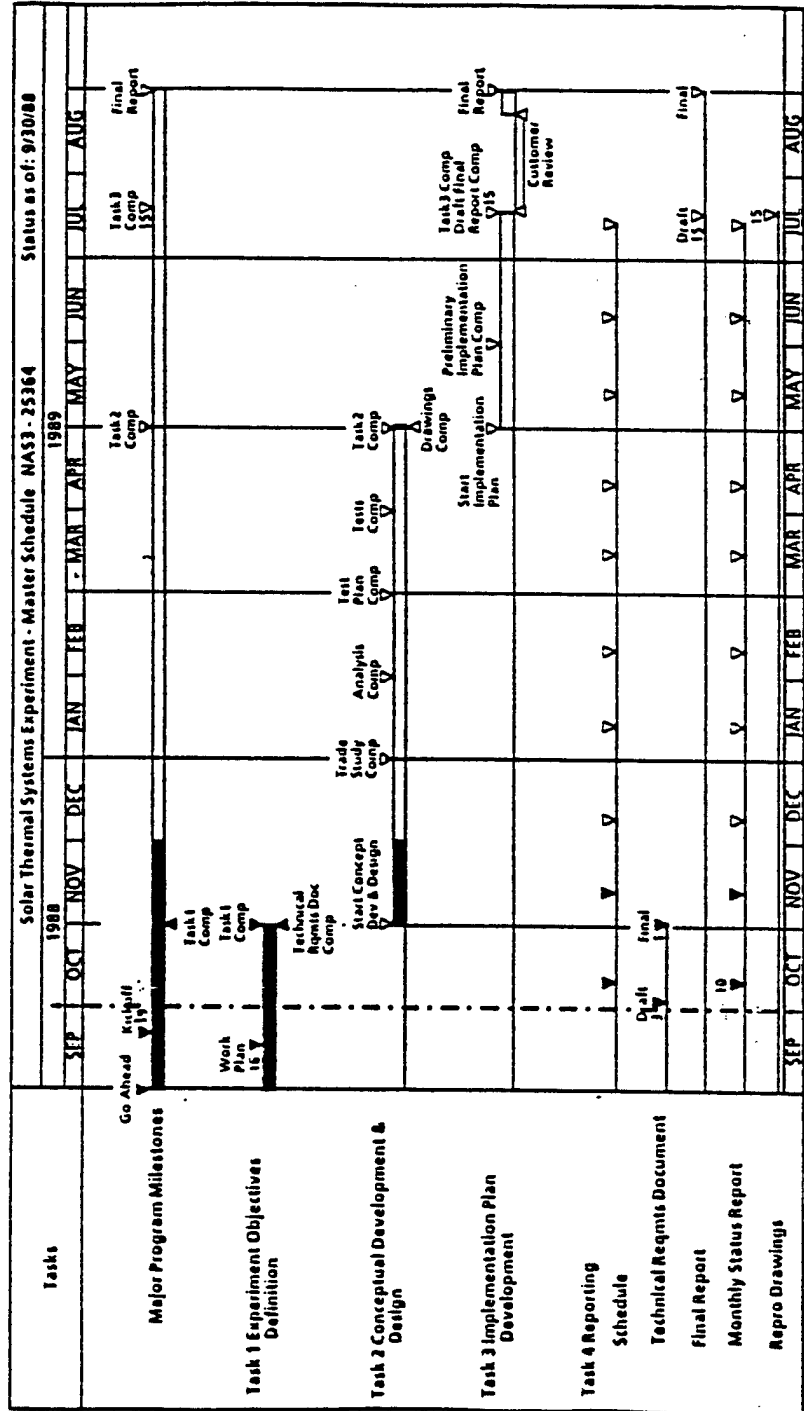
- VERIFY THERMAL PERFORMANCE IN MICROGRAVITY
- VERIFY NON-DESTRUCTIVE METHODS OF DETERMINING VOID DISTRIBUTION
- COMPARE VOID DISTRIBUTION AND VOID MANAGEMENT FOR 1-g AND MICROGRAVITY ENVIRONMENTS
- VALIDATE PERFORMANCE PREDICTION METHODS



Thermal Energy Storage Canisters Contained in an Insulated Box

IN-REACH	THERMAL ENERGY STORAGE FLIGHT EXPERIMENTS FOR SOLAR DYNAMIC POWER SYSTEMS	NASA LeRC

Solar Thermal Systems Experiment - Master Schedule NAS3-25364



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POWER SYSTEMS AND THERMAL MANAGEMENT	IN-SPACE TECHNOLOGY EXPERIMENTS WORKSHOP DECEMBER 6-9, 1988	THERMAL MANAGEMENT

INVESTIGATION OF MICRO-GRAVITY EFFECTS ON HEAT PIPE THERMAL PERFORMANCE AND WORKING FLUID BEHAVIOR

GEORGE L. FLEISCHMAN

**HUGHES AIRCRAFT COMPANY
ELECTRON DYNAMICS DIVISION
3100 W. LOMITA BOULEVARD
TORRANCE, CA 90509-2999**

**NAS5-30359
NASA/GODDARD SPACE FLIGHT CENTER
ROY MCINTOSH 301-286-3478**

EXPERIMENT OBJECTIVE

DEVELOP IN-DEPTH UNDERSTANDING OF THE BEHAVIOR OF HEAT PIPES IN SPACE. BOTH CONSTANT CONDUCTANCE HEAT PIPES WITH AXIAL GROOVES AND VARIABLE CONDUCTANCE HEAT PIPES WITH WICKS WILL BE INVESTIGATED. THIS UNDERSTANDING WILL BE APPLIED TO THE DEVELOPMENT OF:

- IMPROVED PERFORMANCE OF HEAT PIPES SUBJECTED TO VARIOUS ACCELERATIONS IN SPACE.
- MORE EFFICIENT AND RELIABLE SPACECRAFT THERMAL MANAGEMENT SYSTEMS.
- LIGHTER WEIGHT SPACECRAFT THERMAL SYSTEMS.

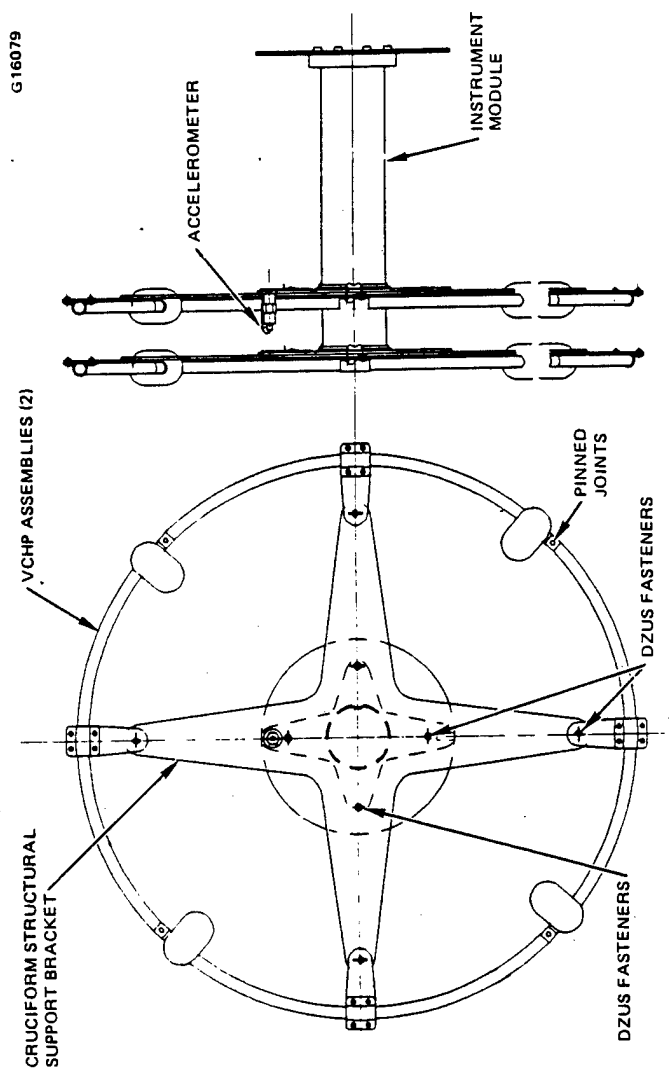
BACKGROUND/TECHNOLOGY NEED

A PROBLEM THAT OFTEN ARISES IS HOW TO USE HEAT PIPE GROUND TEST DATA TO MAKE MICRO-GRAVITY PERFORMANCE PREDICTIONS. DURING GROUND TESTING, GRAVITY DOMINATES THE CAPILLARY FORCES AND BECOMES A LIMITING FACTOR. MOREOVER, BOTH THERMAL PERFORMANCE AND VEHICLE STABILIZATION ARE AFFECTED BY SPACECRAFT ACCELERATIONS CAUSED BY:

- MOTION IN ORBIT
- CHANGING ORBITS
- THREAT AVOIDANCE

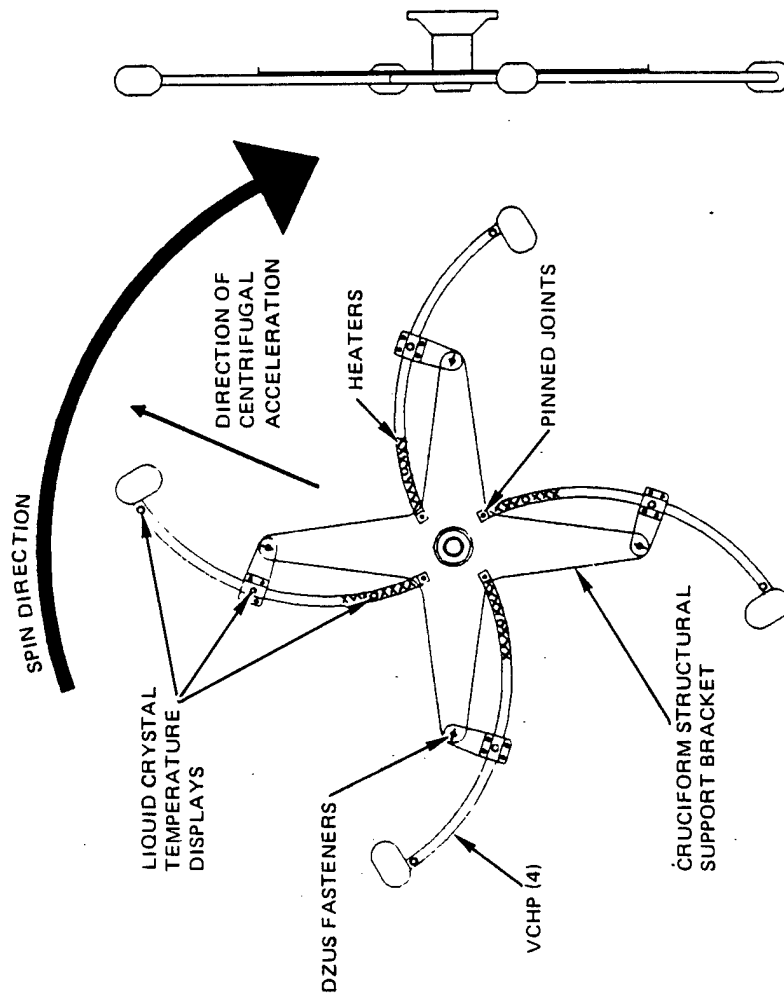
EXPERIMENT DESCRIPTION

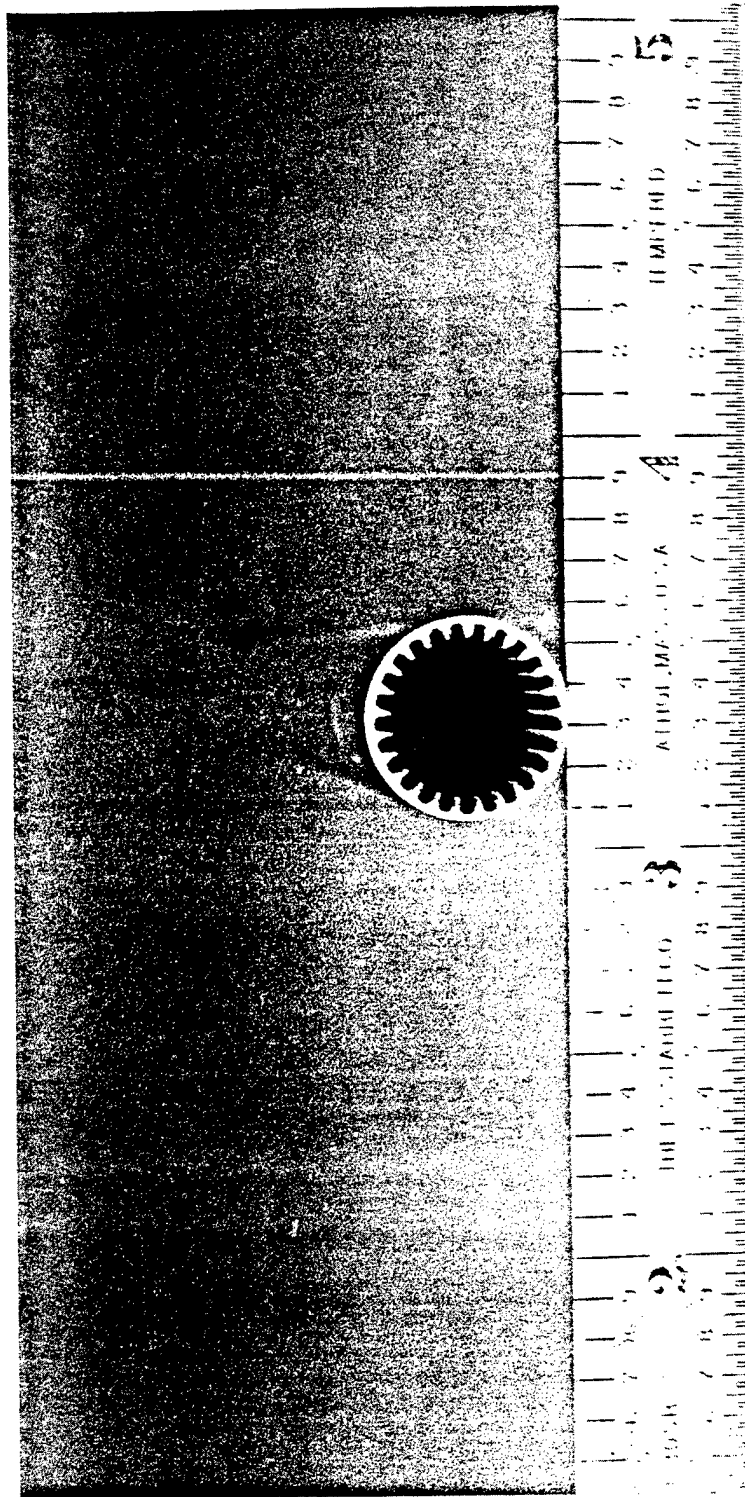
THE APPARATUS WILL PROVIDE THE ABILITY TO SPIN 4 HEAT PIPES, MOUNTED IN A HOOP ASSEMBLY, UP TO SEVERAL HUNDRED RPM, AND TO RECORD THE NUTATION ACCELERATION USING AN INFRA-RED TELEMETRY SYSTEM. THE NUTATION DIVERGENCE FLIGHT TEST MEASURES THE EXPONENTIAL TIME CONSTANT FOR NUTATION DIVERGENCE OF A SPINNING MODEL WITH CIRCUMFERENTIAL HEAT PIPES.



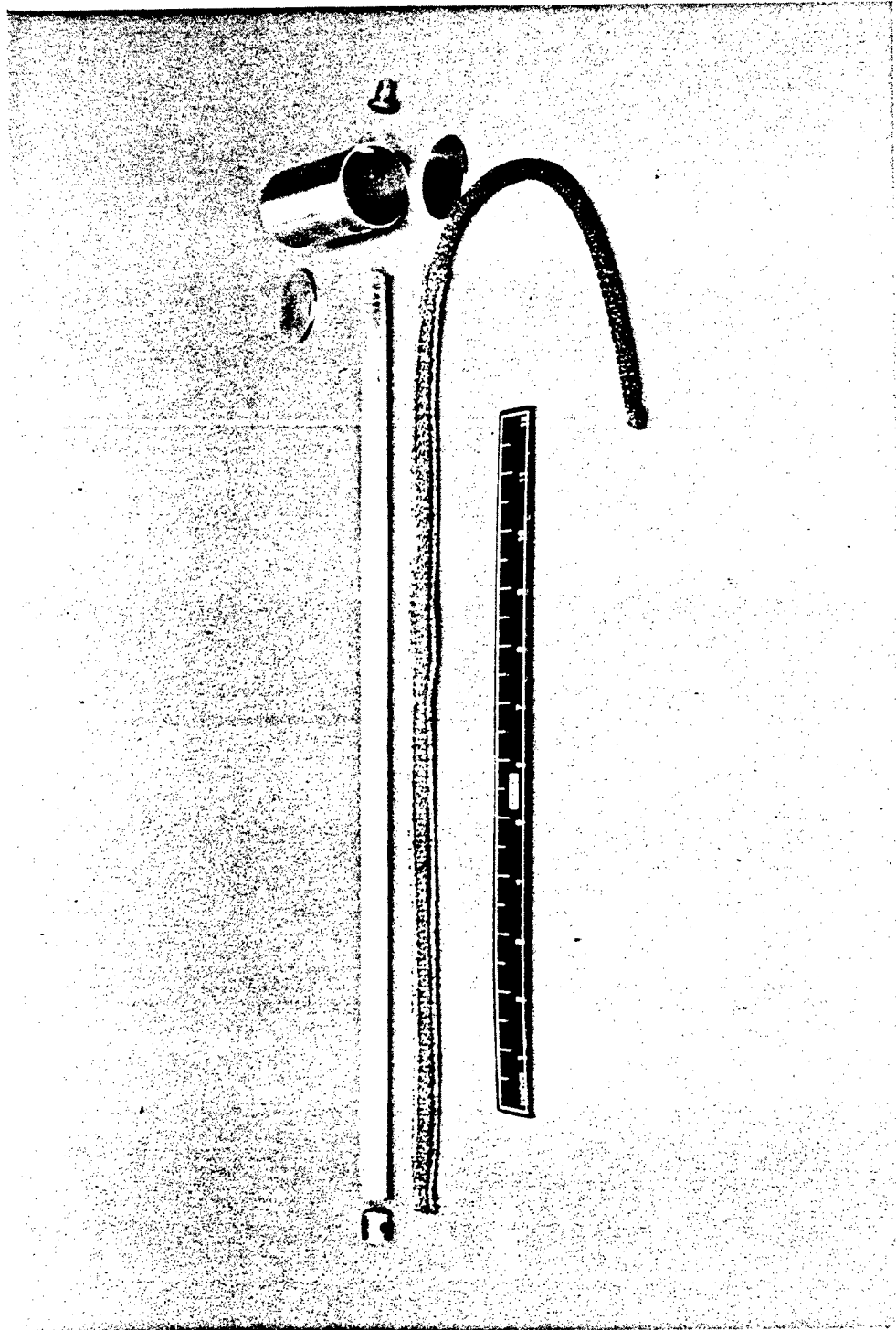
EXPERIMENT DESCRIPTION

THE APPARATUS WILL PROVIDE THE ABILITY TO SPIN 4 HEAT PIPES, MOUNTED IN A RADIAL CONFIGURATION, UP TO 100 RPM TO FORCE THE WORKING FLUID TO ONE ONE OF THE HEAT PIPE. NEXT, THE ASSEMBLY WILL BE BROUGHT TO REST, AND THE EVAPORATOR PORTION OF EACH HEAT PIPE WILL BE HEATED USING BATTERY POWERED HEATERS. REPRIMING RATES, EFFECT OF EXCESS LIQUID AND FLUID DISTRIBUTION WILL BE EVALUATED USING TEMPERATURE SENSITIVE LIQUID CRYSTALS.





GROOVED CONSTANT CONDUCTANCE HEAT PIPE

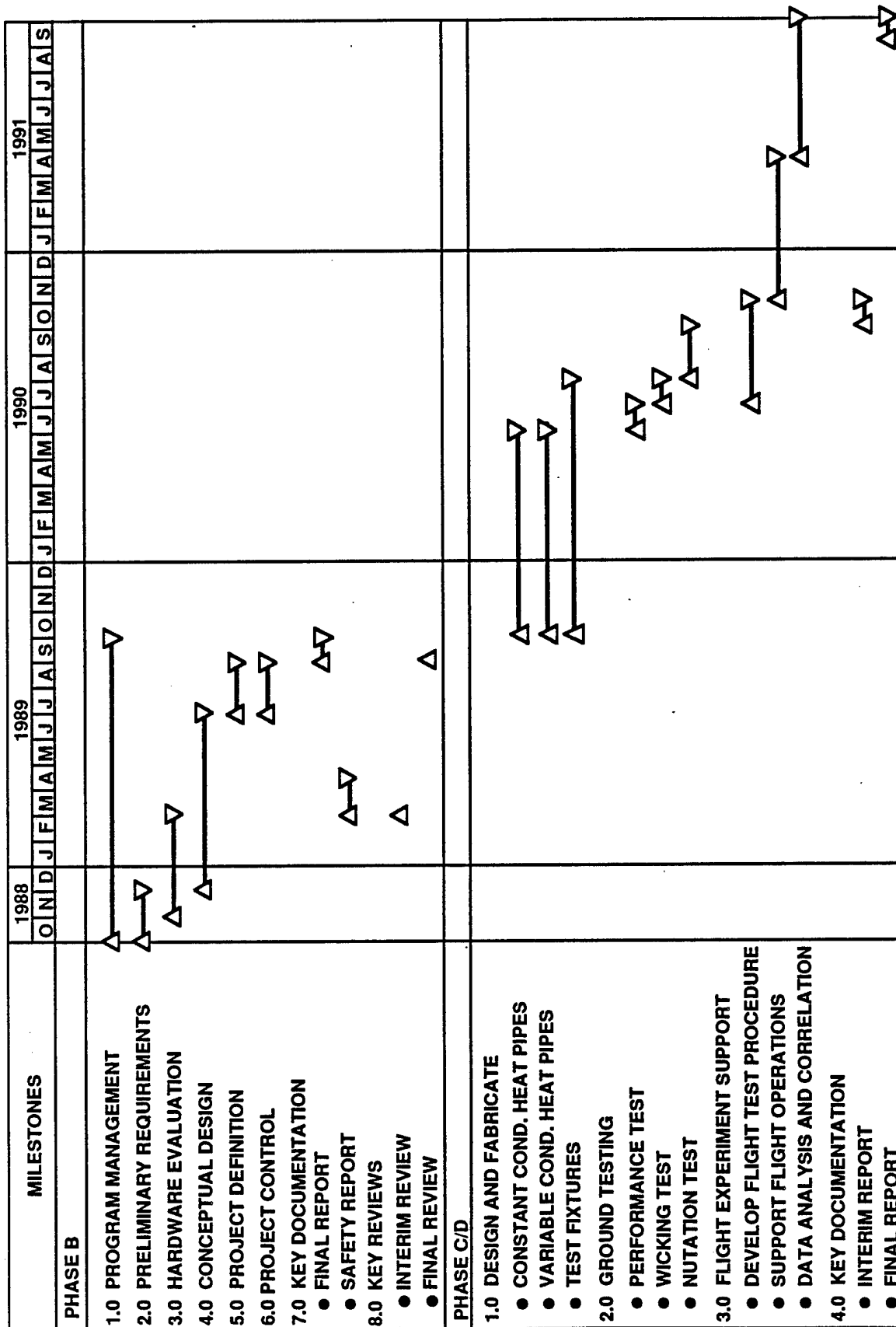


VARIABLE CONDUCTANCE HEAT PIPE WITH CENTRAL CORE WICK

OUTREACH DEVELOPMENT

INVESTIGATION OF MICRO-GRAVITY EFFECTS ON HEAT PIPE THERMAL PERFORMANCE AND WORKING FLUID BEHAVIOR

HUGHES



POWER SYSTEMS AND THERMAL MANAGEMENT	IN-SPACE TECHNOLOGY EXPERIMENTS WORKSHOP DECEMBER 6-9, 1988	THERMAL MANAGEMENT

A HIGH-EFFICIENCY THERMAL INTERFACE (USING CONDENSATION HEAT TRANSFER) BETWEEN A TWO-PHASE FLUID LOOP AND A HEAT PIPE RADIATOR

JOHN A. POHNER

TRW SPACE AND TECHNOLOGY GROUP



**CONTRACT NAS5-30375
GODDARD SPACE FLIGHT CENTER
ROY MCINTOSH**

Outreach	A High-Efficiency Thermal Interface (Using Condensation Heat Transfer) Between a Two-Phase Fluid Loop and a Heat Pipe Radiator Experiment Definition Phase	TRW

EXPERIMENT OBJECTIVE

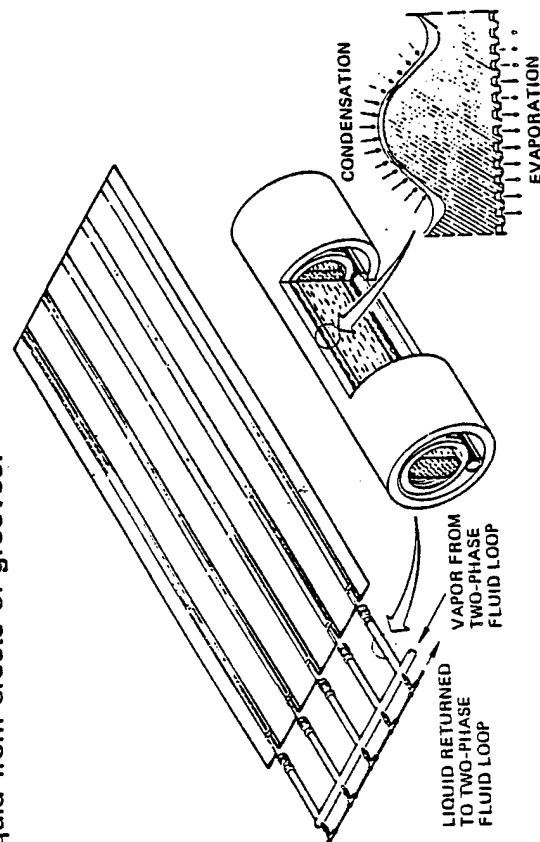
Characterize the microgravity performance of a High-Efficiency Thermal Interface (HETI) which thermally couples a two-phase fluid loop to a heat pipe radiator.

- o For high-power spacecraft which must reject 10 to 100 kW of waste heat, two-phase fluid loops will be required to collect and transport heat, and large deployed radiators will be needed to reject the waste heat to space.
- o High efficiency (low ΔT) interface required between fluid loop and radiator to minimize radiator size and weight.
- o Vapor from two-phase loop condenses on Gregorig-grooved exterior of heat pipe. Gregorig grooves use capillary forces to drain liquid from crests of grooves.

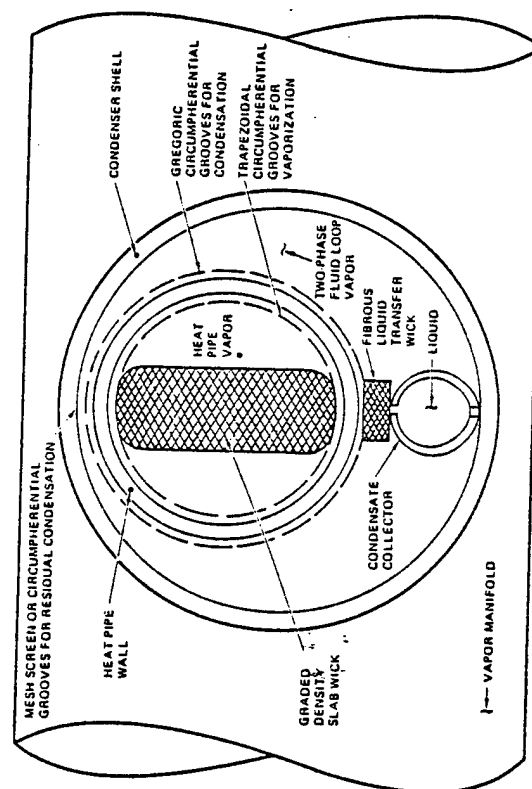
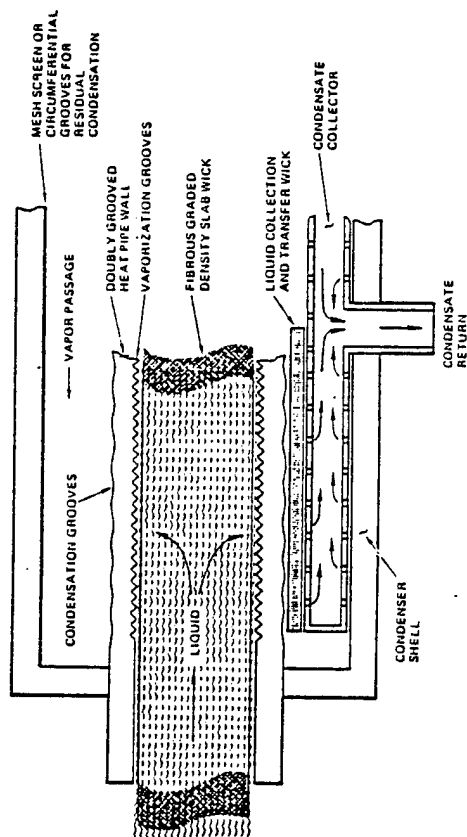
- o Fibrous wick structure transfers liquid from Gregorig groove troughs to liquid return line.

- o Quantities of interest:

- a) Condensation "h" on Gregorig grooves (predicted value = 50 kW/m²-K)
- b) Evaporation "h" in heat pipe
- c) Condensation "h" in heat pipe



DETAILS OF THE HIGH-EFFICIENCY THERMAL INTERFACE



Outreach	A High-Efficiency Thermal Interface (Using Condensation Heat Transfer) Between a Two-Phase Fluid Loop and a Heat Pipe Radiator Experiment Definition Phase	

BACKGROUND

- o TRW developed the High Efficiency Thermal Interface (HETI) under the Air Force Wright Aeronautical Laboratory-sponsored High Power Spacecraft Thermal Management Study (Contract No. F33615-84-C-2414).
- o Prior to development of HETI, no thermal bus-to-radiator heat exchangers suitable to high-power missions (excluding Space Station) were available.
- o Ground testing of a single heat pipe version of the HETI resulted in heat transfer coefficients of the order of 10 kW/m²-K. Satisfactory ground testing is difficult since capillary forces and gravitational body forces are of the same order of magnitude.
- o Microgravity testing is required to determine:
 - a) heat transfer coefficients;
 - b) startup behavior; and
 - c) response to suddenly increased or decreased heat loads.

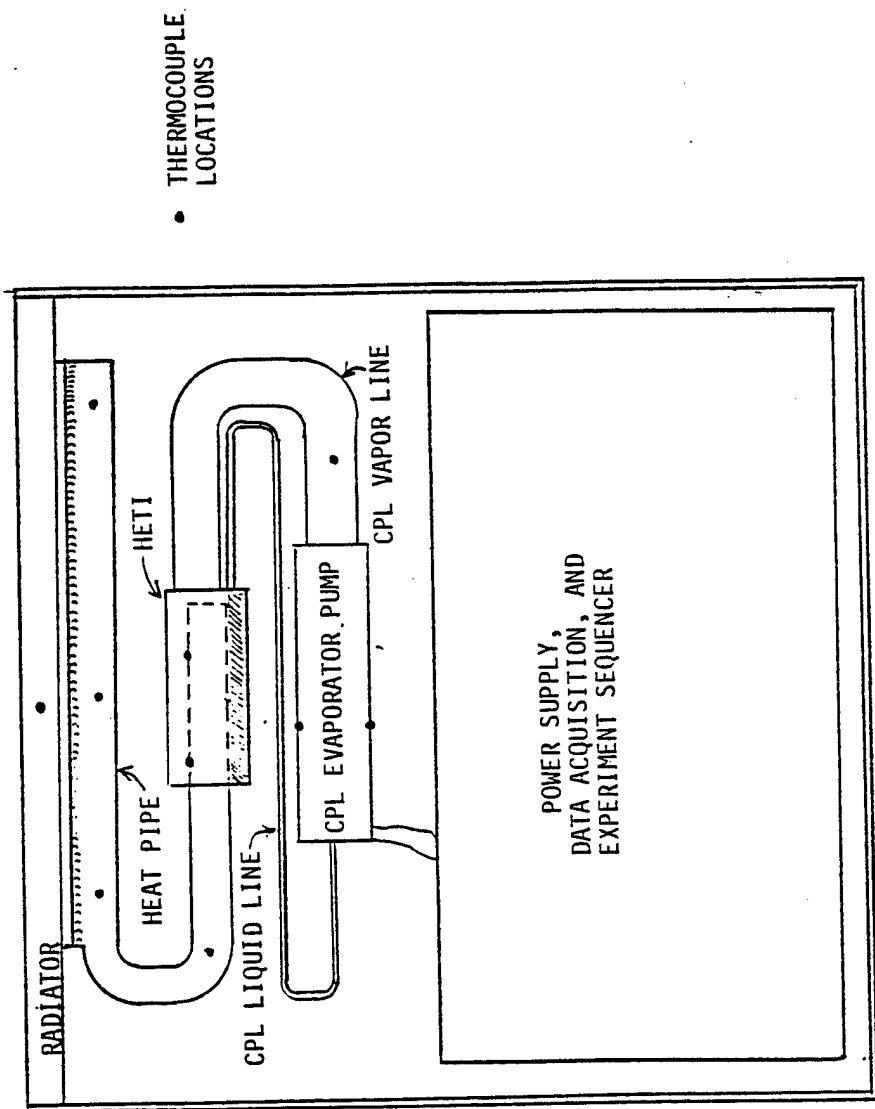
Outreach	A High-Efficiency Thermal Interface (Using Condensation Heat Transfer) Between a Two-Phase Fluid Loop and a Heat Pipe Radiator Experiment Definition Phase	

EXPERIMENT DESCRIPTION

- o Experiment will be configured for Get Away Special or Hitchhiker-G carrier.
- o Key components will include:
 - capillary pumped loop (CPL) including evaporator pump, liquid and vapor transport lines, accumulator (reservoir), and subcooler;
 - two slab wick heat pipes
 - HETI which accomodates two heat pipe's
 - radiator panel
 - battery and power control electronics; and
 - data acquisition electronics package.
- o Heat pipes and CPL will use ammonia as the working fluid.
- o Experiment will be heat sink limited. Increase of radiator mass will alleviate this problem.
- o Experiment will be instrumented so that condensation and evaporation heat transfer coefficients in HETI and heat pipes may be calculated.
- o Radiator panel must accommodate two heat pipes and liquid subcooler.
- o Experiment will be designed to permit preliminary ground testing (heat pipes in reflux mode, evaporator pump of CPL below HETI, gravity-aided drainage of ammonia from Gregorig grooves).

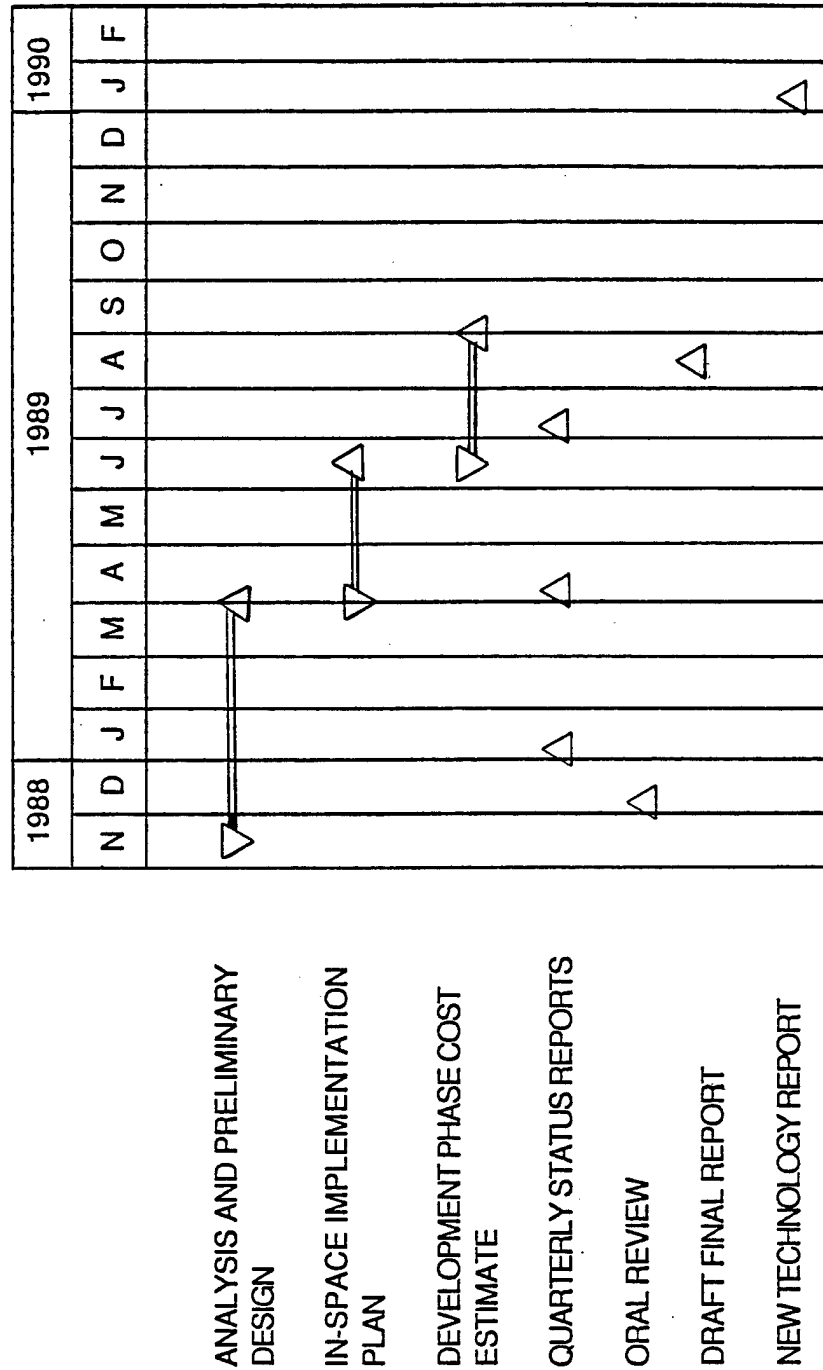
Outreach	A High-Efficiency Thermal Interface (Using Condensation Heat Transfer) Between a Two-Phase Fluid Loop and a Heat Pipe Radiator	

EXPERIMENT DESIGN

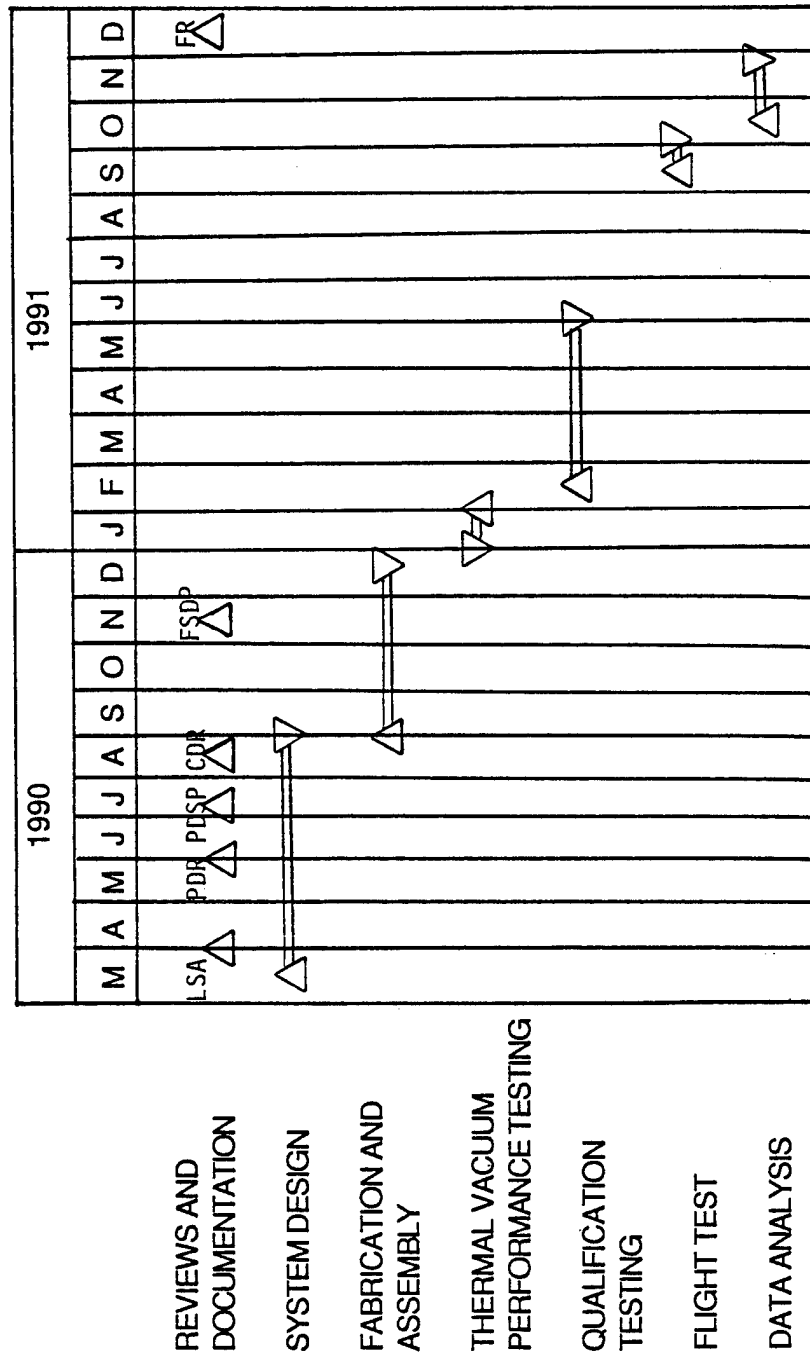


Outreach	A High-Efficiency Thermal Interface (Using Condensation Heat Transfer) Between a Two-Phase Fluid Loop and a Heat Pipe Radiator Experiment Definition Phase	TRW

SCHEDULE - EXPERIMENT DEFINITION PHASE



SCHEDULE - EXPERIMENT DEVELOPMENT PHASE



PDR - Preliminary Design Review
 LSA - Launch Services Agreement
 FSDP - Final Safety Data Package
 FR - Final Report

CDR - Critical Design Review
 PSDP - Preliminary Safety Data Package
 QR - Quarterly Report

POWER SYSTEMS AND THERMAL MANAGEMENT	IN-SPACE TECHNOLOGY EXPERIMENTS WORKSHOP DECEMBER 6-9, 1988	THERMAL MANAGEMENT

MOVING BELT RADIATOR DYNAMICS

W. PETER TEAGAN
ARTHUR D. LITTLE, INC.

CONTRACT NO. NAS3-25356
LEWIS RESEARCH CENTER
ALAN WHITE

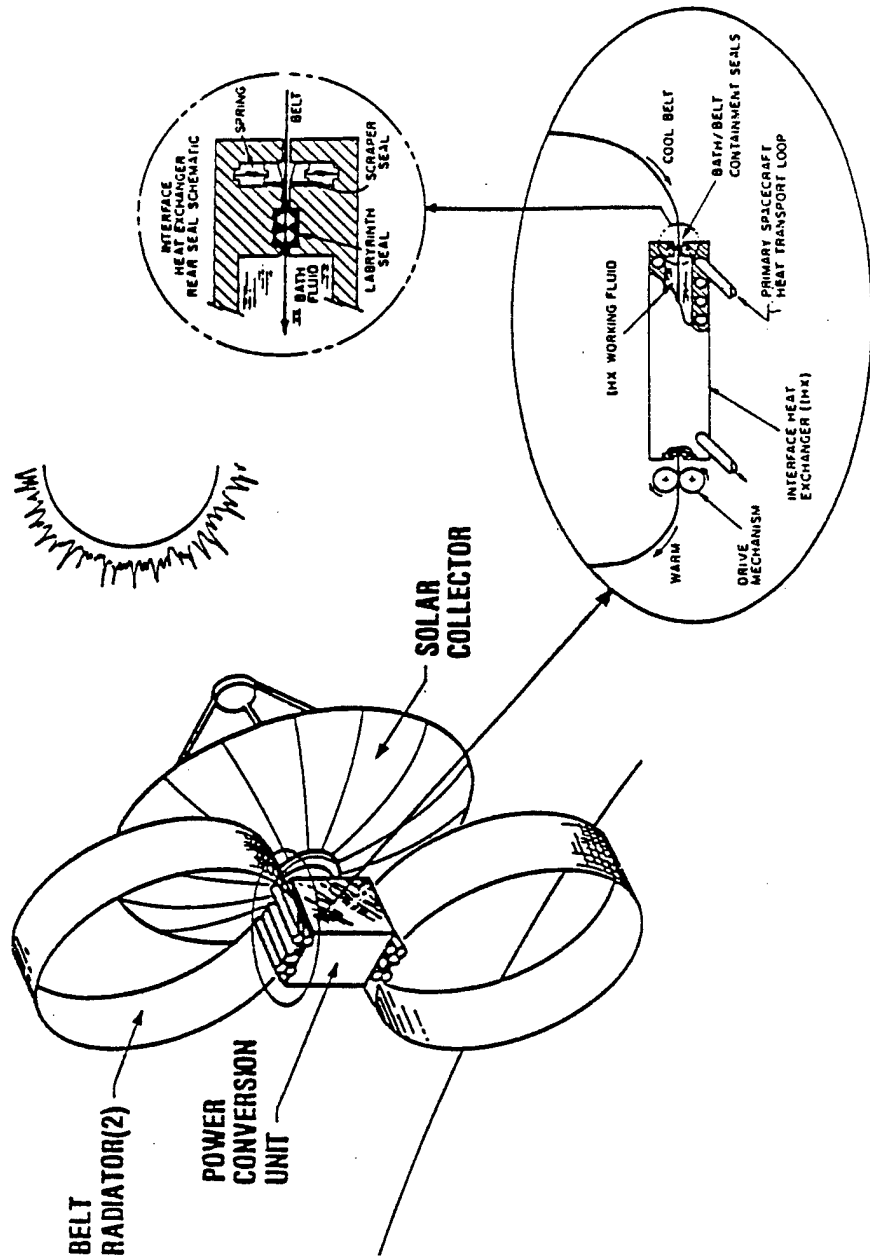
OUT-REACH	MOVING BELT RADIATOR DYNAMICS	AUTHUR D. LITTLE, INC.

EXPERIMENTAL OBJECTIVE

Develop an improved understanding of the dynamics of a Moving Belt Radiator (MBR) during deployment and operation. In a zero gravity environment the primary forces on the belt will be those due to rotational motion (centrifugal forces) and spacecraft accelerations.

This understanding is needed to:

- Verify analytical methods developed to model the dynamics of flexible moving belt structures.
- Design MBR systems (belt structures, deployment, operation, and control)



LIQUID BELT RADIATOR CONCEPT

OUT-REACH	MOVING BELT RADIATOR DYNAMICS	AUTHUR D. LITTLE, INC.

BACKGROUND/TECHNOLOGY NEED

- Computerized dynamic models have been developed to describe shape of MBR as influenced by rotational speeds, acceleration fields, and belt structure
- Ground based testing subject to gravity are not very useful since gravity forces will dominate the centrifugal forces which define belt dynamics in a space environment
- Ground based zero-G experiments (drop towers, KC135 test plane) provide too short a test period for extensive testing
- Lack of an experimentally verified dynamic model adds uncertainty to the design of this class of radiator - possibly resulting in overly conservative design criteria

OUT-REACH	MOVING BELT RADIATOR DYNAMICS	AUTHUR D. LITTLE, INC.

EXPERIMENTAL DESCRIPTION

- Experimental apparatus is a small scale moving belt structure 2-4 feet in diameter. Means are provided to:
 - vary belt rotational speed
 - subject belt to short term accelerations
 - vary sealing forces in interface heat exchanger structure
- Belt motion visualization (photographic) and measurements of forces on the IHX due to a belt motion, sealing pressure, and imposed acceleration will allow refinement of analytical models

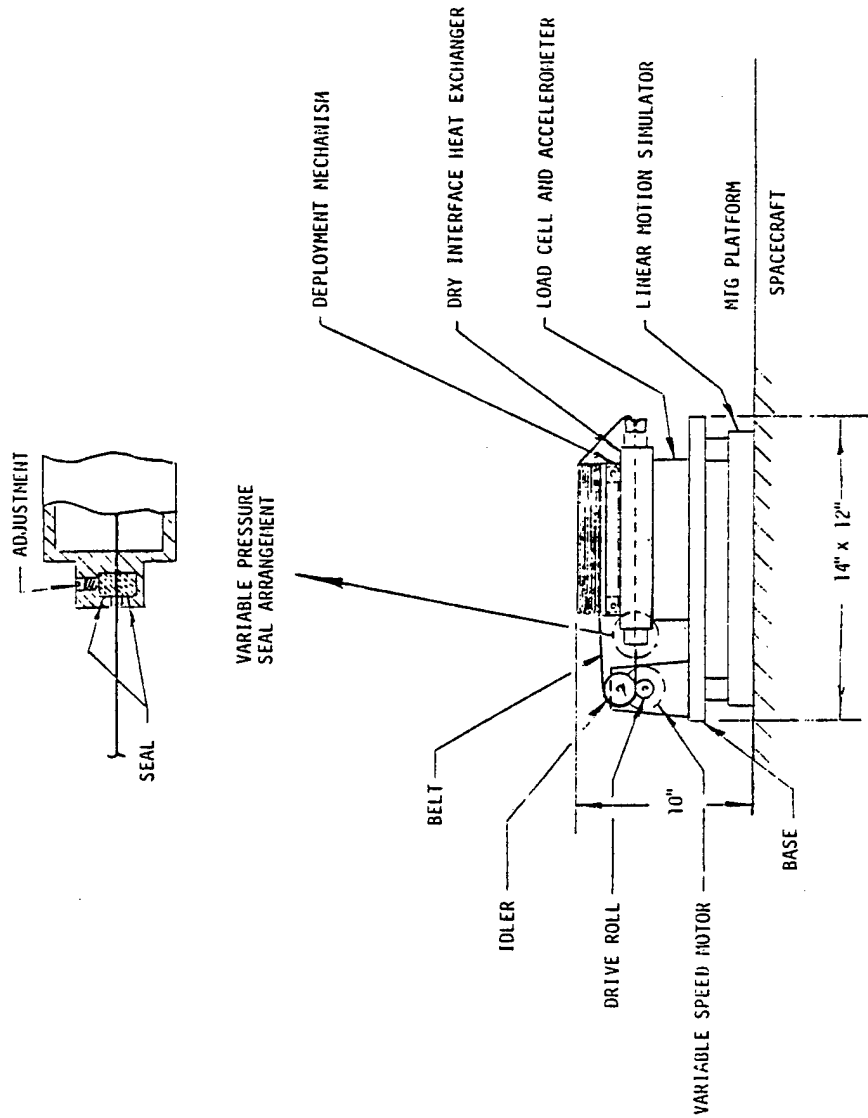


FIGURE 1 MBR TEST APPARATUS IN STOWED POSITION

OUT-REACH	MOVING BELT RADIATOR DYNAMICS	AUTHUR D. LITTLE, INC.

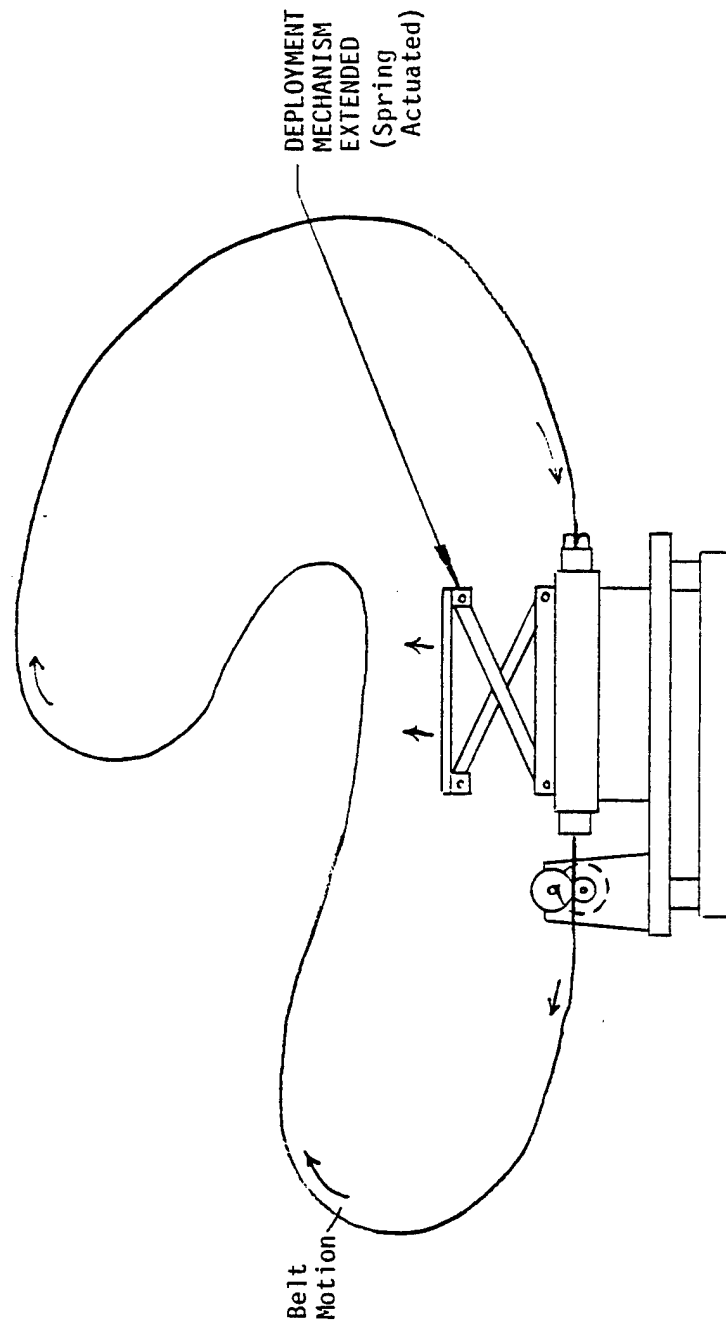


FIGURE 2 MBR SHAPE DURING DEPLOYMENT PROCESS

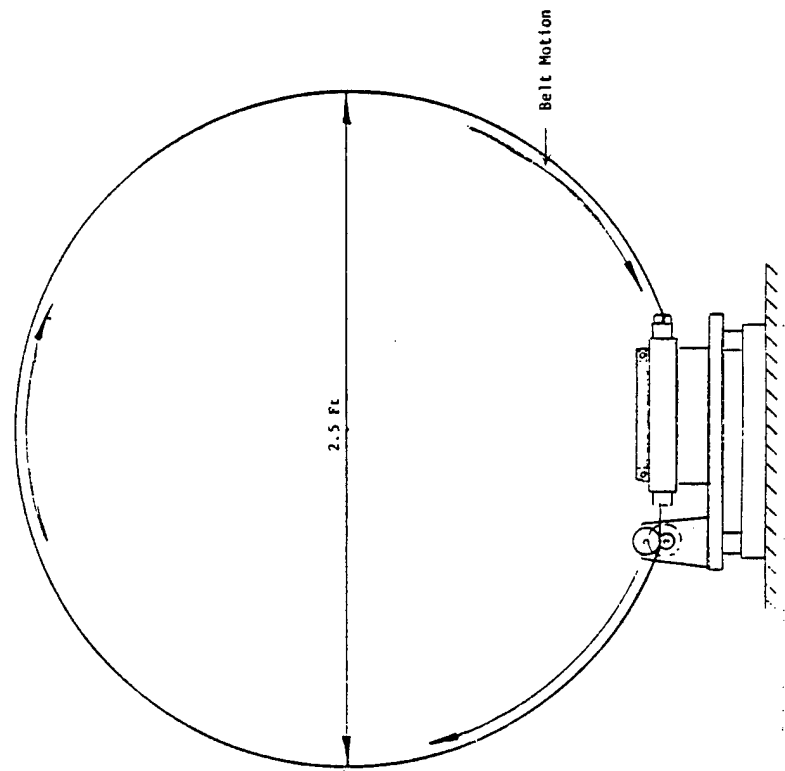


FIGURE 3 TEST APPARATUS DURING OPERATION (no perturbation)

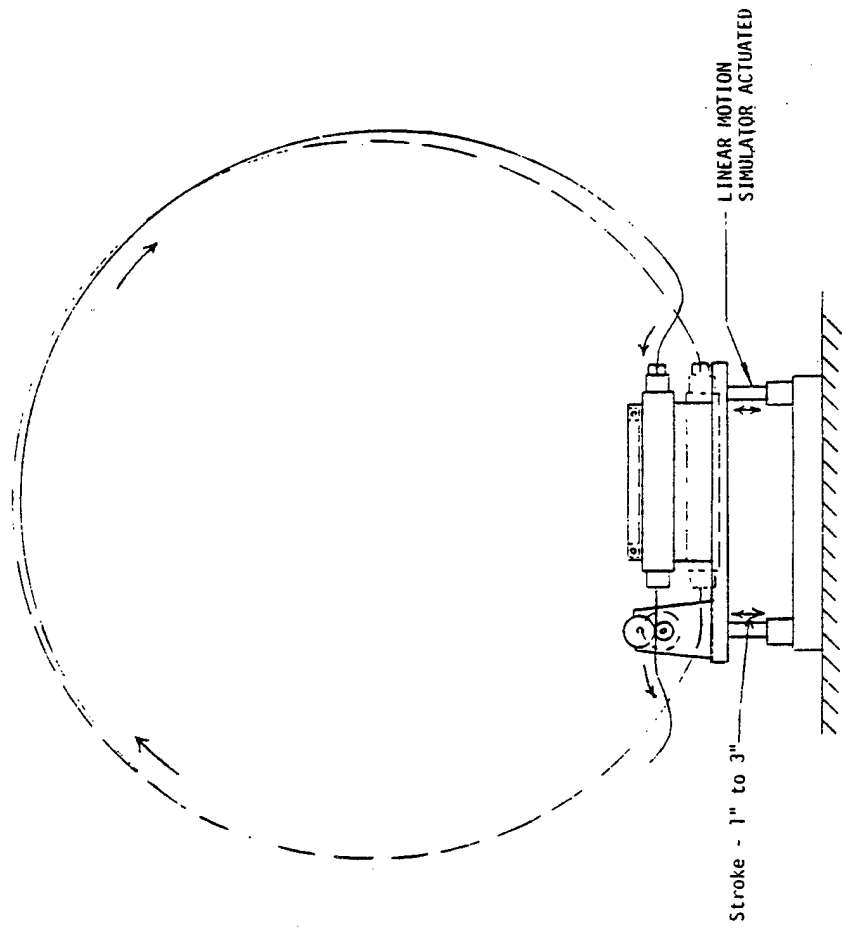
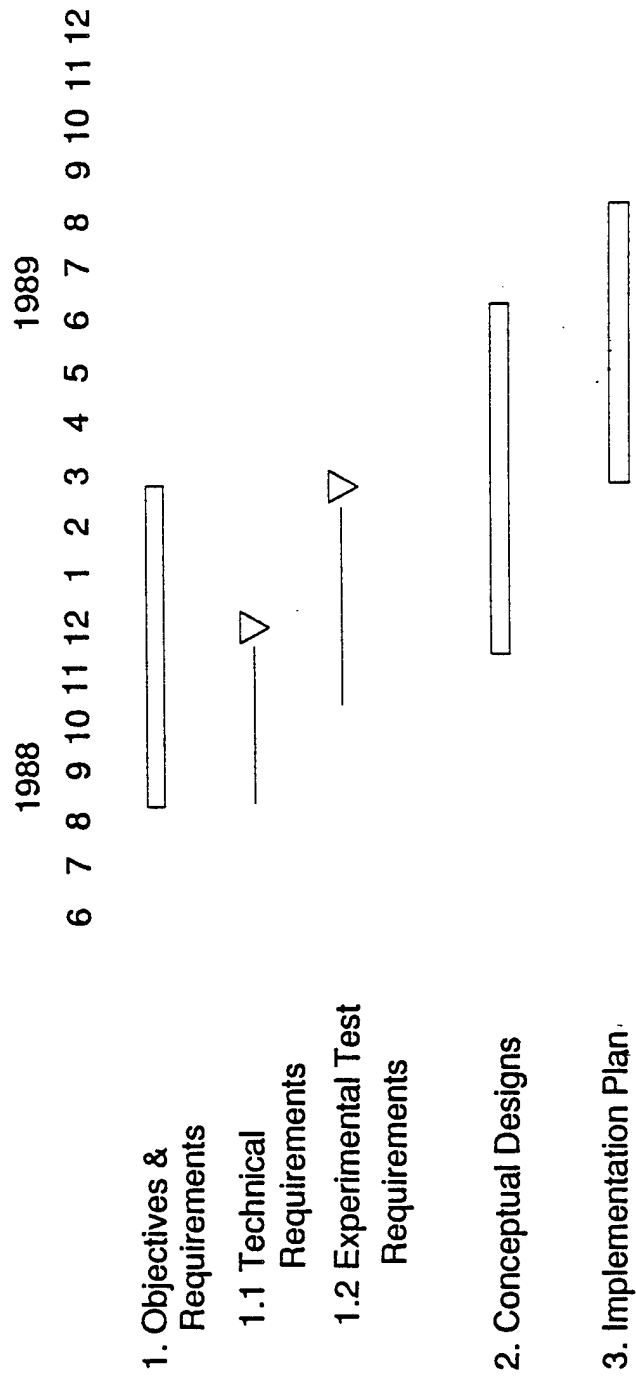


FIGURE 4 EXPERIMENTAL APPARATUS DURING LINEAR PERTURBATION

OUT-REACH	MOVING BELT RADIATOR DYNAMICS	AUTHUR D. LITTLE, INC.

PROJECT IS IN EXPERIMENTAL DEFINITION PHASE



POWER SYSTEMS AND THERMAL MANAGEMENT	IN-SPACE TECHNOLOGY EXPERIMENTS WORKSHOP DECEMBER 6-9, 1988	THERMAL MANAGEMENT

LIQUID DROPLET RADIATOR

SHLOMO L. PFEIFFER
GRUMMAN SPACE SYSTEMS

CONTRACT NO. NAS3-25357
LEWIS RESEARCH CENTER
ALAN WHITE

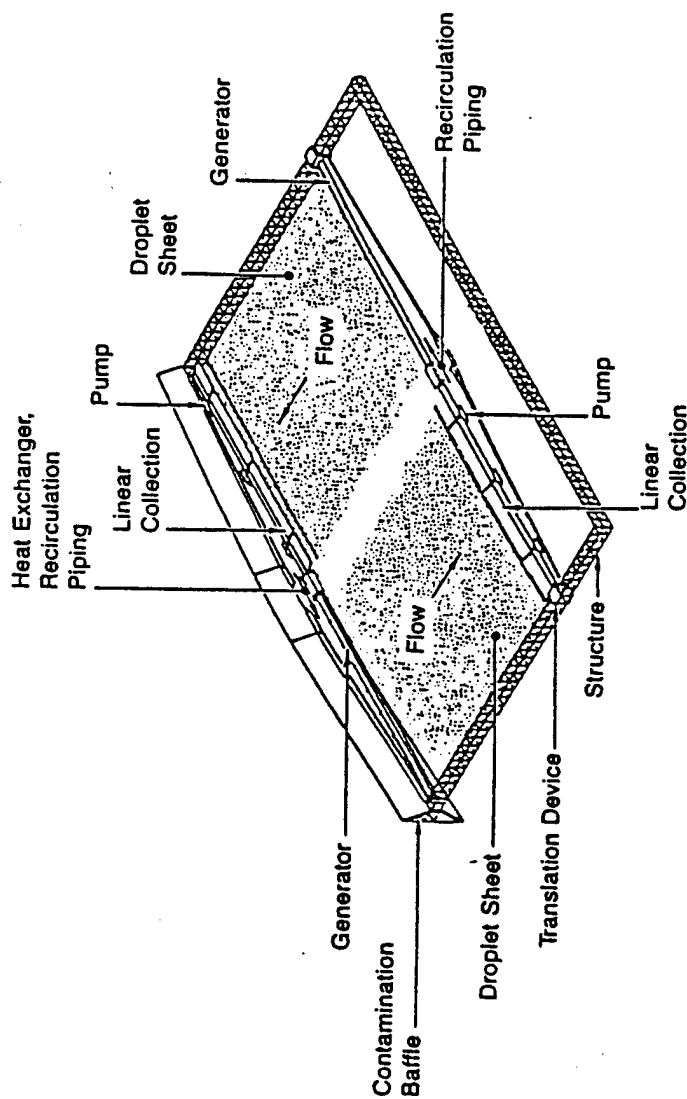
OUTREACH	Liquid Droplet Radiator	GRUMMAN

Background

- Power levels for future space applications are increasing
- The heat rejection system can represent the dominant weight penalty of future space platforms
- Studies have shown that the Liquid Droplet Radiator (LDR) is significantly lighter than conventional radiators
- Contracts sponsored by NASA LeRC and AFAL have demonstrated LDR generator and collector operation

Need

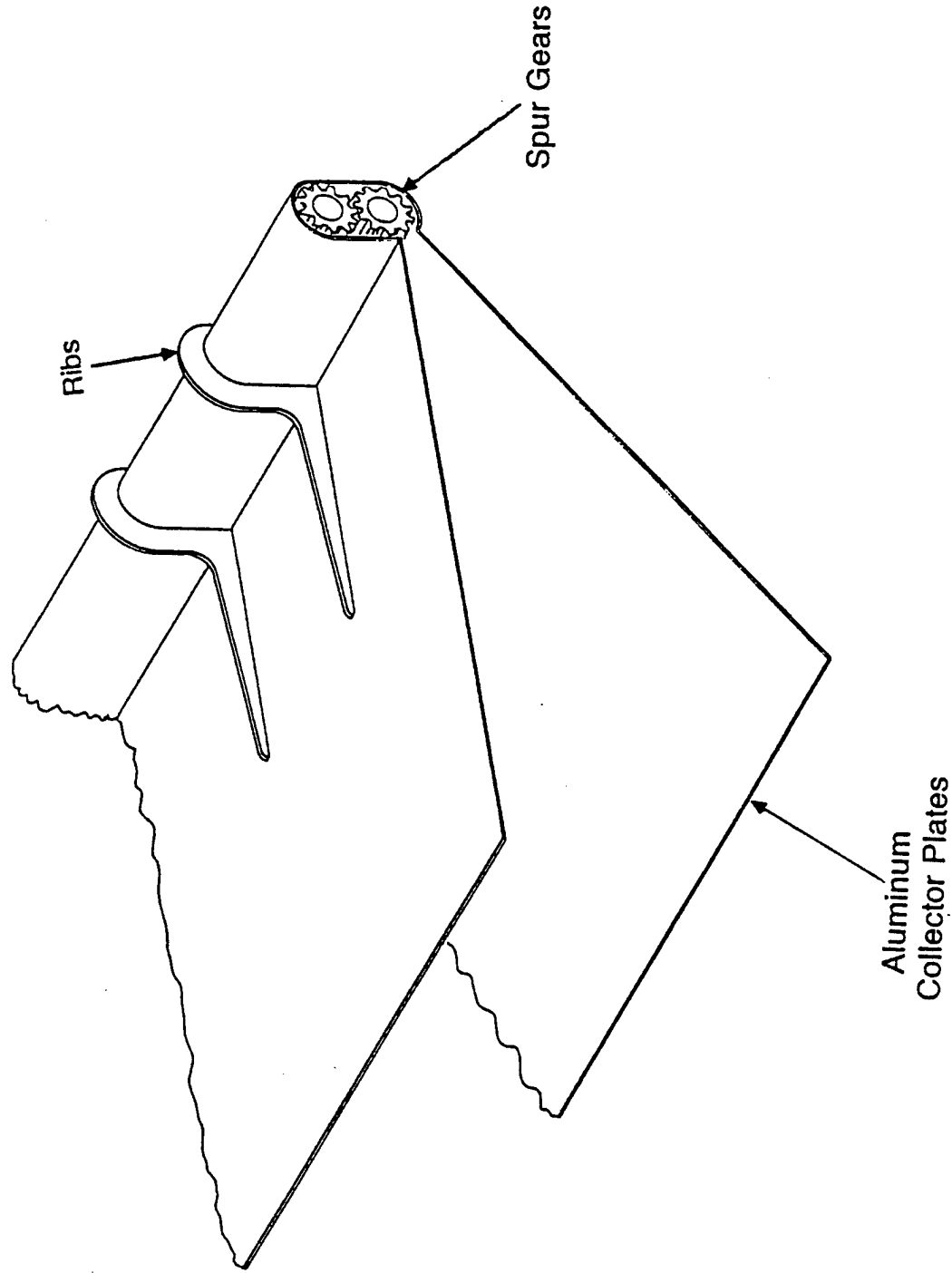
- Test subscale LDR system which will provide end-to-end system verification of the LDR concept in zero-g



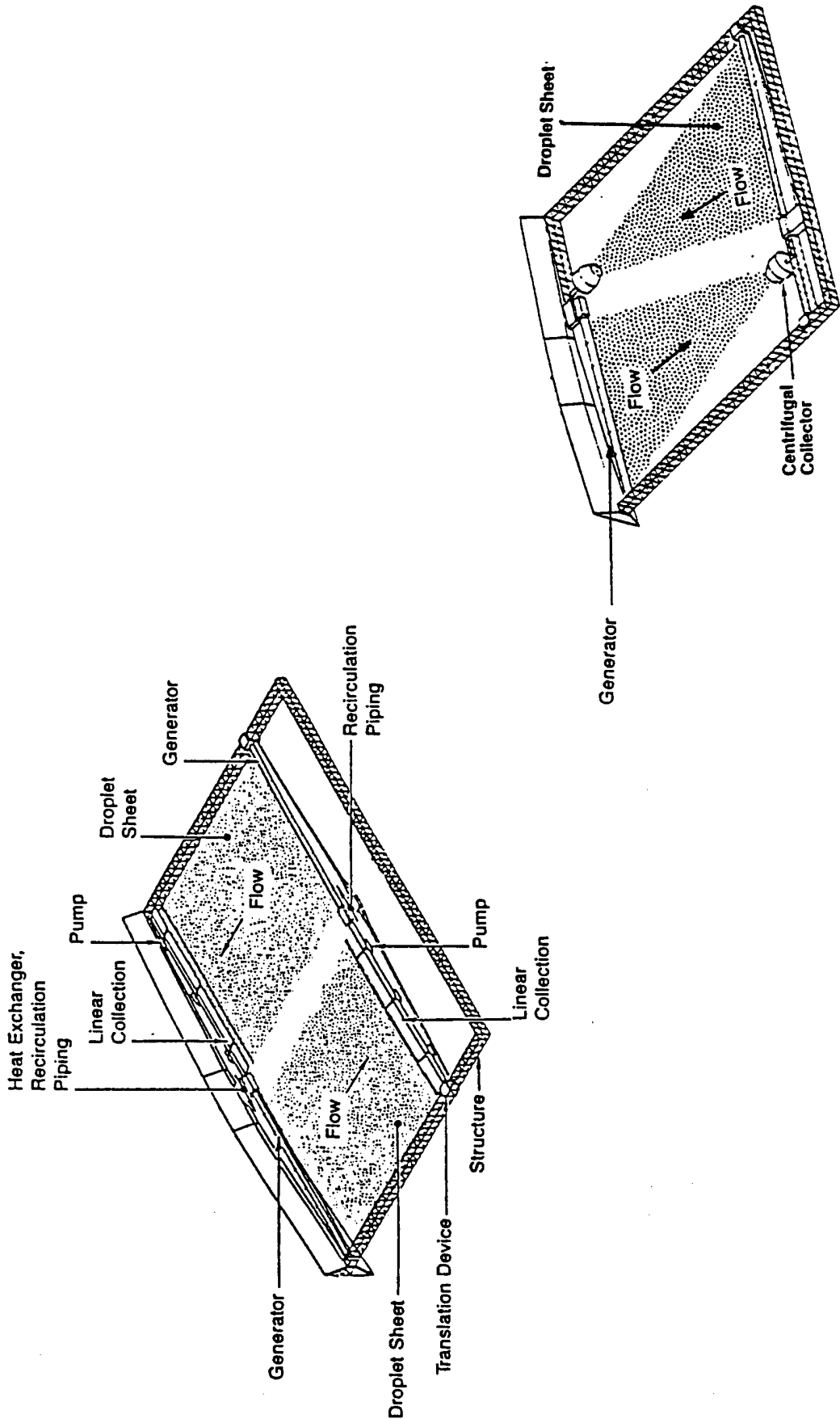
- Heated fluid is generated into a spray of droplets
- Droplets radiatively cool as they pass through space
- Droplets are collected and recycled back to the heat source

OUTREACH	Liquid Droplet Radiator	GRUMMAN

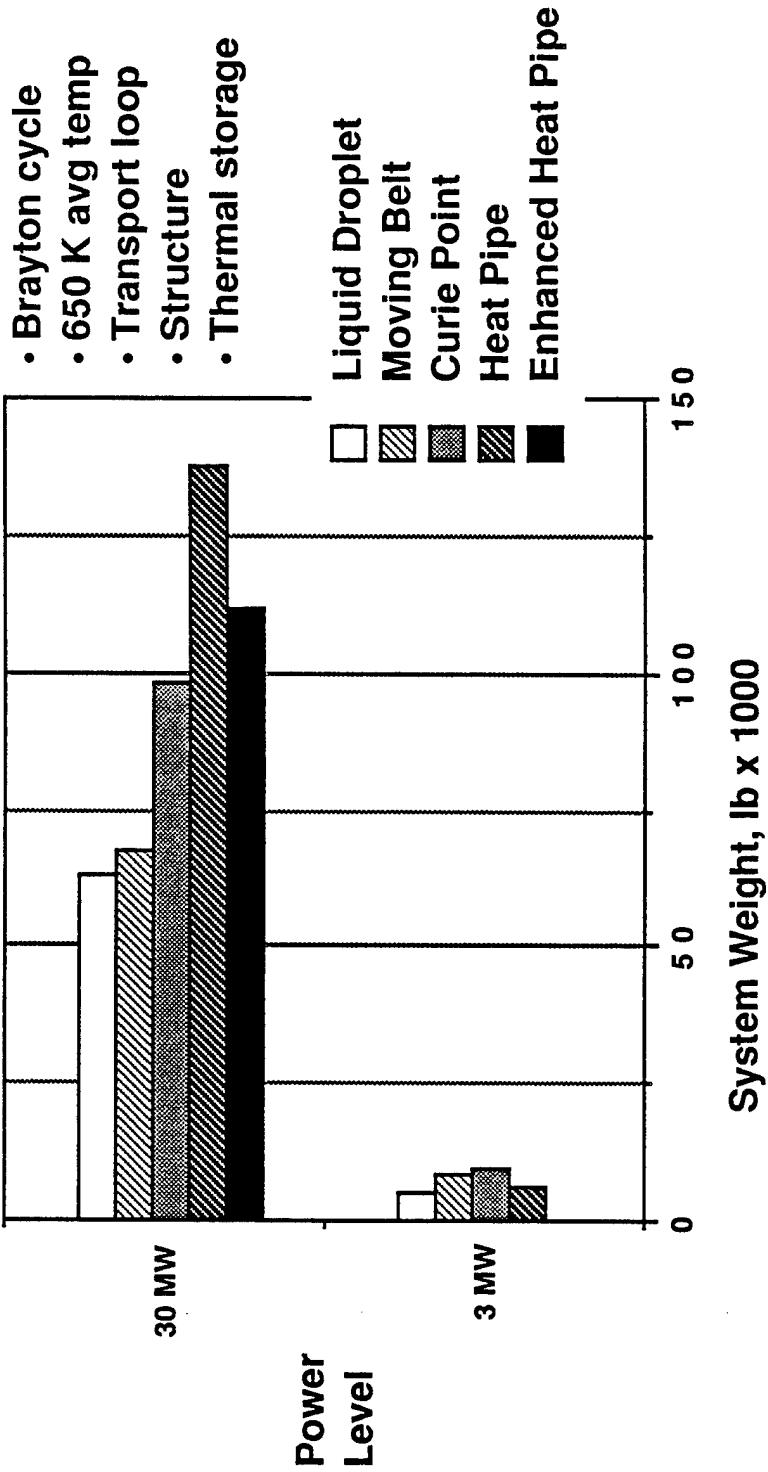
Conceptual Design of Linear Collector



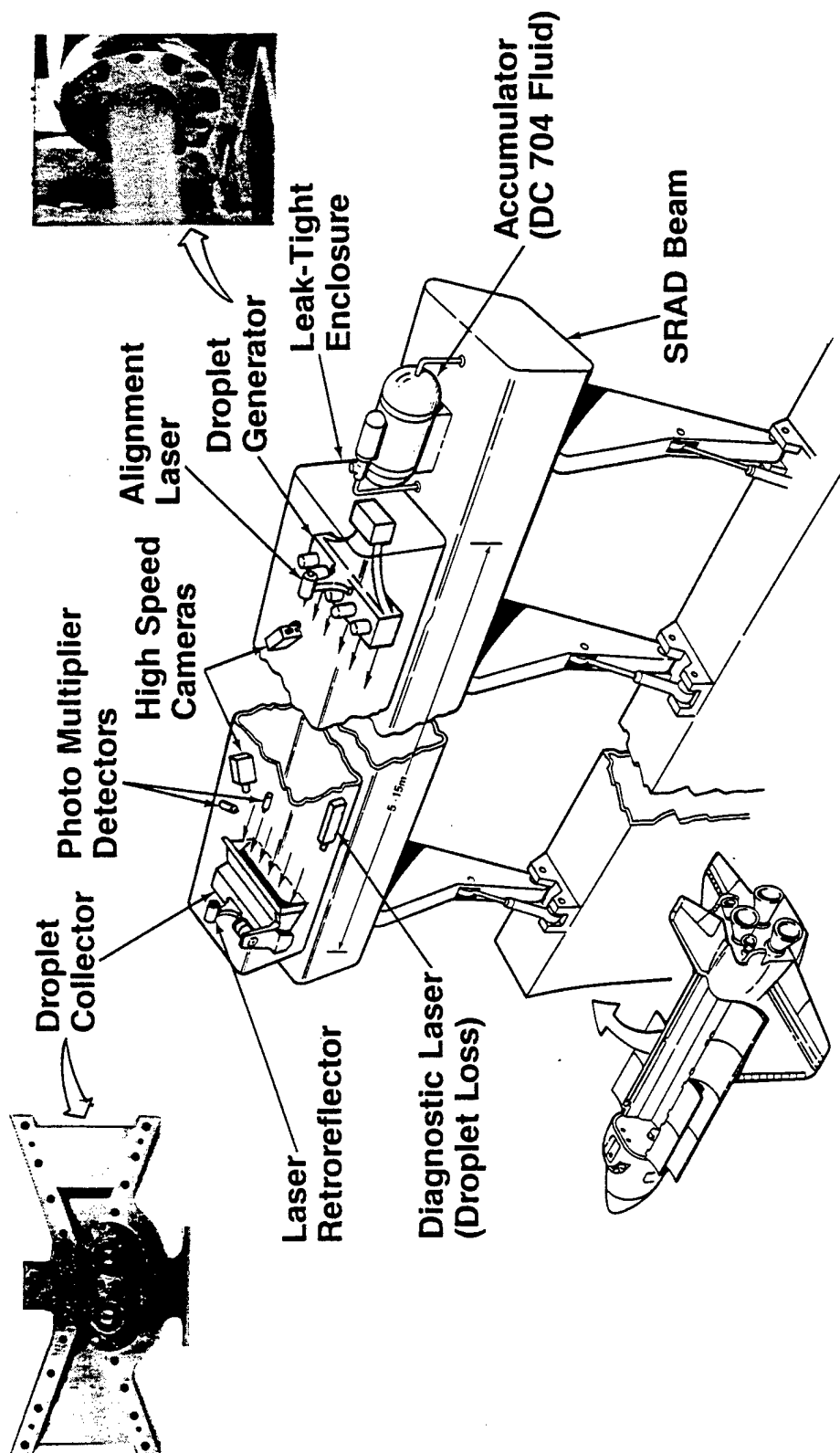
Rectangular and Triangular LDR Conceptual Designs



Heat Rejection System Weight Comparison



Liquid Droplet Radiator In-Space Experiment



LIQUID DROPLET RADIATOR (LDR)

The LDR is an advanced heat rejection concept which can be used to radiate large amounts of heat using minimal weight. The heated fluid is generated into a spray of droplets which radiatively cool as they pass through space. The fluid is then collected and recycled back to the heat source.

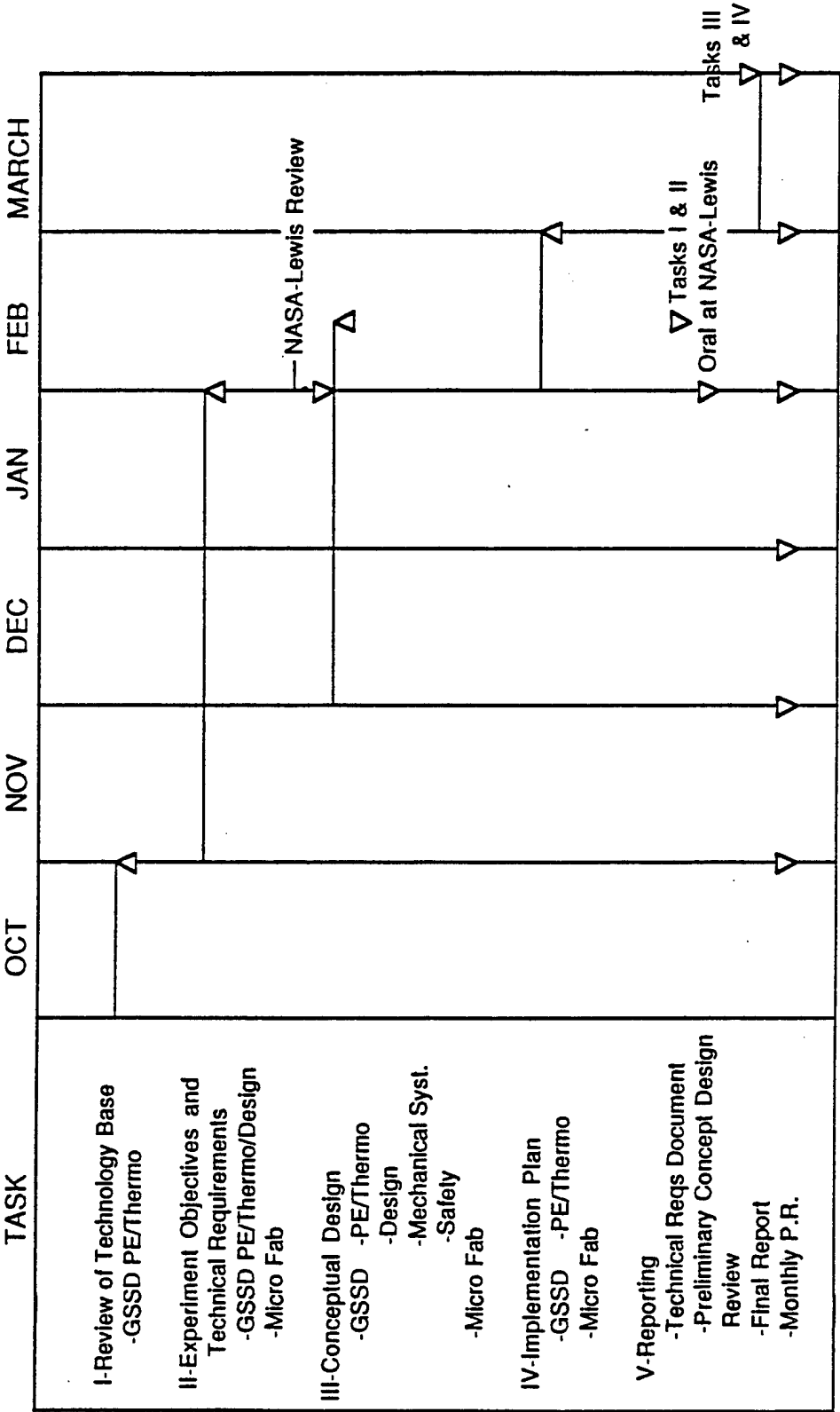
GRUMMAN

OUTREACH	Liquid Droplet Radiator	GRUMMAN

Zero-g Experimental Objectives

- Startup
 - Generator fluid loss
 - Film/stream interaction at the collector
 - Initial film capture and pressurization
- Steady state running
 - Droplet stream characteristics
 - Generator/collector operation
- Shutdown
 - Effect of fluid decay on pump operation
 - Fluid losses at generator and collector

Program Schedule



4. FLUID MANAGEMENT AND PROPULSION SYSTEMS

FLUID MANAGEMENT AND PROPULSION SYSTEMS	IN-SPACE TECHNOLOGY EXPERIMENTS WORKSHOP DECEMBER 6-9, 1988	ON-ORBIT FLUID MANAGEMENT

TANK PRESSURE CONTROL EXPERIMENT

M. D. BENTZ
BOEING AEROSPACE

Contract No. NAS3-25363
Lewis Research Center
R. Knoll - Project Manager

OUTREACH FLIGHT DEVELOPMENT	TANK PRESSURE CONTROL EXPERIMENT	BOEING AEROSPACE

EXPERIMENT OBJECTIVE:

Improve our understanding of jet mixing and its effect on thermal stratification, develop a better predictive capability, and give confidence in our ability to positively and reliably control cryogenic tank pressures in low gravity.

Our specific objectives are to:

- Measure heat and mass transfer rates and compare with models
- Observe mixing flow patterns to confirm/extend empirical correlations
- Obtain data to validate or improve NASA-ECLIPSE computer code
- Together with COLD-SAT experiment, show effects of tank scale and fluid properties on mixing

OUTREACH FLIGHT DEVELOPMENT	TANK PRESSURE CONTROL EXPERIMENT	BOEING AEROSPACE

BACKGROUND/TECHNOLOGY NEED

Justification:

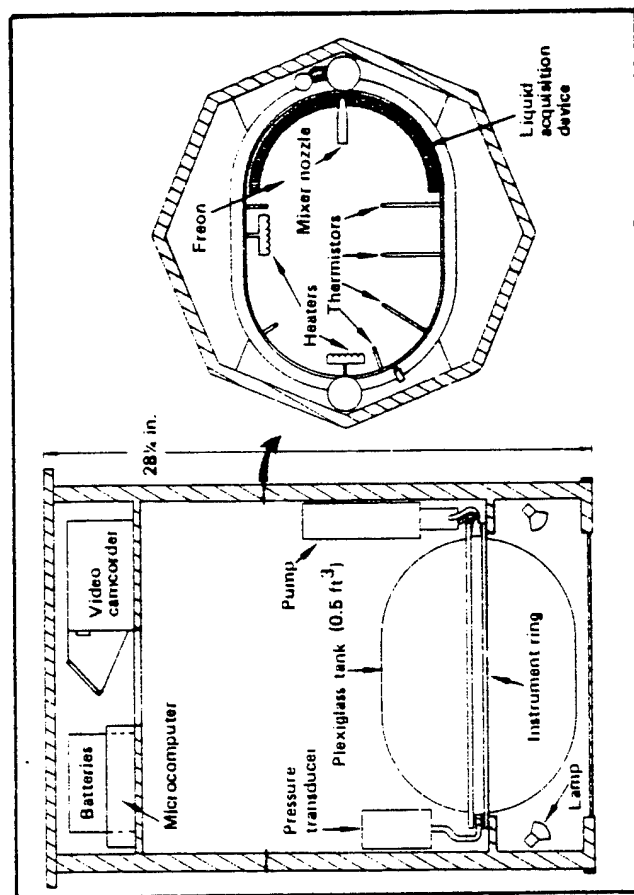
- Future space systems will require storage and transfer of cryogenic fluids
 - STV / OTV
 - manned Mars mission stage
 - Space Station nitrogen supply
 - satellite propellants, reactants, coolants
- Lack of natural convection in low-g leads to increased thermal stratification, higher tank pressures, and possibly longer no-vent fill times
- Use of refrigeration or TVS for pressure control depends on distribution of cooling in tank
- Compact forced-convection heat exchanger could save cost and weight
- Mixing energy should be minimized but must provide reliable pressure control

Previous Work:

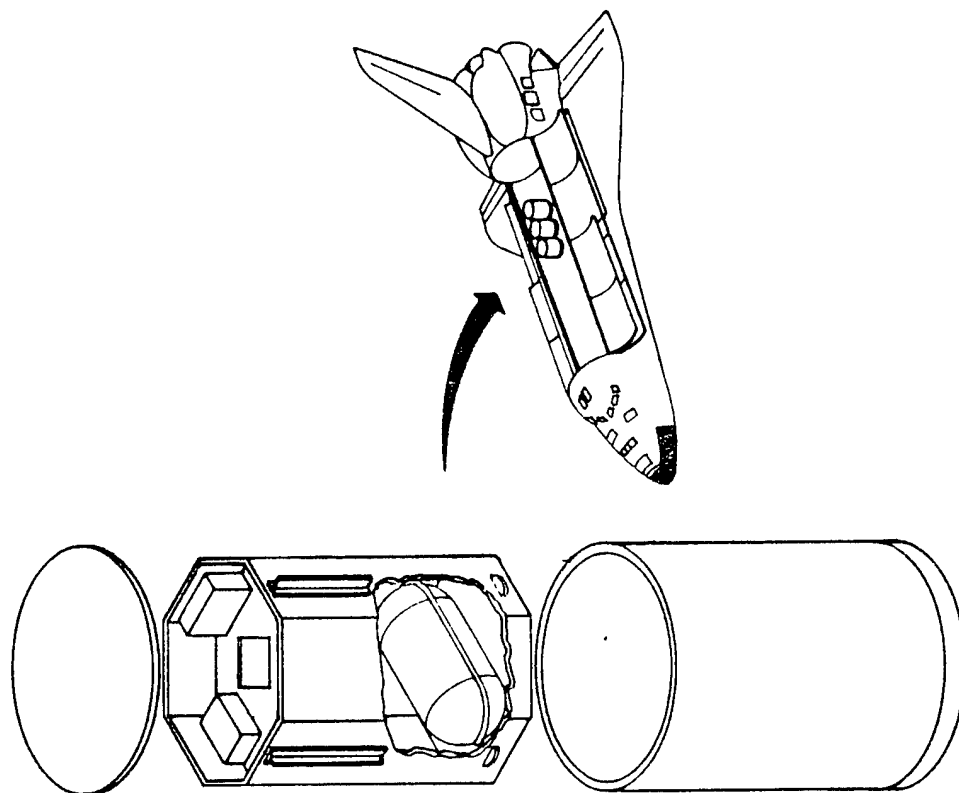
- One-g thermal mixing tests
- Small-scale low-g dye mixing tests in drop tower
- Low-g simulations
- NASA-ECLIPSE code development
- In-space experiment needed to provide low-g data of sufficient duration and scale

EXPERIMENT DESCRIPTION:

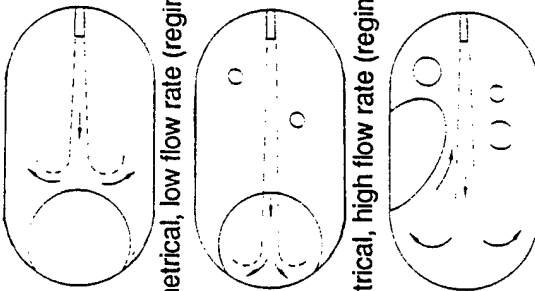
- Small Self-Contained Payload (GAS)
- 5.0 cu-ft., approx. 160 lbm
- autonomous control and data recording
- 800 W-hr power supply (alkaline cells)



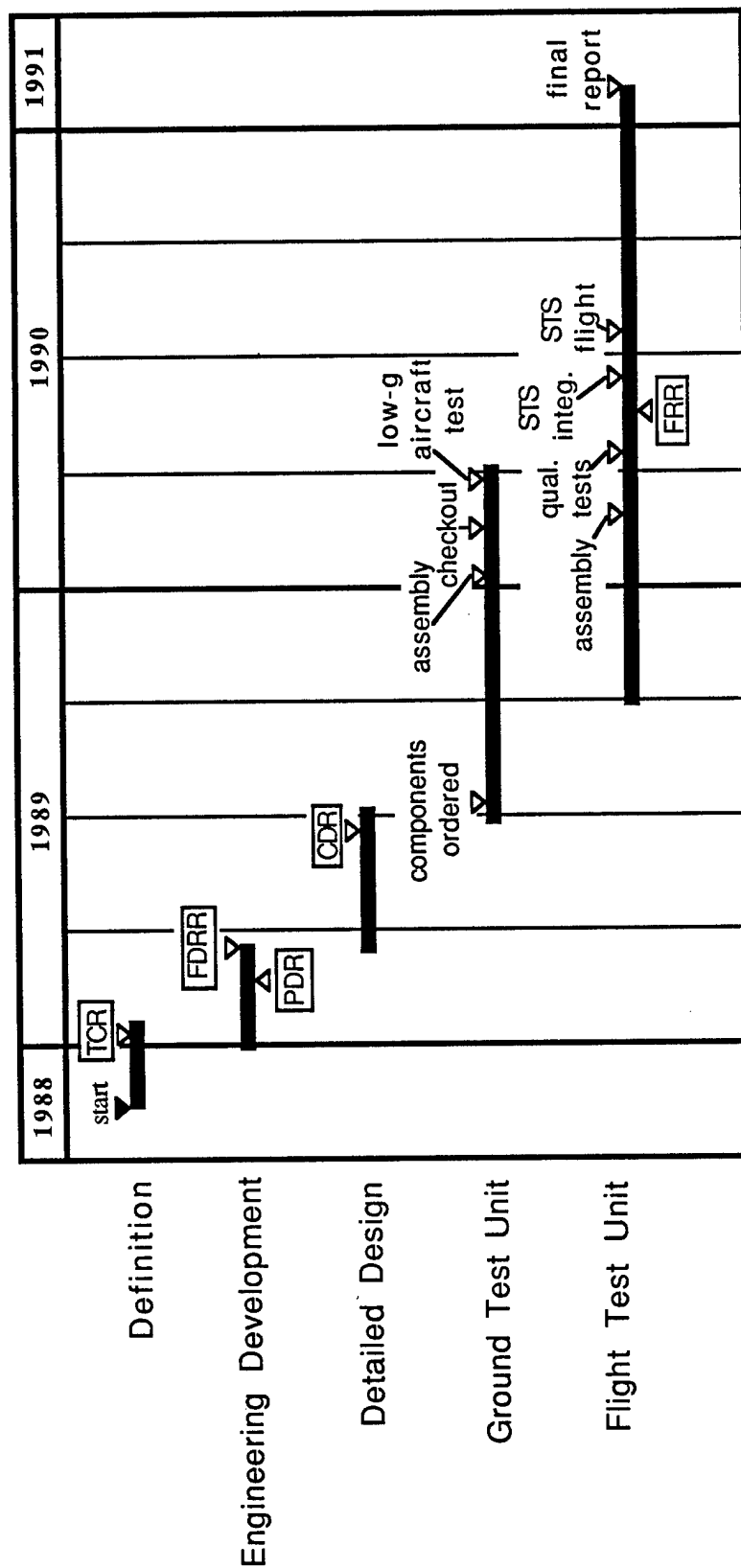
Experiment Layout



Payload Installation

OUTREACH FLIGHT DEVELOPMENT	TANK PRESSURE CONTROL EXPERIMENT	BOEING AEROSPACE
<u>PROPOSED TESTS</u> • Measure effect of low-g on stratification buildup • Measure performance of mixer as functions of flow rate and vapor location expected flow patterns:  symmetrical, low flow rate (regime I) symmetrical, high flow rate (regime IV) unsymmetrical, high flow rate	<u>PROCEDURE</u> • Heat fluid at one of two locations • Measure pressure rise rate and temperature gradients • Mix contents at a range of flow rates and measure pressure collapse rate, temperature transients • Record liquid/vapor orientations and flow patterns on video	<u>END RESULTS</u> • Demonstrate effective pressure control • Determine minimum mixing energy • Understand effect of g-jitter on self-mixing • Provide visual record of fluid behavior • Validate or identify needed improvements to NASA-ECLIPSE and other models

OUTREACH FLIGHT DEVELOPMENT	TANK PRESSURE CONTROL EXPERIMENT	BOEING AEROSPACE



TCR: Technical Concept Review
 PDR: Preliminary Design Review
 FDRR: Flight Development Readiness Review
 CDR: Critical Design Review
 FRR: Flight Readiness Review

**IN-SPACE TECHNOLOGY EXPERIMENTS WORKSHOP
DECEMBER 6-9, 1988**

**INTEGRATED CRYOGENIC EXPERIMENT (ICE)
MICROSPHERE INSULATION INVESTIGATION**

PRESENTED BY

DEAN C. READ

**CONTRACT NO. NAS2-12897
AMES RESEARCH CENTER
JEFFREY M. LEE**

**Research & Development Division
LOCKHEED MISSILES & SPACE COMPANY, INC.
Palo Alto, California 94304**

EXPERIMENT OBJECTIVE

- MEASURE THE LOW-G PERFORMANCE OF VARIOUS MICROSPHERE INSULATIONS OVER AN APPROPRIATE RANGE OF BOUNDARY TEMPERATURES. RESULTS OF PARTICULAR INTEREST ARE:
 - 1) COMPARISON OF ONE-G AND LOW-G PERFORMANCE
 - 2) PERFORMANCE AT LOW HOT BOUNDARY TEMPERATURES
 - 3) PERFORMANCE OF DIFFERENT TYPES OF MICROSPHERES
 - 4) COMPARISON TO MLI PERFORMANCE
- THE EXPERIMENT WILL BE MOUNTED IN THE INSTRUMENT WELL OF THE HELIUM EXTENDED LIFE DEWAR (HELD). USING THE HELD WILL ALLOW A CHARACTERIZATION OF THE DYNAMIC PROPERTIES OF THE PASSIVE ORBITAL DISCONNECT STRUT (PODS) SUPPORT SYSTEM UNDER LOW-G CONDITIONS.
- OTHER EXPERIMENTS MAY ALSO BE INCLUDED IN THE HELD.

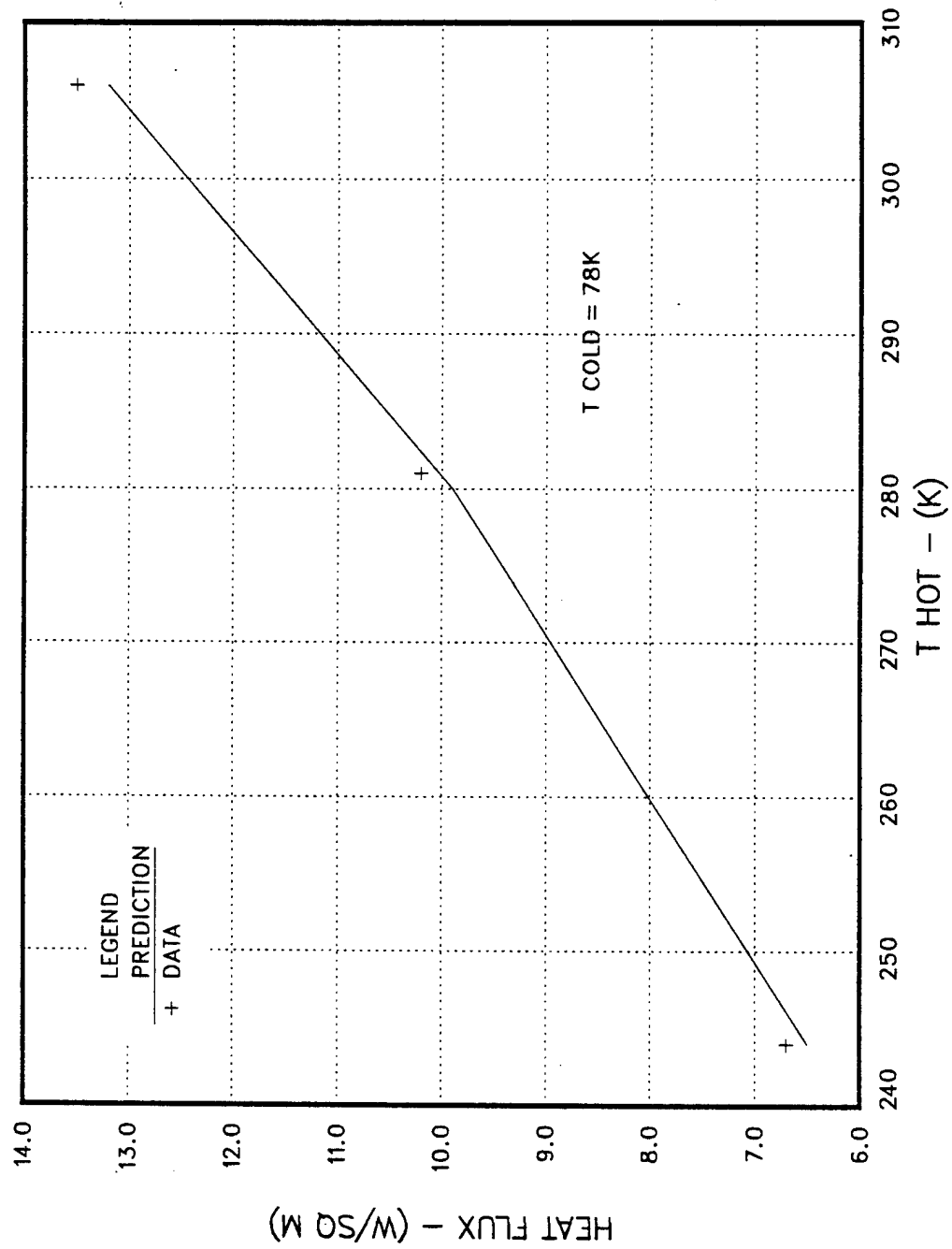
BACKGROUND

- IMPROVED INSULATION SYSTEMS ARE OF GREAT INTEREST SINCE THEY ARE A MAJOR COMPONENT IN DETERMINING THE LIFETIME AND COST OF A CRYOGENIC SYSTEM.
- THE BENEFITS OF A MICROSPHERE INSULATION SYSTEM ARE:
 - 1) LOW-G PREDICTIONS SHOW THE POTENTIAL FOR BETTER PERFORMANCE THAN MLI.
 - 2) INSTALLATION OF MICROSPHERES IS LESS LABOR INTENSIVE THAN MLI, RESULTING IN A SUBSTANTIAL COST SAVINGS.
 - 3) POTENTIAL FOR BETTER PERFORMANCE WITH GEOMETRIES THAT ARE DIFFICULT TO WRAP WITH MLI.

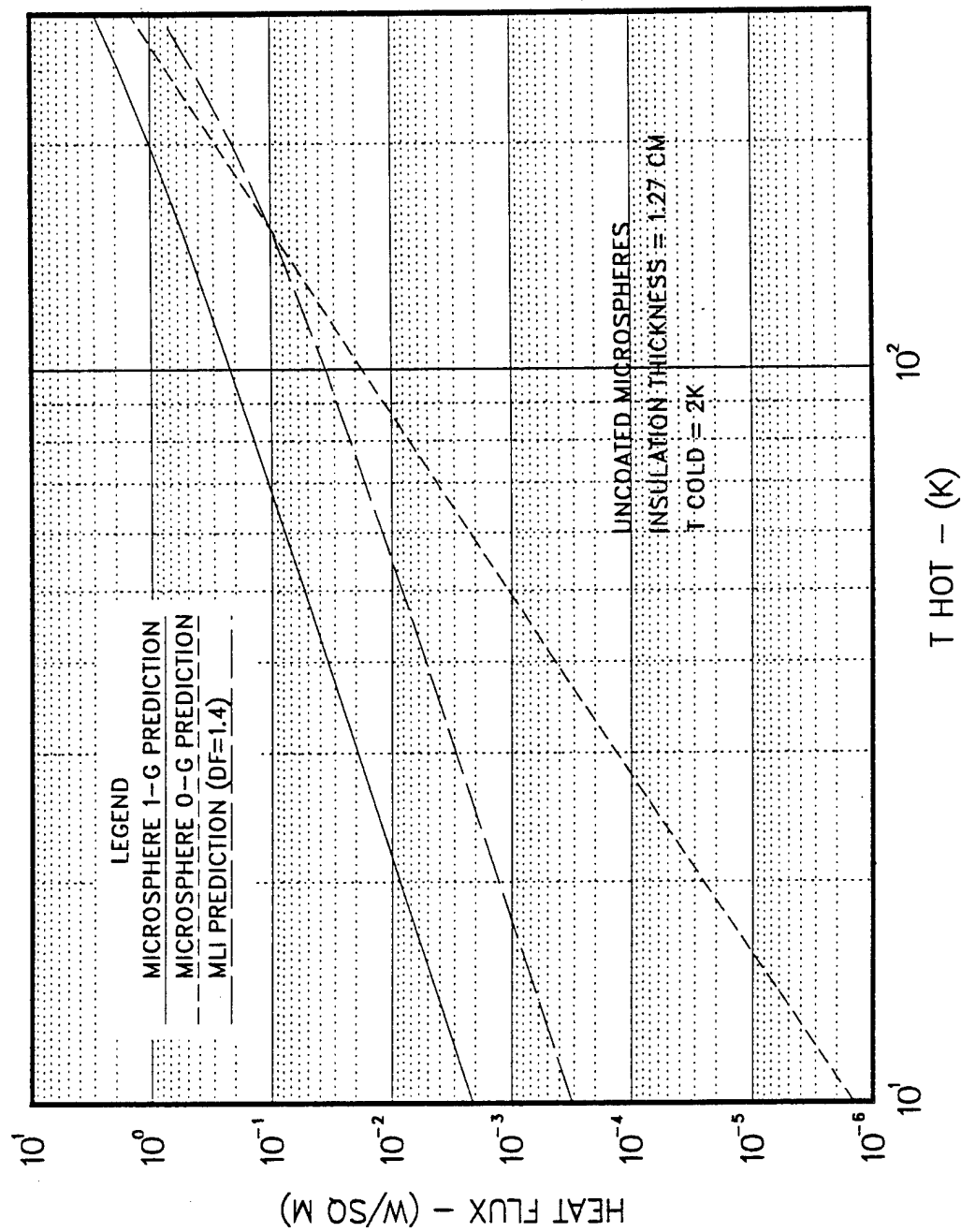
TECHNOLOGY NEEDED

- EXTENSIVE TESTING AT LMSC HAS VERIFIED MLI AND MICROSPHERE PERFORMANCE PREDICTIONS. EXTRAPOLATING THESE PREDICTIONS FROM ONE-G TO LOW-G CONDITIONS SHOW A SUBSTANTIAL IMPROVEMENT IN MICROSPHERE PERFORMANCE.
- THE EFFECTIVE THERMAL CONDUCTIVITY OF MICROSPHERES CAN BE APPROXIMATED BY THE LINEAR SUMMATION OF THE CONDUCTION AND RADIATION COMPONENTS.
- IN ONE-G, THE RADIATION COMPONENT DOMINATES AT HIGH BOUNDARY TEMPERATURES AND THE SOLID CONDUCTION TERM DOMINATES AT LOW VALUES OF THE HOT BOUNDARY TEMPERATURE.
- IN LOW-G, THE SOLID CONDUCTION COMPONENT WOULD BE ZERO AND RADIATION WOULD BE THE ONLY HEAT TRANSFER MECHANISM.

COMPARISON OF CALCULATED AND MEASURED HEAT RATES



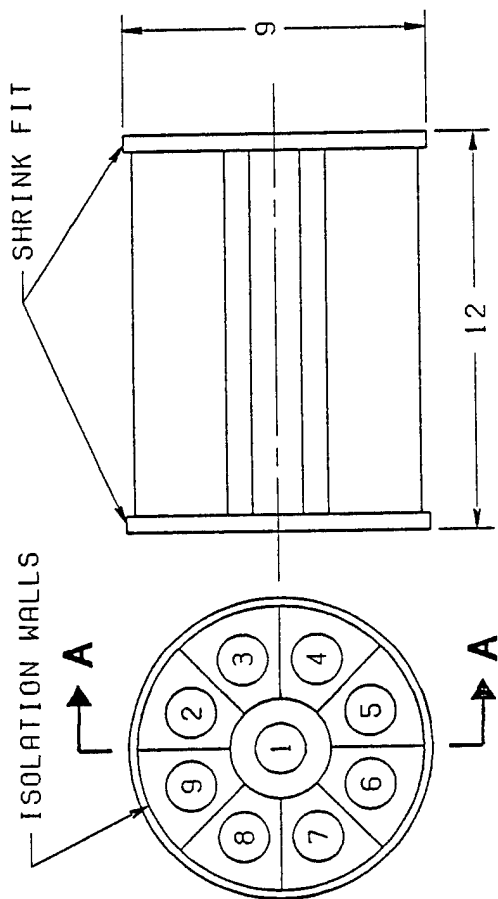
COMPARISON OF MICROSPHERE AND MLI PERFORMANCE PREDICTIONS



EXPERIMENT DESCRIPTION

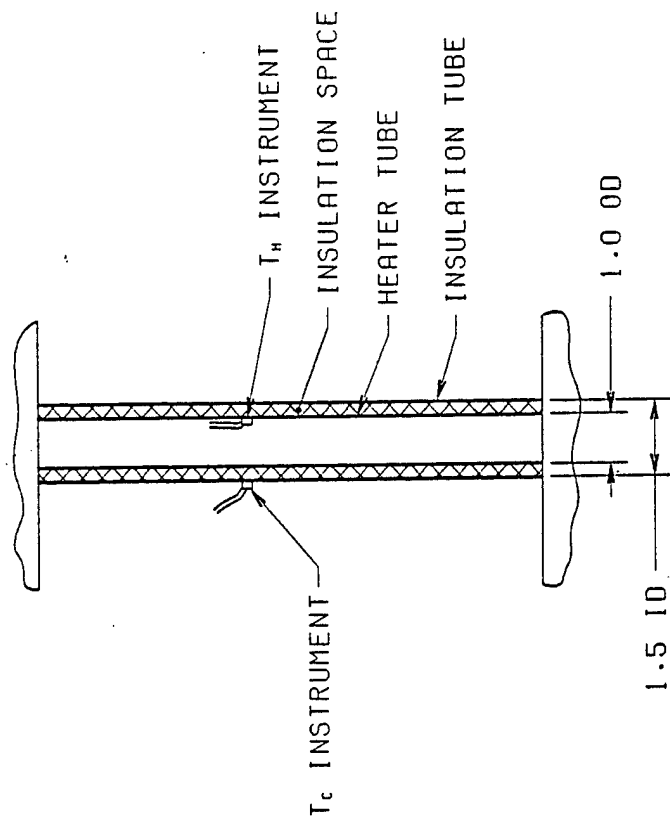
- MICROSPHERE PARAMETERS TO BE TESTED INCLUDE DIAMETER, COATINGS, PACKING DENSITY, MIXES OF DIFFERENT MICROSPHERES, ETC.
- IF THE HEAT TRANSFER IS TOTALLY BY RADIATION, CHANGES IN THE HOT BOUNDARY TEMPERATURE WILL BE EASY TO DETECT FOR SMALL CHANGES IN HEATER POWER SINCE $q \propto T^4$.

EXPERIMENT CONFIGURATION

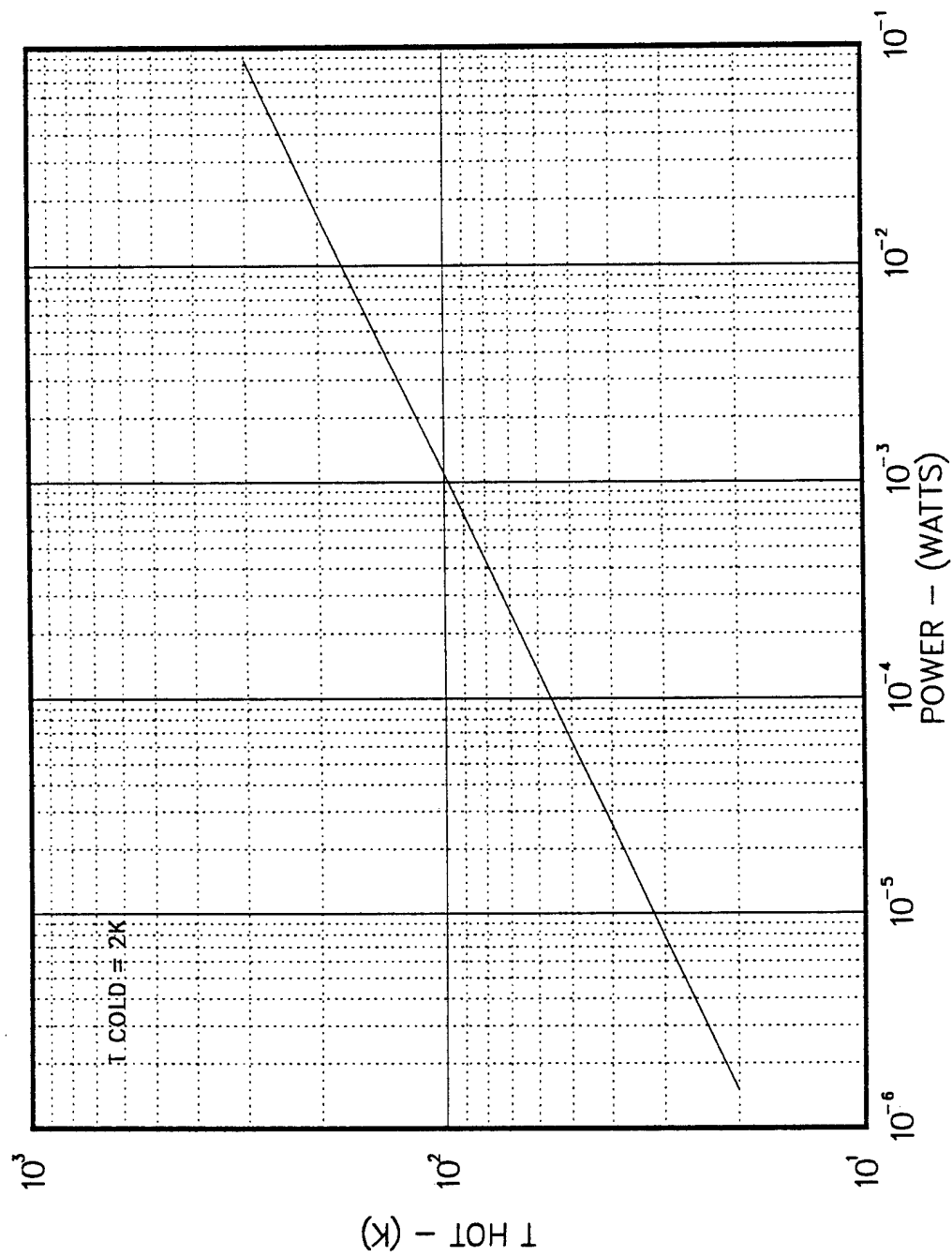


- 1 - REFERENCE INSULATION TUBE
- 2 THRU 9 - MICROSPHERE TUBES

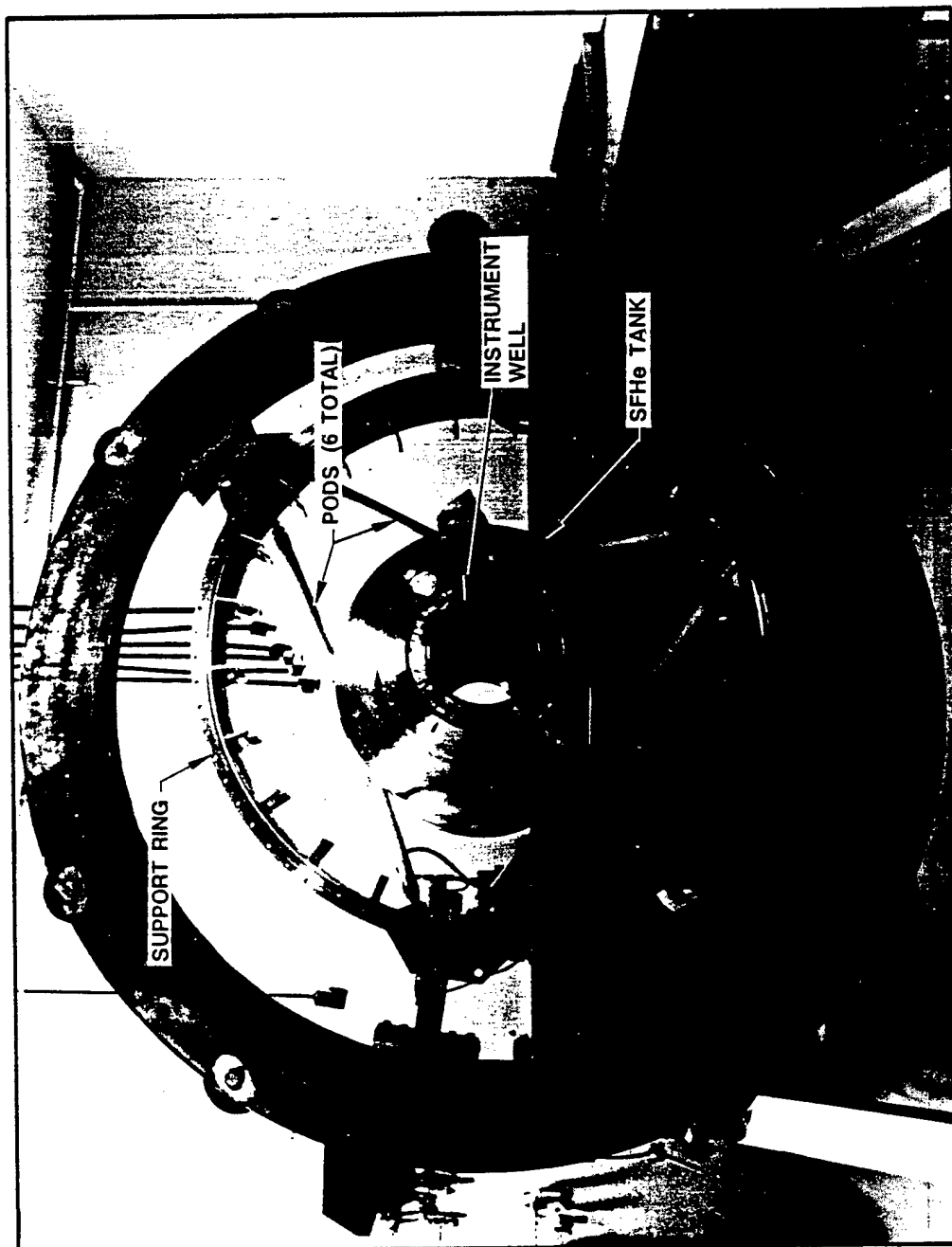
INSULATION TUBE CONFIGURATION



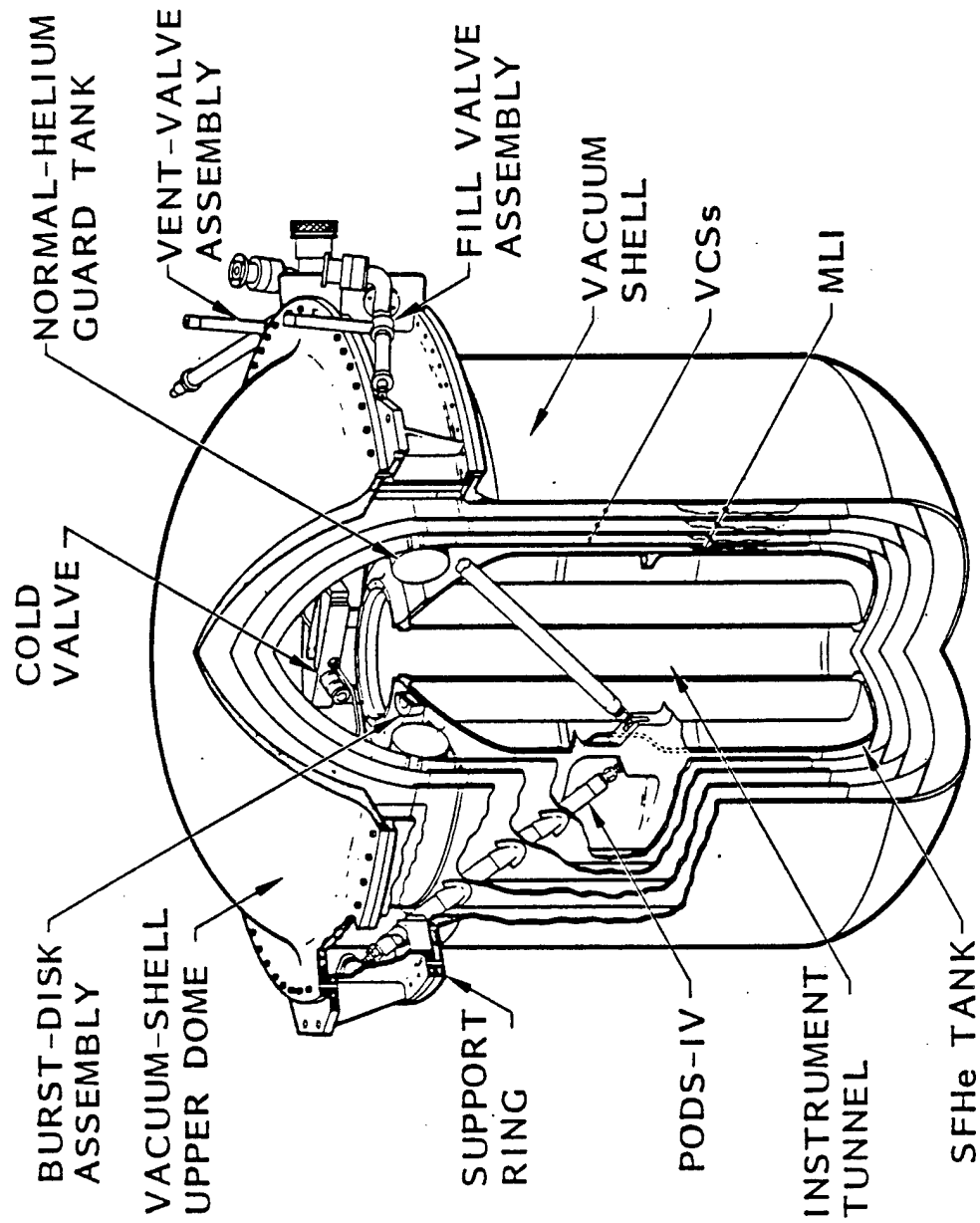
PREDICTED EXPERIMENTAL RESULTS



HELIUM EXTENDED LIFE DEWAR



HELIUM EXTENDED LIFE DEWAR



MASTER SCHEDULE

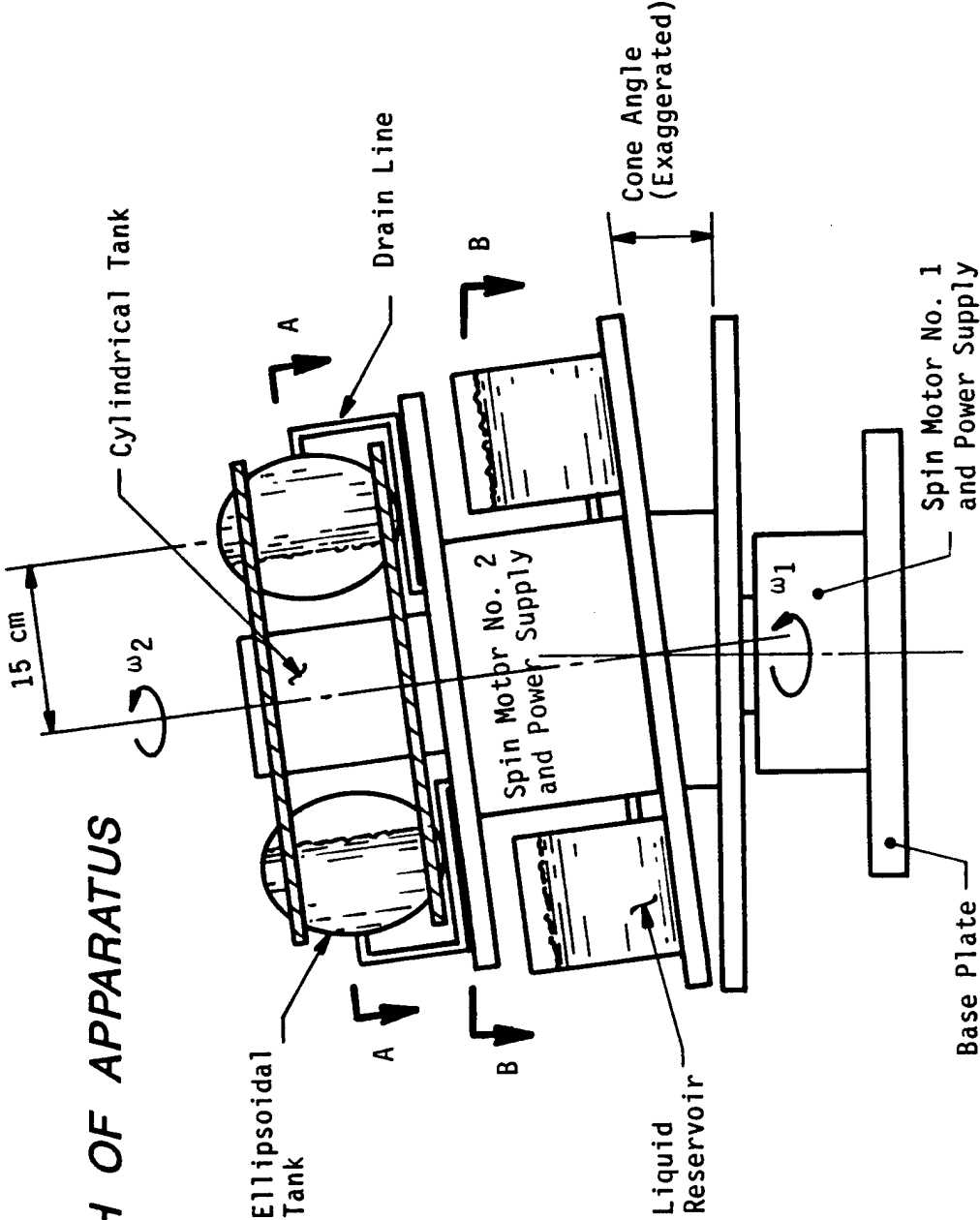
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EXPERIMENT REQUIREMENTS & OBJECTIVES																					
PRELIMINARY DESIGN																					
PROJECT PLAN																					
EXPERIMENT ENGINEERING & DESIGN																					
FABRICATION & ASSEMBLY																					
TESTING & FLIGHT QUALIFICATION																					
PAYLOAD INTEGRATION & CHECKOUT																					
FIRST FLIGHT																					

Fluid Management and Propulsion Systems	IN-SPACE TECHNOLOGY EXPERIMENTS WORKSHOP December 6-9, 1988	On-Orbit Fluid Management
LIQUID MOTION IN A ROTATING TANK FRANKLIN T. DODGE SOUTHWEST RESEARCH INSTITUTE Contract NAS3-25358 Lewis Research Center F. P. Chiamonte		

Outreach	LIQUID MOTION IN A ROTATING TANK	Southwest Research Institute
	<i>EXPERIMENT OBJECTIVE</i> Develop a detailed understanding of liquid motions in a tank spinning about an external axis - primarily "inertial waves." Rotation rate can be so low that surface tension effects are important. This understanding is needed for: • general scientific knowledge (many unanswered theoretical questions that cannot be resolved by ground-based testing) • design of spinning spacecraft (attitude control and stability problems)	

Outreach	LIQUID MOTION IN A ROTATING TANK	Southwest Research Institute
<i>BACKGROUND / TECHNOLOGY NEED</i> • Basic theory still has unresolved questions. CFD codes have not yet proved applicable. Good data is needed to guide theoretical work. • Ground-based fundamental experiments are practically impossible - spin rate must be large to eliminate gravitational effects. Observation and measurement under such conditions are practically impossible. • Liquid torques and energy dissipation interfere with attitude control systems and can cause a "flat" spin for a "prolate" spinner. • Lack of good models and data lead to overly conservative satellite design.		

Outreach	LIQUID MOTION IN A ROTATING TANK	Southwest Research Institute
EXPERIMENT DESCRIPTION • Basic experimental apparatus is a forced motion spin table to control the motion of the test tanks - steady spin - 0 - 10 rpm - nutation (wobbling) frequency is less than twice the spin rate • Flow visualization and measurement of fluid torque used to determine resonant frequencies and flow characteristics • Two sets of tanks - ellipsoids and cylinders - 15 cm diameter		

Outreach	LIQUID MOTION IN A ROTATING TANK	Southwest Research Institute
SKETCH OF APPARATUS 		

Outreach	LIQUID MOTION IN A ROTATING TANK	Southwest Research Institute
SKETCH OF APPARATUS (cont'd) 45 cm Cylindrical Tank (2) Load Cell (4) Ellipsoidal Tank (2) Video Camera 15 cm View A-A Sp'n Motor No. 2 Telemetering and Control Electronics (4) Liquid Reservoir (2) View B-B		

Outreach	LIQUID MOTION IN A ROTATING TANK	Southwest Research Institute
PROJECT IS <i>IN EXPERIMENT DEFINITION</i> PHASE 1988 07 08 09 10 11 12 01 02 03 04 05 06 07 1989 Objectives & Requirements Modeling Conceptual Design Develop Plans, Schedule & Cost		

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FLUID MANAGEMENT & PROPULSION SYSTEMS	IN-SPACE TECHNOLOGY EXPERIMENTS WORKSHOP DECEMBER 6-9, 1988	FLUID PHYSICS

THERMOACOUSTIC CONVECTION HEAT TRANSFER

PROF. MASOOD PARANG

**MECHANICAL AND AEROSPACE ENGINEERING DEPARTMENT
UNIVERSITY OF TENNESSEE
KNOXVILLE, TN**

**CONTRACT NAS3-25359
LEWIS RESEARCH CENTER
DR. AN-TI CHAI**

OUTREACH	THERMOACOUSTIC CONVECTION HEAT TRANSFER	UNIVERSITY OF TENNESSEE KNOXVILLE, TN

EXPERIMENT OBJECTIVE

THE OBJECTIVE IS TO ENHANCE FUNDAMENTAL UNDERSTANDING OF THERMOACOUSTIC CONVECTION (TAC) HEAT TRANSFER PHENOMENON AND EVALUATE ITS IMPORTANCE IN VARIOUS PROCESSES INVOLVING TRANSIENT HEAT TRANSFER IN LOW GRAVITY ENVIRONMENT. THE EXPERIMENT WILL PROVIDE DATA WHICH WILL BE USED TO VERIFY ANALYTICAL RESULTS AND COMPARE WITH GROUND-BASED EXPERIMENTS. THE UNDERSTANDING OF THIS PHENOMENON WILL BE APPLICABLE TO:

- DEVELOP INNOVATIVE WAYS FOR RAPID HEATING UNDER MICROGRAVITY CONDITIONS
- IMPROVE HEAT TRANSFER CONTROL IN FLUID HANDLING, STORAGE AND TRANSPORT
- UNDERSTAND THE ROLE AND IMPORTANCE OF HEAT TRANSFER IN ACOUSTIC LEVITATORS

OUTREACH	THERMOACOUSTIC CONVECTION HEAT TRANSFER	UNIVERSITY OF TENNESSEE KNOXVILLE, TN

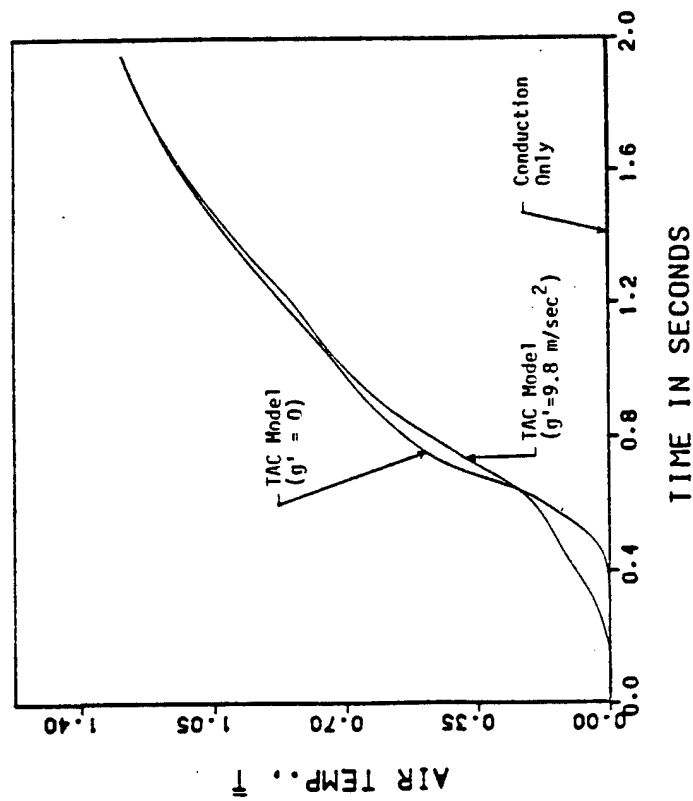
BACKGROUND

ANALYTICAL STUDIES INDICATE:

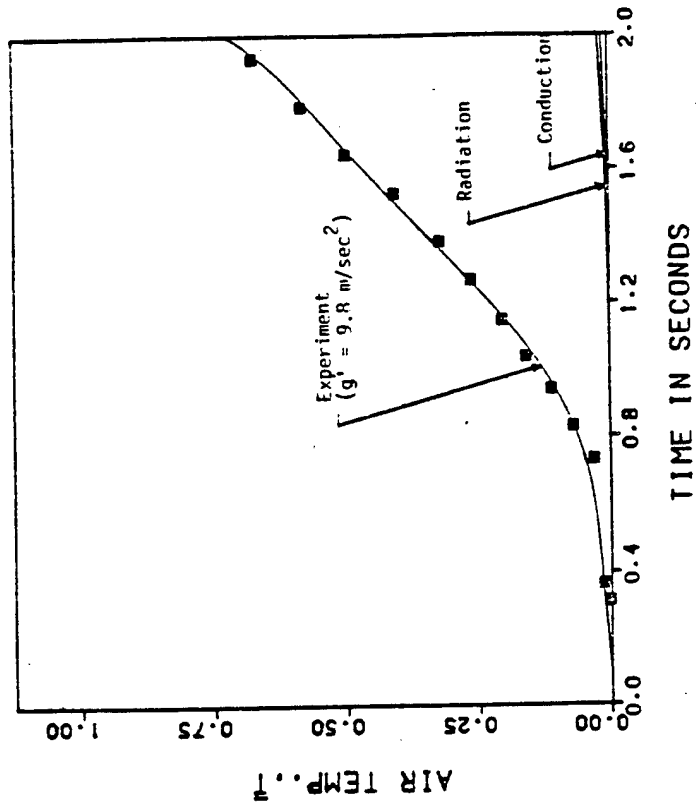
- VERY LARGE HEAT TRANSFER COMPARED TO CONDUCTION
- VERY SMALL TRANSIENT TIME

EXPERIMENTAL STUDIES SHOW:

- CONTRADICTIONARY AND INCONCLUSIVE RESULTS
- WHEN TAC EFFECTS ARE OBSERVED, THEIR IMPORTANCE IS SEEN TO BE NOT AS SIGNIFICANT



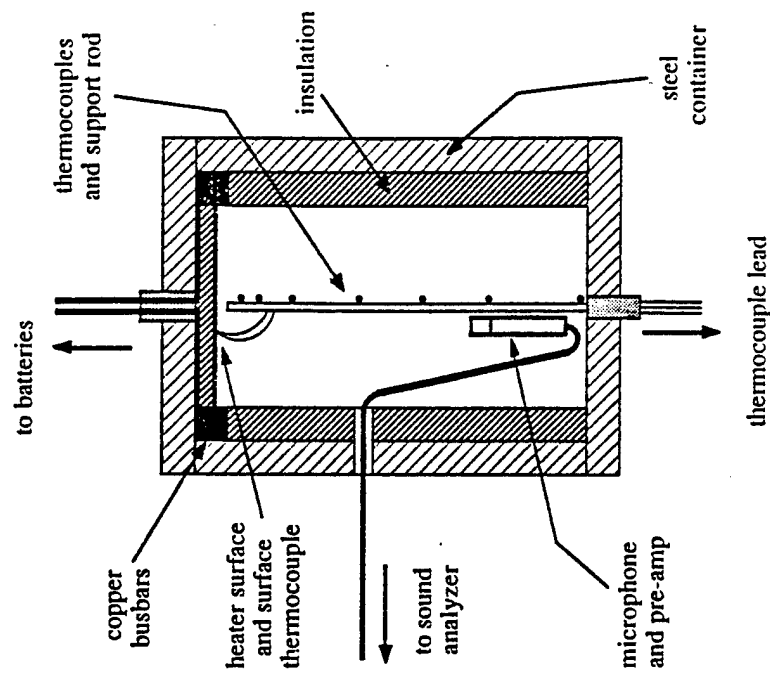
Comparison of the Results of the TAC Numerical Model with the Pure Conduction Solution



Comparison of the Numerical Results (Conduction and Radiation) and Experimental Results

EXPERIMENT DESCRIPTION

THE APPARATUS WILL PROVIDE RAPID HEATING OF A COMPRESSIBLE FLUID NEAR A BOUNDARY. THE SYSTEM CAN BE MODIFIED TO PROVIDE EXPERIMENTAL DATA FOR BOTH CLOSED AND OPEN-ENDED VESSEL GEOMETRY. INSTRUMENTATION FOR TEMPERATURE AND PRESSURE MEASUREMENTS ARE REQUIRED TO DETECT AND RECORD THE EFFECTS OF THERMOCONVECTIVE WAVES.



5. AUTOMATION AND ROBOTICS

AUTOMATION & ROBOTICS	IN-SPACE TECHNOLOGY EXPERIMENTS WORKSHOP DECEMBER 6-9, 1988	ROBOTIC SYSTEMS

RESEARCH AND DESIGN OF MANIPULATOR FLIGHT TESTBEDS

T. M. DEPKOVICH
MARTIN MARIETTA ASTRONAUTICS GROUP

CONTRACT NO. NAS9-17907
JOHNSON SPACE CENTER
JERRY REUTER

Outreach	Research and Design of Manipulators Flight Testbed	Martin Marietta Astronautics Group

EXPERIMENT OBJECTIVES

Advance the state-of-the-art in space robotics through the design and development of manipulator testbeds to be flown on the Space Transportation System (STS) supporting:

- Rigid Link Manipulators
- Large, Flexible Manipulators

Outreach	Research and Design of Manipulators Flight Testbed	Martin Marietta Astronautics Group

BACKGROUND/TECHNOLOGY NEED

- Significant results from ground experimentation have not been validated in space
- Space robotics R & D program has need for long-term testbed capability in support of:
 - Mechanisms
 - Sensors
 - Processing
 - Controls
- On-orbit experimentation is required to provide a database for defining technology directions

Outreach	Research and Design of Manipulators Flight Testbed	Martin Marietta Astronautics Group

EXPERIMENT DESCRIPTION

- Experiment will support rigid and flexible arm experiments
- Processing system will support varied controls research objectives
- Experiment will support both autonomous and teleoperated functions
- Emphasis is on growth capability

Outreach	Research and Design of Manipulators Flight Testbed	Martin Marietta Astronautics Group

SCHEDULE

RESEARCH AND DESIGN	1988								1989			
	J	J	A	S	O	N	D	J	F	M	A	
MASTER SCHEDULE												
FACE/DMACE												
Requirements Definition												
Concept Definition												
Program Definition												
Program Plan												

Outreach	Research and Design of Manipulators Flight Testbed	Martin Marietta Astronautics Group

SUMMARY

- A need exists for research testbeds, on orbit, to support validation of technology
- Must support both:
 - rigid and flexible structures
 - teleoperation and autonomy
 - operation from ground or space
- Key design feature: ability to integrate new technology

AUTOMATION & ROBOTICS	IN-SPACE TECHNOLOGY EXPERIMENTS WORKSHOP DECEMBER 6-9, 1988	ROBOTIC SYSTEMS

CONTROL OF FLEXIBLE ROBOT MANIPULATORS IN ZERO GRAVITY

PRINCIPAL INVESTIGATOR

WARREN F. PHILLIPS

CENTER FOR COMPUTER AIDED DESIGN AND MANUFACTURING
UTAH STATE UNIVERSITY
LOGAN, UTAH 84322-4130

TELEPHONE: (801) 750-2950

CONTRACT NO. NAS8-37754
MARSHALL SPACE FLIGHT CENTER
PAMELA NELSON

OUT-REACH	CONTROL OF FLEXIBLE ROBOT MANIPULATORS IN ZERO GRAVITY	UTAH STATE UNIVERSITY

EXPERIMENT OBJECTIVE

DEVELOP A MANIPULATOR CONTROL SYSTEM CAPABLE OF ACCURATELY CONTROLLING A ROBOT ARM WITH LIGHTWEIGHT NON-RIGID LINKS IN A ZERO GRAVITY VACUUM. THIS CONTROL SYSTEM MUST MEET THE FOLLOWING REQUIREMENTS:

- POSITION CONTROL OF THE END-EFFECTOR MUST BE AS GOOD AS OR BETTER THAN PRESENT DAY INDUSTRIAL ROBOTS.
- CONTROL ACCURACY MUST NOT BE A FUNCTION OF PAYLOAD MASS OVER THE DESIGN LOAD-RANGE.
- STRUCTURAL STIFFNESS OF THE MANIPULATOR LINKS MUST NOT SIGNIFICANTLY AFFECT THE POSITION CONTROL ACCURACY.

OUT-REACH	CONTROL OF FLEXIBLE ROBOT MANIPULATORS IN ZERO GRAVITY	UTAH STATE UNIVERSITY

BACKGROUND / TECHNOLOGY NEED

PROBLEMS ASSOCIATED WITH USING A COMPLETE MODEL BASED, DECOUPLING AND LINEARIZING MANIPULATOR CONTROL SYSTEM:

- IT IS COMPUTATIONALLY VERY EXPENSIVE TO USE THE ENTIRE DYNAMIC MODEL INSIDE THE CONTROL LOOP.
- THE VALUES OF THE PARAMETERS IN THE DYNAMIC MODEL ARE OFTEN NOT ACCURATELY KNOWN.
- SOME OF THE PARAMETERS ARE NOT REPEATABLE BECAUSE THEY CHANGE AS THE ROBOT AGES.
- STRUCTURAL VIBRATIONS MAY BE INDUCED BY THE CONTROL SYSTEMS IN MANIPULATORS WITH FINITE STIFFNESS.

OUT-REACH	CONTROL OF FLEXIBLE ROBOT MANIPULATORS IN ZERO GRAVITY	UTAH STATE UNIVERSITY

BACKGROUND / TECHNOLOGY NEED

SIMPLIFICATIONS MADE IN MOST PRESENT DAY INDUSTRIAL
ROBOT CONTROL SYSTEMS:

- THE DYNAMIC MODEL IS NOT USED AT ALL INSIDE THE CONTROL LOOP.
- THE CONTROL SYSTEM GAINS ARE ALL SET TO CONSTANT DIAGONAL MATRICES.
- THE CONSTANT GAINS ARE SET AS HIGH AS POSSIBLE, SO THAT THE ERRORS CAUSED BY THE JOINT COUPLING WILL BE QUICKLY SUPPRESSED BY THE ERROR DRIVEN CONTROL LAW.
- ALL LINKS ARE CONSTRUCTED TO BE VERY STIFF, TO PREVENT THE HIGH GAINS FROM INDUCING STRUCTURAL VIBRATIONS.

OUT-REACH	CONTROL OF FLEXIBLE ROBOT MANIPULATORS IN ZERO GRAVITY	UTAH STATE UNIVERSITY

BACKGROUND / TECHNOLOGY NEED

PROBLEMS ASSOCIATED WITH USING PRESENT INDUSTRIAL
ROBOT CONTROL SYSTEMS FOR IN-SPACE APPLICATIONS:

- IF THE MANIPULATOR IS DESIGNED TO HAVE VERY STIFF LINKS, IT NATURALLY MUST BE VERY HEAVY. A ROBOT TO PAYLOAD WEIGHT RATIO OF 50 IS COMMON.
- IF THE LINK WEIGHT AND STIFFNESS IS REDUCED, THE HIGH CONSTANT GAINS WILL EXCITE THE NATURAL VIBRATION MODES OF THE MANIPULATOR.
- IF THE CONSTANT GAINS ARE REDUCED, ERRORS INDUCED BY THE JOINT COUPLING WILL NOT BE ADEQUATELY SUPPRESSED.

OUT-REACH	CONTROL OF FLEXIBLE ROBOT MANIPULATORS IN ZERO GRAVITY	UTAH STATE UNIVERSITY

EXPERIMENT DESCRIPTION

THE PRESENT RESEARCH WILL TEST THE FEASIBILITY OF ACCURATELY CONTROLLING A ROBOT ARM WITH LIGHTWEIGHT NON-RIGID LINKS IN A ZERO GRAVITY VACUUM. THE WORK WILL BE CARRIED OUT IN THREE PHASES:

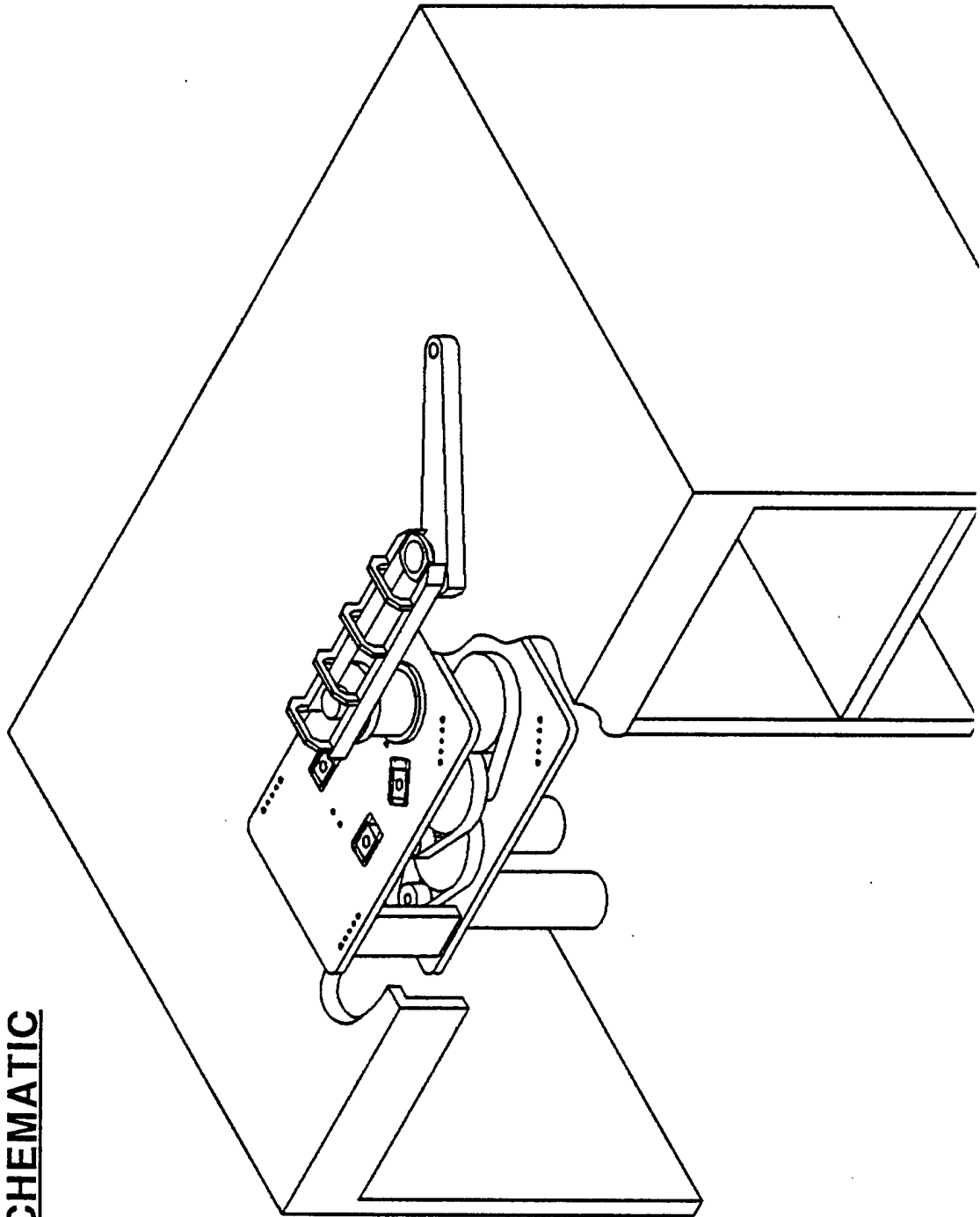
- THE DEVELOPMENT OF A 2-AXIS ROBOT WHICH MINIMIZES THE EFFECTS OF GRAVITY AND CAN BE USED FOR PRELIMINARY GROUND TESTING OF THE CONTROL SYSTEM.
- THE DEVELOPMENT OF A COMPUTER SIMULATION FOR THE TEST ROBOT AND THE CONTROL SYSTEM.
- THE DEVELOPMENT OF A 3-AXIS ROBOT TO BE USED FOR IN-SPACE TESTING OF THE CONTROL SYSTEM.

OUT-REACH

CONTROL OF FLEXIBLE ROBOT MANIPULATORS
IN ZERO GRAVITY

UTAH STATE
UNIVERSITY

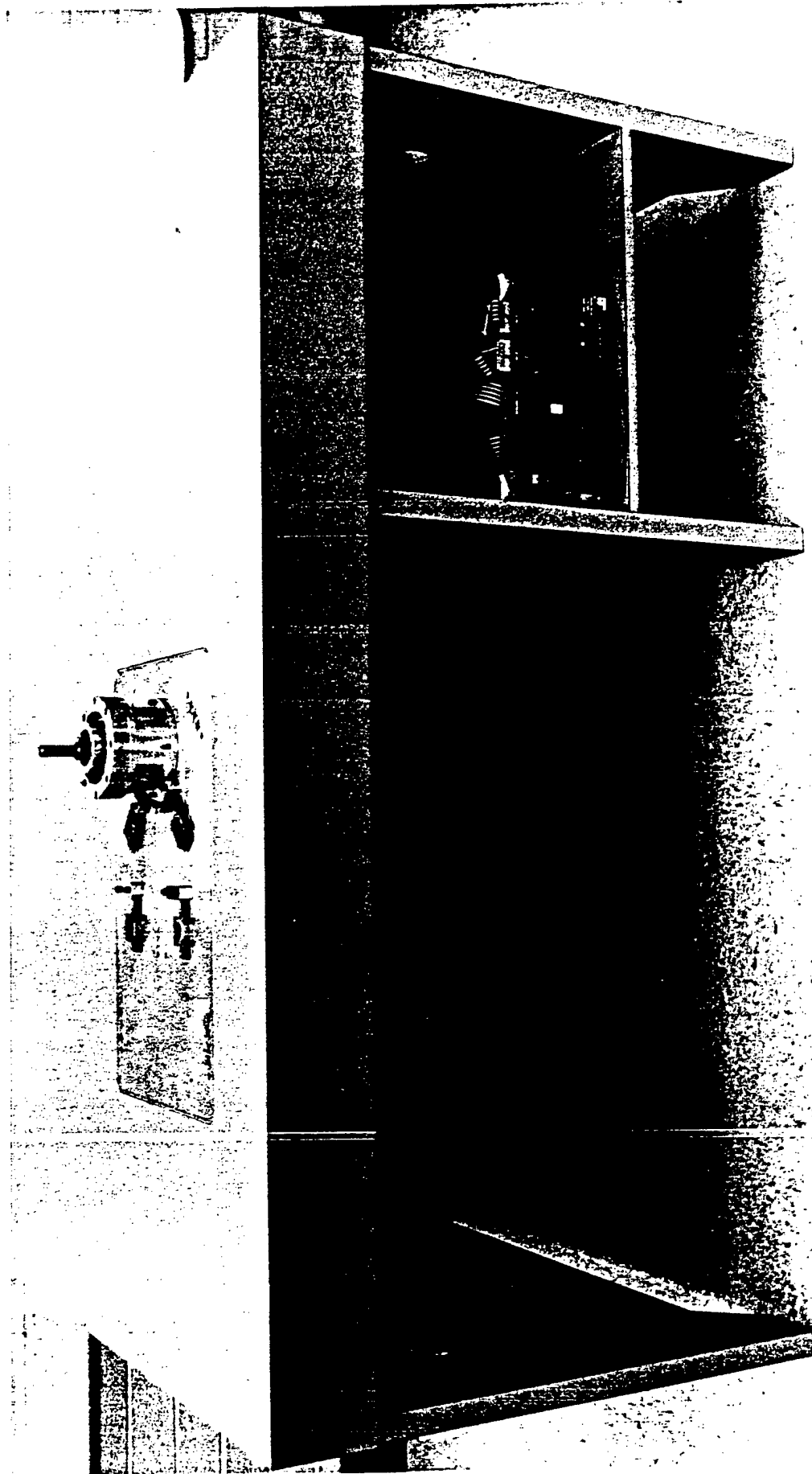
SCHEMATIC



UTAH STATE
UNIVERSITY

CONTROL OF FLEXIBLE ROBOT MANIPULATORS
IN ZERO GRAVITY

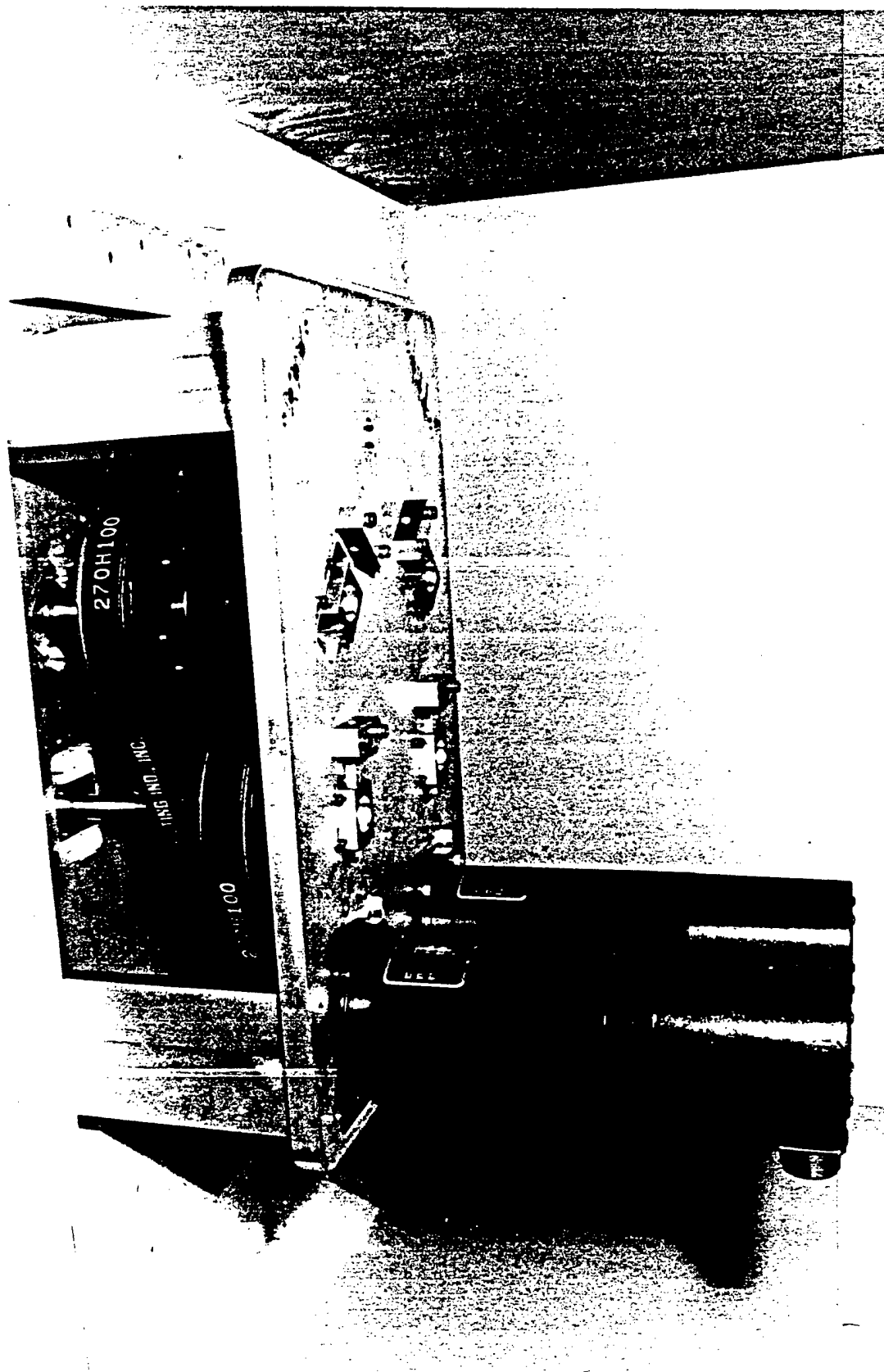
OUT-REACH



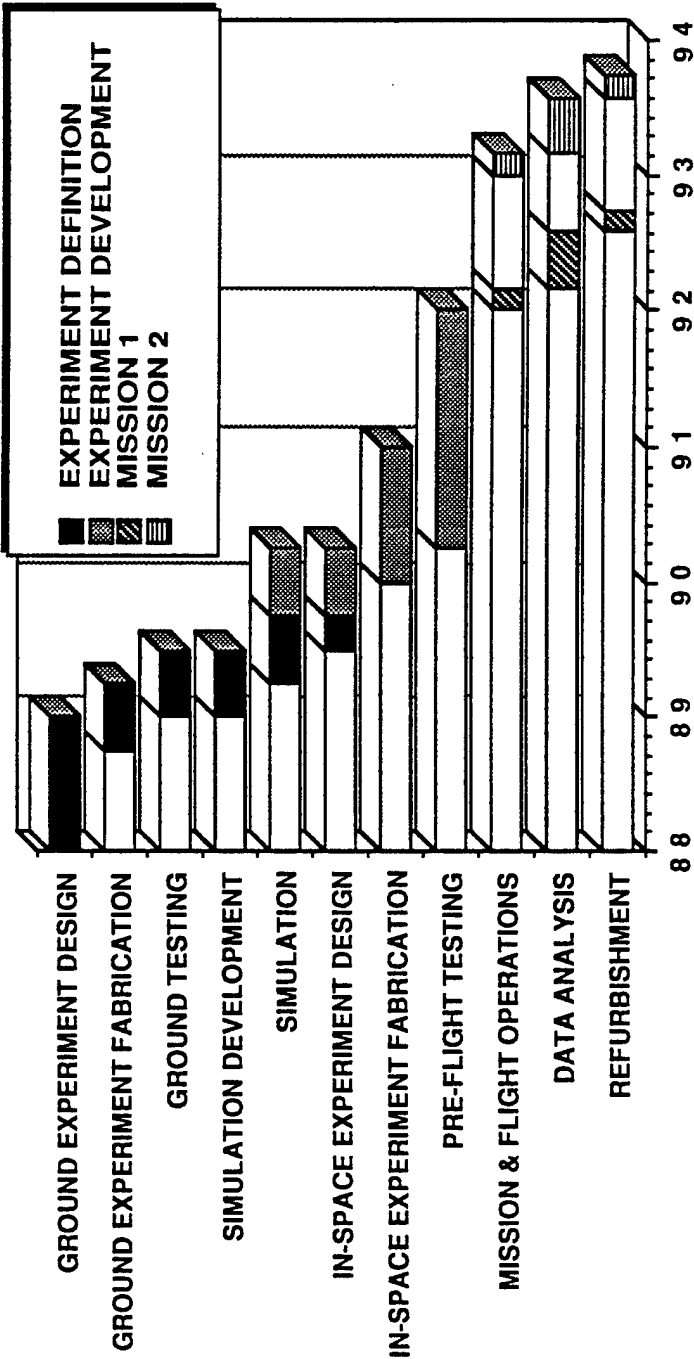
OUT-REACH

CONTROL OF FLEXIBLE ROBOT MANIPULATORS
IN ZERO GRAVITY

UTAH STATE
UNIVERSITY



MASTER SCHEDULE



AUTOMATION & ROBOTICS	IN-SPACE TECHNOLOGY EXPERIMENTS WORKSHOP		ROBOTIC SYSTEMS
	SPACE STRUCTURES	DECEMBER 6-9, 1988	
			CONTROL/STRUCTURE INTERACTION

JITTER SUPPRESSION FOR PRECISION SPACE STRUCTURES

ROBERT M. LAURENSEN
MCDONNELL DOUGLAS
(314) 234-8706

CONTRACT NO. NAS1-18689
LANGLEY RESEARCH CENTER
DEAN W. SPARKS, JR.

JET PROPULSION LABORATORY
JOHN A. GARBA

OUTREACH	JITTER SUPPRESSION FOR PRECISION SPACE STRUCTURES	MCDONNELL DOUGLAS

EXPERIMENT OBJECTIVE

- IN-SPACE DEMONSTRATION OF ACTIVE AND PASSIVE DAMPING TECHNIQUES TO SUPPRESS JITTER FOR PRECISION SPACE STRUCTURES
- IMPLEMENT A SHUTTLE PAYLOAD BAY EXPERIMENT TO ACCOUNT FOR IN-SPACE CONDITIONS
- ESTABLISH GROUND/FLIGHT DATABASE ON JITTER SUPPRESSION TECHNIQUES

OUTREACH	JITTER SUPPRESSION FOR PRECISION SPACE STRUCTURES	MCDONNELL DOUGLAS

BACKGROUND/TECHNOLOGY NEED

- BACKGROUND
 - SPACE-BASED OPTICAL APPLICATIONS REQUIRE LOW LINE-OF-SIGHT RESIDUAL JITTER LEVELS
 - LASER COMMUNICATIONS AND LASER RADAR ARE REPRESENTATIVE SYSTEMS
 - JITTER SUPPRESSION PLACES DEMANDS ON STRUCTURAL SUBSYSTEM
 - PRESENT SYSTEMS – MICRORADIAN POINTING BUDGETS
 - FUTURE SYSTEMS – SUB-MICRORADIAN POINTING AND/OR LARGER / COMPLEX CONFIGURATIONS
- TECHNOLOGY NEED
 - GROUND TEST VALIDATION IS INADEQUATE
 - DATA NEEDED FOR LOW-G, THERMAL/VACUUM ENVIRONMENT OF SPACE
 - PROVIDE VALIDATION OF JITTER SUPPRESSION TECHNIQUES FOR SPACE APPLICATION

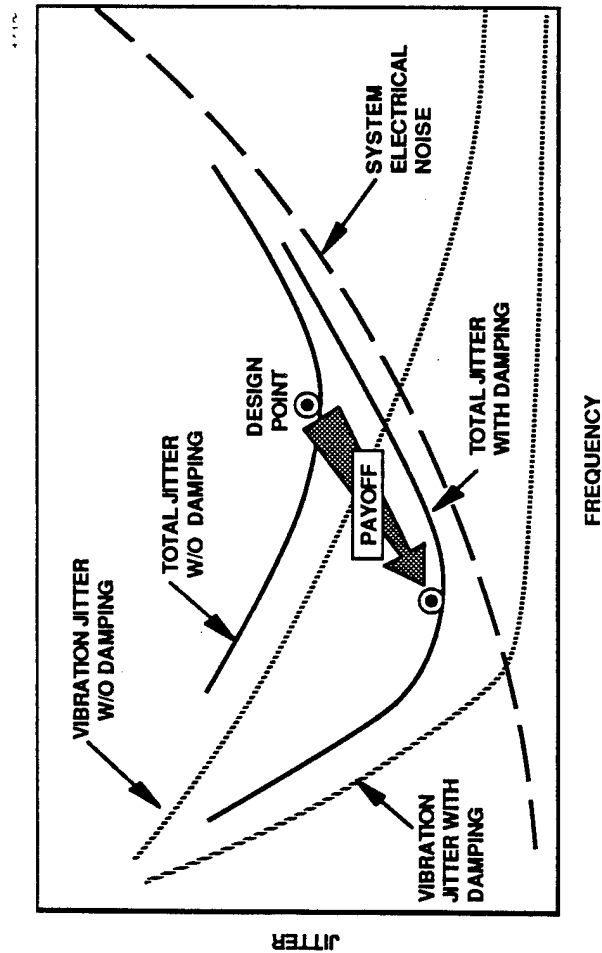
OUTREACH	JITTER SUPPRESSION FOR PRECISION SPACE STRUCTURES	MCDONNELL DOUGLAS

REDUCED JITTER YIELDS SYSTEM PAYOFF

REDUCED JITTER WITH DAMPING

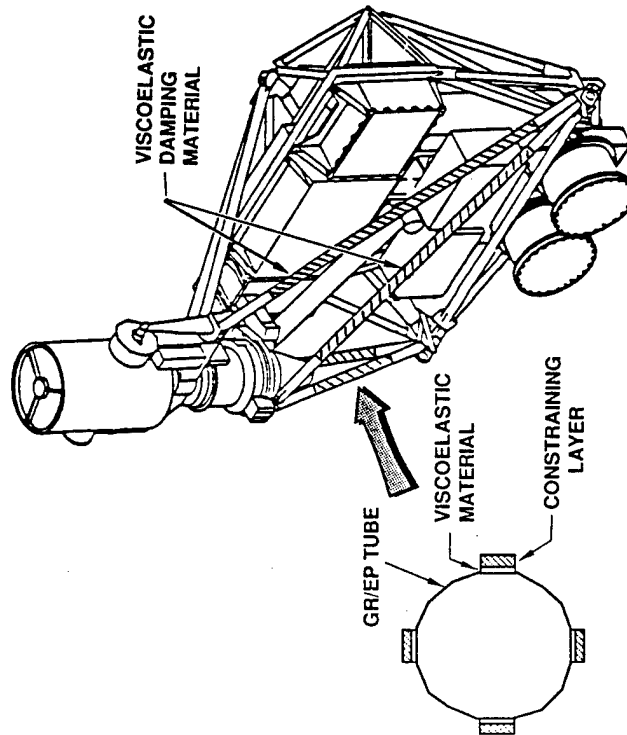
SYSTEM PAYOFF

- REDUCED POWER
- REDUCED WEIGHT
- LOWER COST
- HIGHER RELIABILITY
- INCREASED LIFE

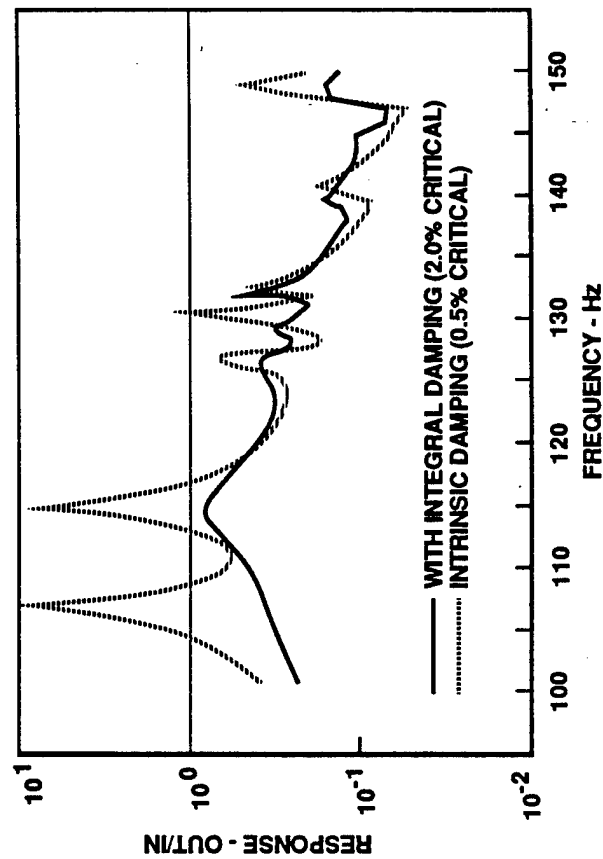


ANALYSES DEMONSTRATE JITTER REDUCTION WITH INTEGRAL DAMPING

VISCOELASTIC DAMPING MATERIAL IMPLEMENTATION



JITTER ATTENUATION WITH VISCOELASTIC DAMPING



- ASSESSMENT OF PIEZOELECTRIC DAMPING
 - EFFECTIVE MODAL DAMPING
 - ORDER OF MAGNITUDE GREATER THAN VISCOELASTIC DAMPING

OUTREACH	JITTER SUPPRESSION FOR PRECISION SPACE STRUCTURES	MCDONNELL DOUGLAS

EXPERIMENT DESCRIPTION

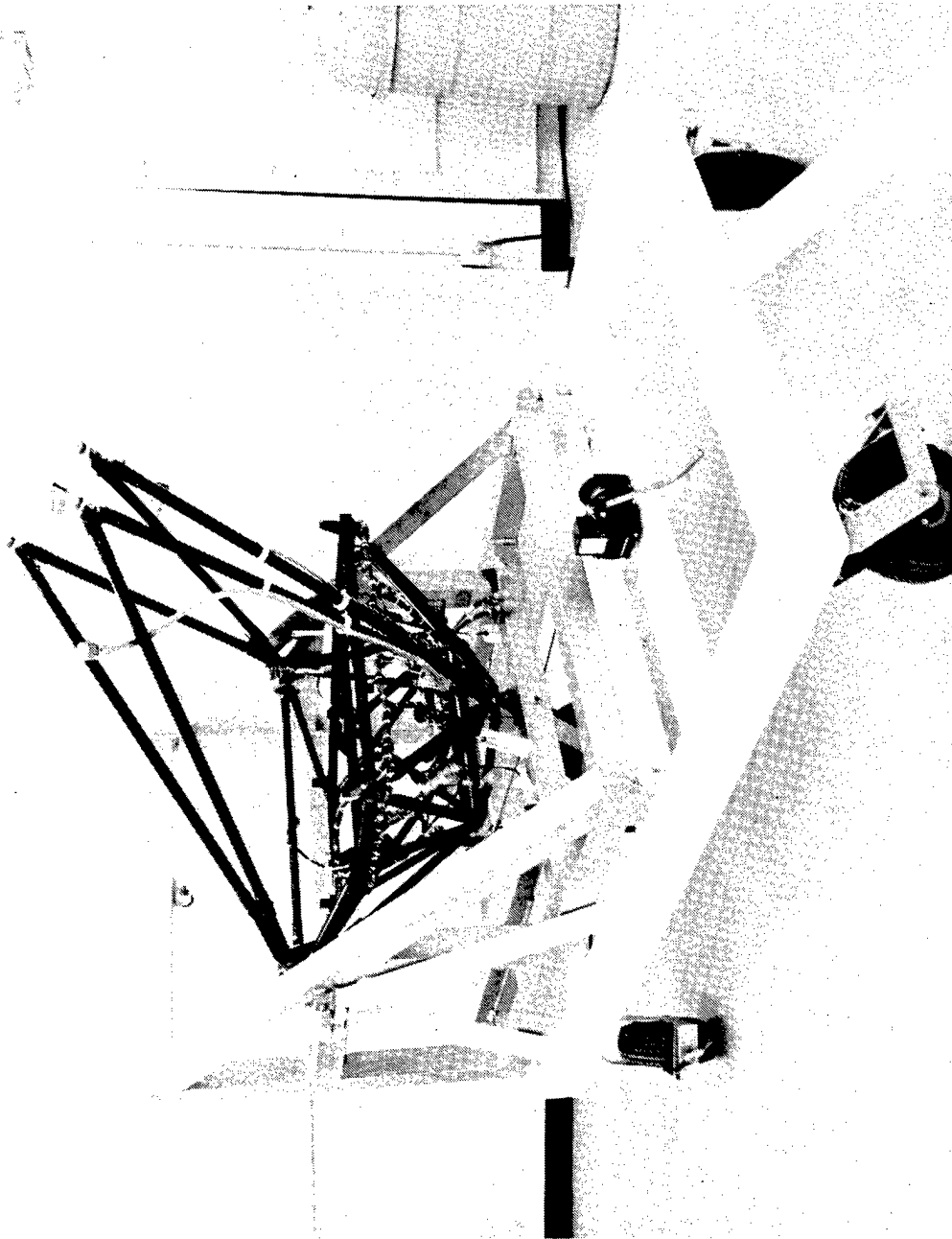
- BASED ON EXISTING SPACE-BASED LASER COMMUNICATIONS SUBSYSTEM DESIGN
- USE EXISTING ENGINEERING MODEL HARDWARE
 - MASS SIMULATED EQUIPMENT COMPONENTS
- INTEGRATE DAMPING INTO GRAPHITE/EPOXY STRUCTURE
 - PASSIVE VISCOELASTIC DAMPING
 - ACTIVE PIEZOELECTRIC DAMPING
- PROVIDE EXCITATION SOURCES AND INSTRUMENTATION
- INTEGRATE INTO SHUTTLE PAYLOAD BAY EXPERIMENT

OUTREACH

JITTER SUPPRESSION FOR
PRECISION SPACE STRUCTURES

MCDONNELL
DOUGLAS

ENGINEERING MODEL UNIT STRUCTURE GRAPHITE/EPOXY CONSTRUCTION

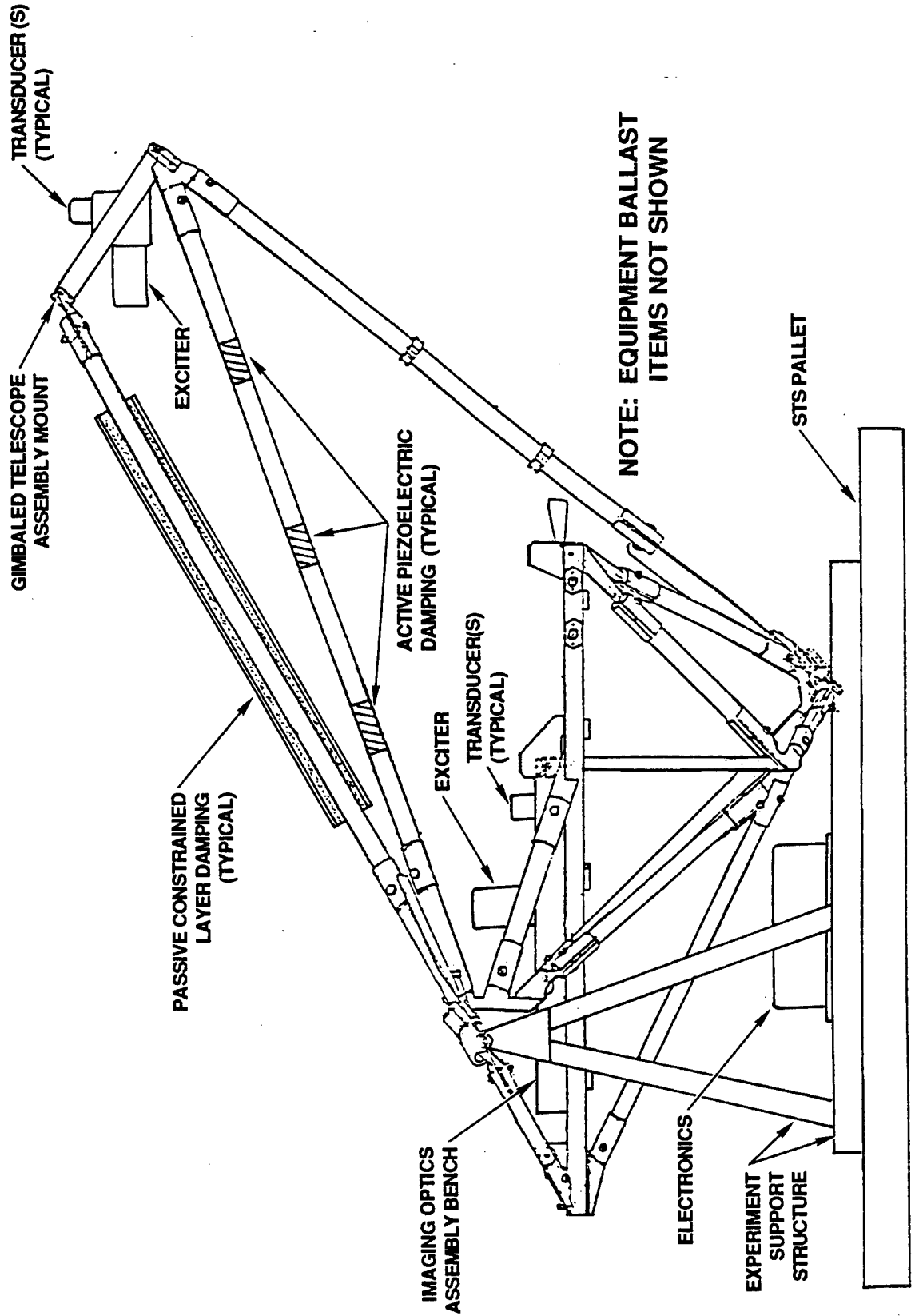


JITTER SUPPRESSION FOR PRECISION SPACE STRUCTURES

OUTREACH

MCDONNELL
DOUGLAS

PRELIMINARY EXPERIMENT CONCEPT



OUTREACH	JITTER SUPPRESSION FOR PRECISION SPACE STRUCTURES	MCDONNELL DOUGLAS

SUMMARY

- EXPERIMENT DEFINITION PHASE
 - JUNE 88 THROUGH FEBRUARY 89
- BASED ON SPACE-BASED LASER COMMUNICATIONS DESIGN
 - HARDWARE IS AVAILABLE
 - MODIFICATIONS FOR EXPERIMENT BEING DEFINED
- PERFORM PRELIMINARY ANALYSES
 - DISTURBANCE SOURCES
 - DAMPING IMPLEMENTATION
 - SUPPORTING ANALYSES
 - INSTRUMENTATION
- DEVELOP PRELIMINARY PLANS
 - GROUND TEST, SHUTTLE INTEGRATION, IMPLEMENTATION (COST/SCHEDULE)
- INTEGRATION WITH OTHER EXPERIMENTS MAY BE BENEFICIAL
 - REDUCED COST
 - MAXIMUM PAYLOAD BAY UTILIZATION

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**AUTOMATION
AND ROBOTICS**

**IN-SPACE TECHNOLOGY EXPERIMENTS WORK SHOP
DECEMBER 6-9 1988**

**ROBOTIC
SYSTEMS**

PASSIVE DAMPING AUGMENTATION FOR SPACE MANIPULATORS

**Dr. Thomas E. Alberts
Old Dominion University**

With support from 3M Corporation

CONTRACT NO. NAS-18687

LaRC

Tech. Monitor:

Jack Pennington

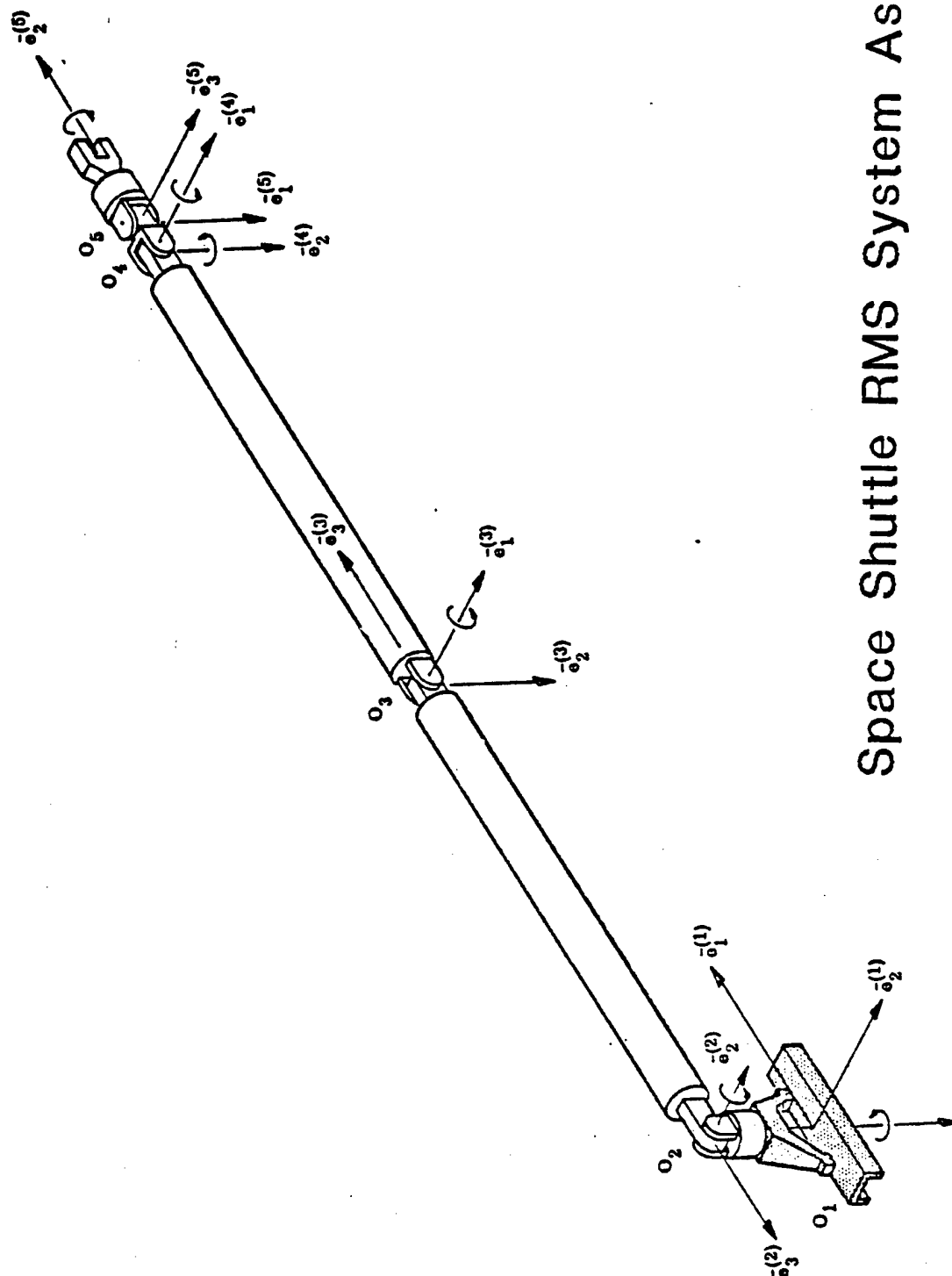
AUTOMATION AND ROBOTICS	IN-SPACE TECHNOLOGY EXPERIMENTS WORK SHOP DECEMBER 6-9 1988	ROBOTIC SYSTEMS

EXPERIMENT OBJECTIVE

Demonstrate the use of constrained layer viscoelastic damping treatments to reduce vibrations in flexible space manipulators. The target example is the space shuttle RMS. The current phase of the project includes:

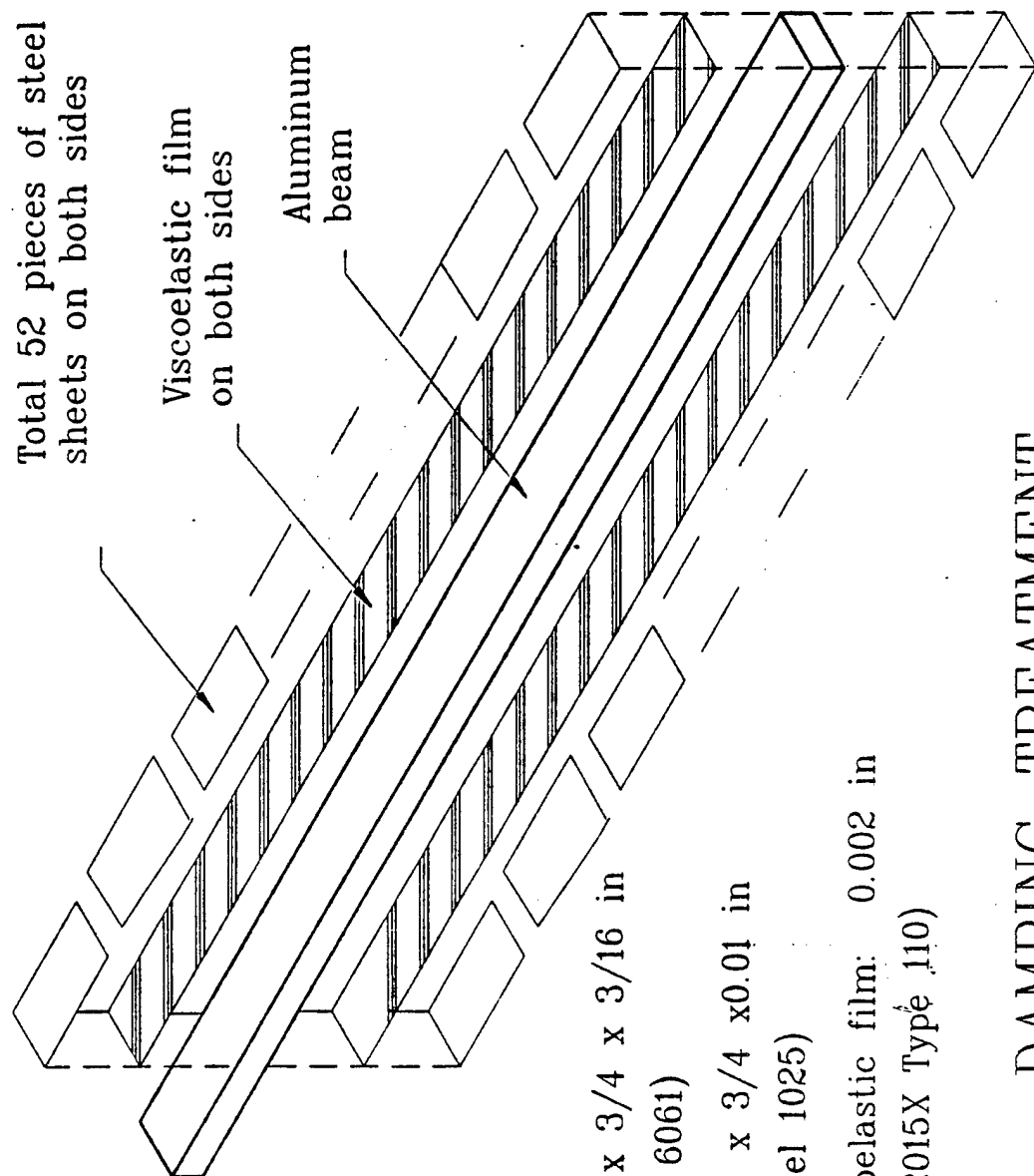
- Analysis and design of damping treatment for bending and torsion.
- Design for reduced sensitivity to temperature variations.
- Simulate and evaluate results.
- Experimental verification.

Outreach Program	PASSIVE DAMPING AUGMENTATION FOR SPACE MANIPULATORS	Old Dominion University



Space Shuttle RMS System Assembly.

Outreach Program	PASSIVE DAMPING AUGMENTATION FOR SPACE MANIPULATORS	Old Dominion University



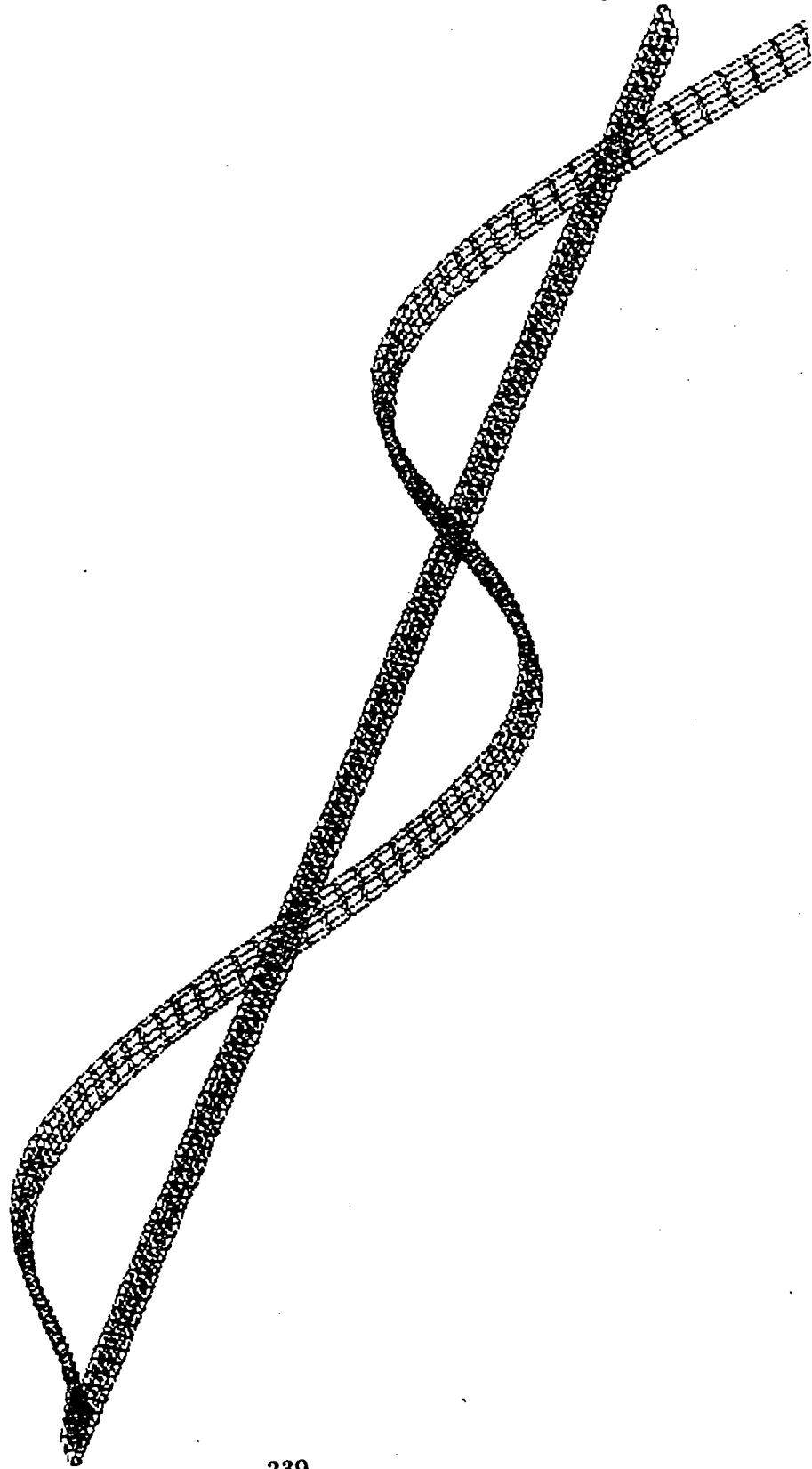
Beam size: 48 x 3/4 x 3/16 in
(AL 6061)

Steel sheet: 1.72 x 3/4 x 0.01 in
(steel 1025)

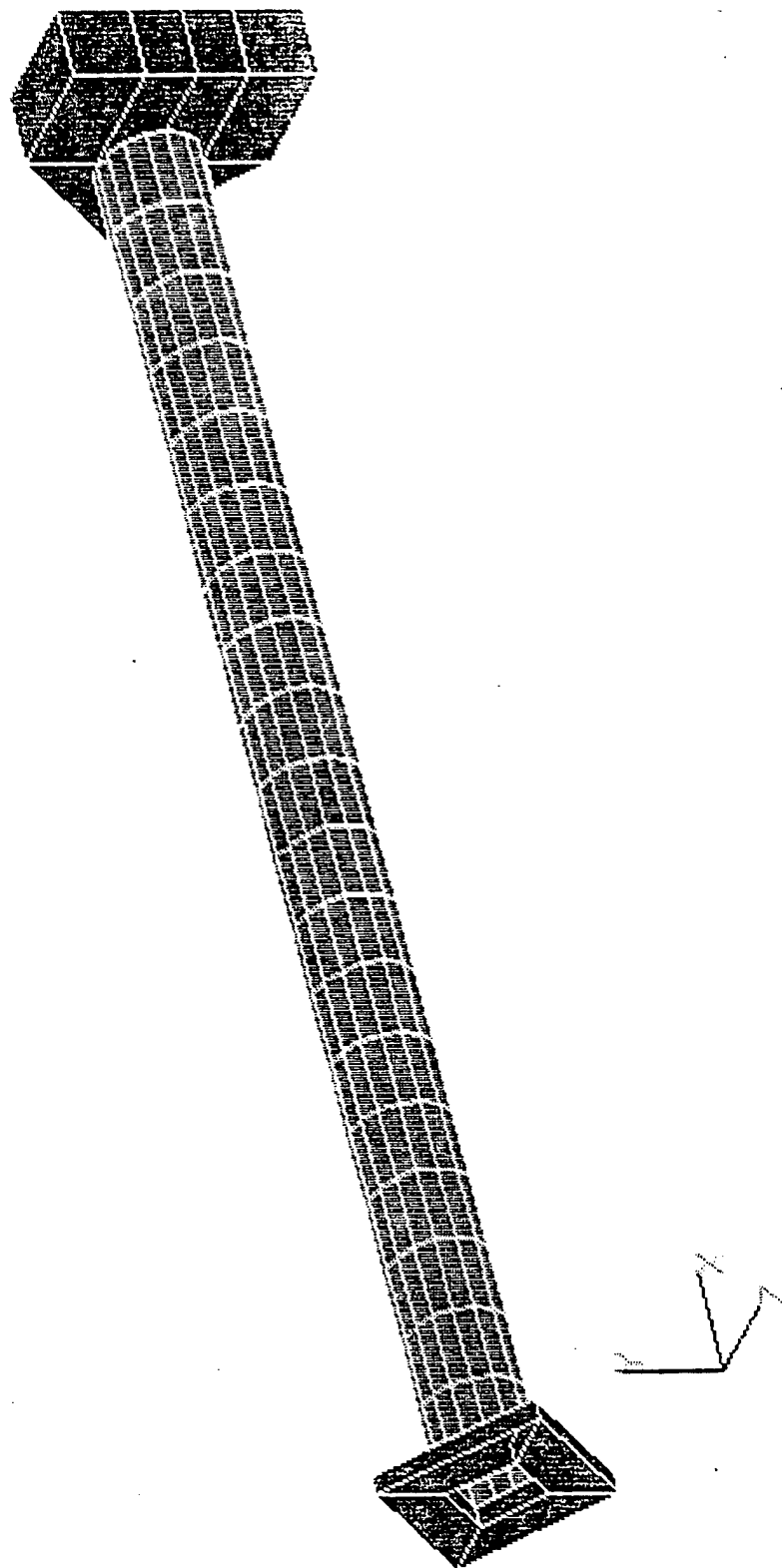
Thickness of viscoelastic film: 0.002 in
(SJ2015X Type 110)

DAMPING TREATMENT

Outreach Program	PASSIVE DAMPING AUGMENTATION FOR SPACE MANIPULATORS	Old Dominion University

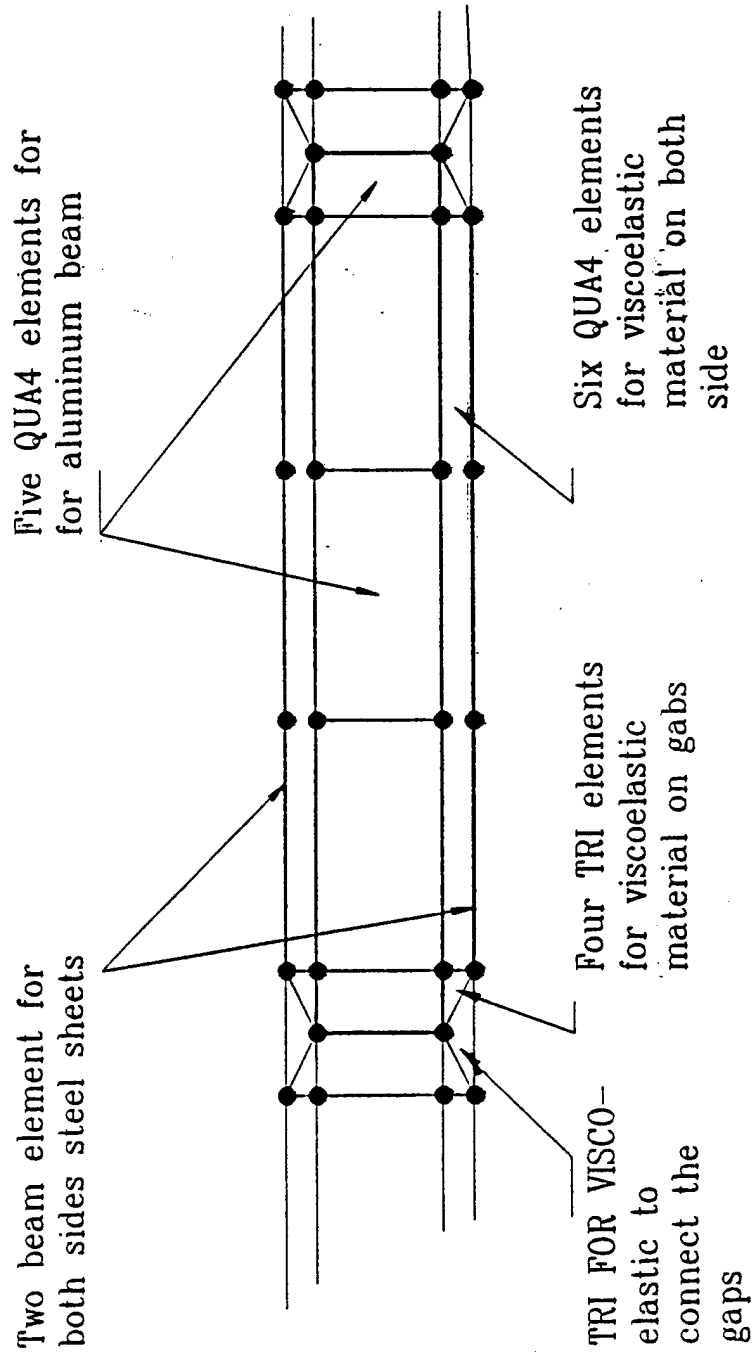


Outreach Program	PASSIVE DAMPING AUGMENTATION FOR SPACE MANIPULATORS	Old Dominion University



Finite Element Analysis of Damped System - Torsion.

Outreach Program	PASSIVE DAMPING AUGMENTATION FOR SPACE MANIPULATORS	Old Dominion University



FINITE MESH FOR RECTANGULAR BEAM

Outreach Program	PASSIVE DAMPING AUGMENTATION FOR SPACE MANIPULATORS	Old Dominion University

DAMPING ANALYSIS

- Finite element analysis of single layer treatments.

Bending

Torsion

Experiment

- Use validated code to evaluate multi-layer treatments designed to extend effective temperature range.
- Use damping results in full scale simulation.

6.0 SENSORS AND INFORMATION SYSTEMS

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SENSORS AND INFORMATION SYSTEMS	IN-SPACE TECHNOLOGY EXPERIMENTS WORKSHOP DECEMBER 6-9, 1988	SENSORS

DEVELOPMENT OF EMULSION CHAMBER TECHNOLOGY

JOHN GREGORY
THE UNIVERSITY OF ALABAMA IN HUNTSVILLE

CONTRACT NO. NAS8-37751
MARSHALL SPACE FLIGHT CENTER
JON HAUSSLER

OUT-REACH	DEVELOPMENT OF EMULSION CHAMBER TECHNOLOGY	UNIVERSITY OF ALABAMA IN HUNTSVILLE

OBJECTIVES

- O DESIGN, FABRICATE AND FLY ON THE STS AN EMULSION CHAMBER OF THE GENERAL TYPE WHICH WILL BE A LIKELY CANDIDATE FOR COSMIC RAY AND HIGH ENERGY PHYSICS STUDIES ON THE SPACE STATION.
- O ASSESS THE RADIATION BACKGROUND ENCOUNTERED IN SUCH DETECTORS IN ORBITS UP TO 400 km.
- O ASSESS PRE- AND POST-FLIGHT ENVIRONMENTAL EFFECTS ON PASSIVE DETECTORS.
- O ASSESS THE EFFECTS OF LARGE SHIELDING ON DOSE IN SPACE STATION ORBITS.
- O PROVIDE THE ASTROPHYSICS COMMUNITY WITH AN ENVIRONMENTAL ASSESSMENT OF THE PERFORMANCE CAPABILITIES OF EMULSION TECHNIQUES IN SPACE.
- O DEVELOP AND MODIFY EMULSION TECHNIQUES AS NECESSARY TO ALLOW OPTIMUM USE OF THE POWER OF THE METHOD.

OUT-REACH	DEVELOPMENT OF EMULSION CHAMBER TECHNOLOGY	UNIVERSITY OF ALABAMA IN HUNTSVILLE

BACKGROUND

- NUCLEAR TRACK EMULSIONS HAVE BEEN USED FOR 50 YEARS IN PARTICLE PHYSICS AND COSMIC RAY PHYSICS AND HAVE PRODUCED MANY LANDMARK DISCOVERIES OR MEASUREMENTS:
 - FIRST-DEMONSTRATION OF EXISTENCE OF π -MESON (1947).
 - DISCOVERY OF HEAVY ELEMENTS IN COSMIC RAYS (1948).
 - FIRST MEASUREMENT OF HELIUM SPECTRUM (1957).
 - CONFIRMATION OF TRANS-IRON NUCLEI IN COSMIC RAYS (1967).
 - OBSERVATION OF EVIDENCE OF QUARK-GLUON PLASMA FORMATION IN HEAVY NUCLEUS COLLISIONS ABOVE 1TeV/n.
 - FIRST MEASUREMENT OF CHEMICAL COMPOSITION OF COSMIC RAYS AT 10^{14} eV.

OUT-REACH	DEVELOPMENT OF EMULSION CHAMBER TECHNOLOGY	UNIVERSITY OF ALABAMA IN HUNTSVILLE

TECHNOLOGY NEEDS

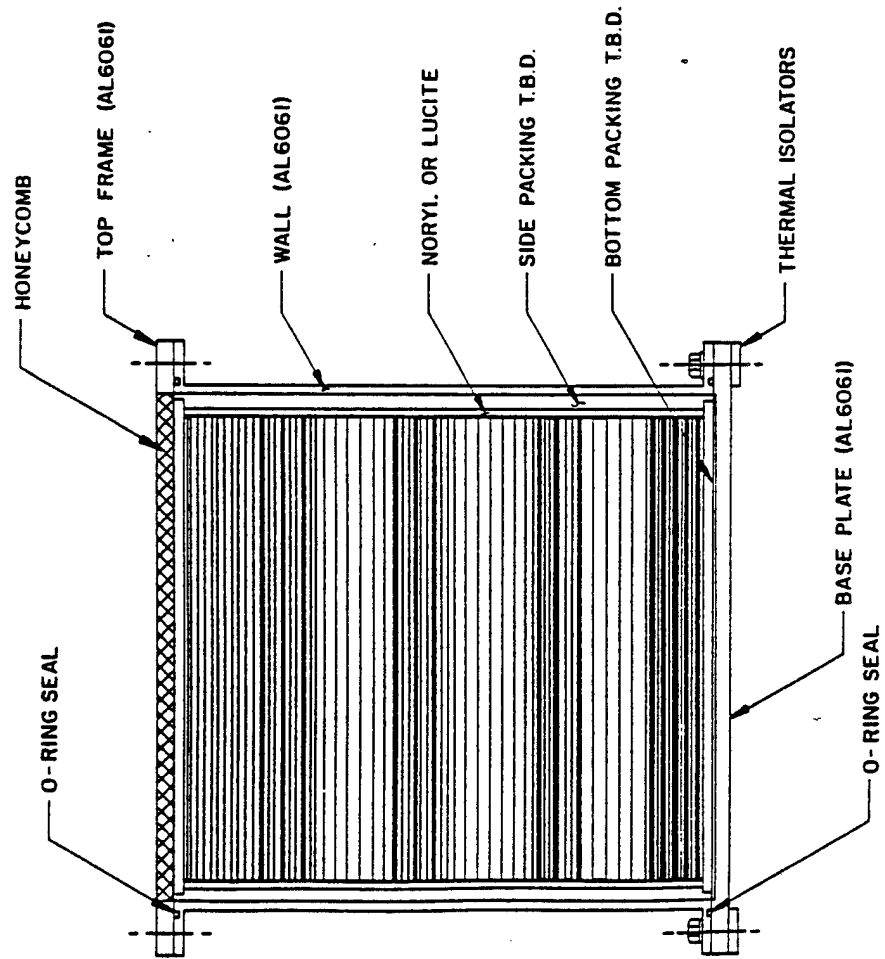
(TO BE ADDRESSED BY ENGINEERING FLIGHT OF EMULSION CHAMBER.)

- O RADIATION-INDUCED BACKGROUND IN ORBIT. SELF-SHIELDING TO AMBIENT RADIATION. SHOWER PRODUCTION WITHIN THE CHAMBER FROM ENERGETIC BACKGROUND RADIATION.
- O RADIATION-INDUCED BACKGROUND ACCUMULATED DURING STORAGE AND GROUND OPERATIONS.
- O TEMPERATURE AND HUMIDITY EFFECTS: IMPACT ON MECHANICAL DESIGN AND GROUND OPERATIONS. TEMPERATURE GRADIENT EFFECTS WITHIN THE CHAMBER.
- O ABILITY TO PERFORM VARIOUS MEASUREMENTS ON INTERACTIONS OBSERVED IN THE TEST FLIGHT CHAMBER WITH A KNOWN BACKGROUND.

OUT-REACH	DEVELOPMENT OF EMULSION CHAMBER TECHNOLOGY	UNIVERSITY OF ALABAMA IN HUNTSVILLE

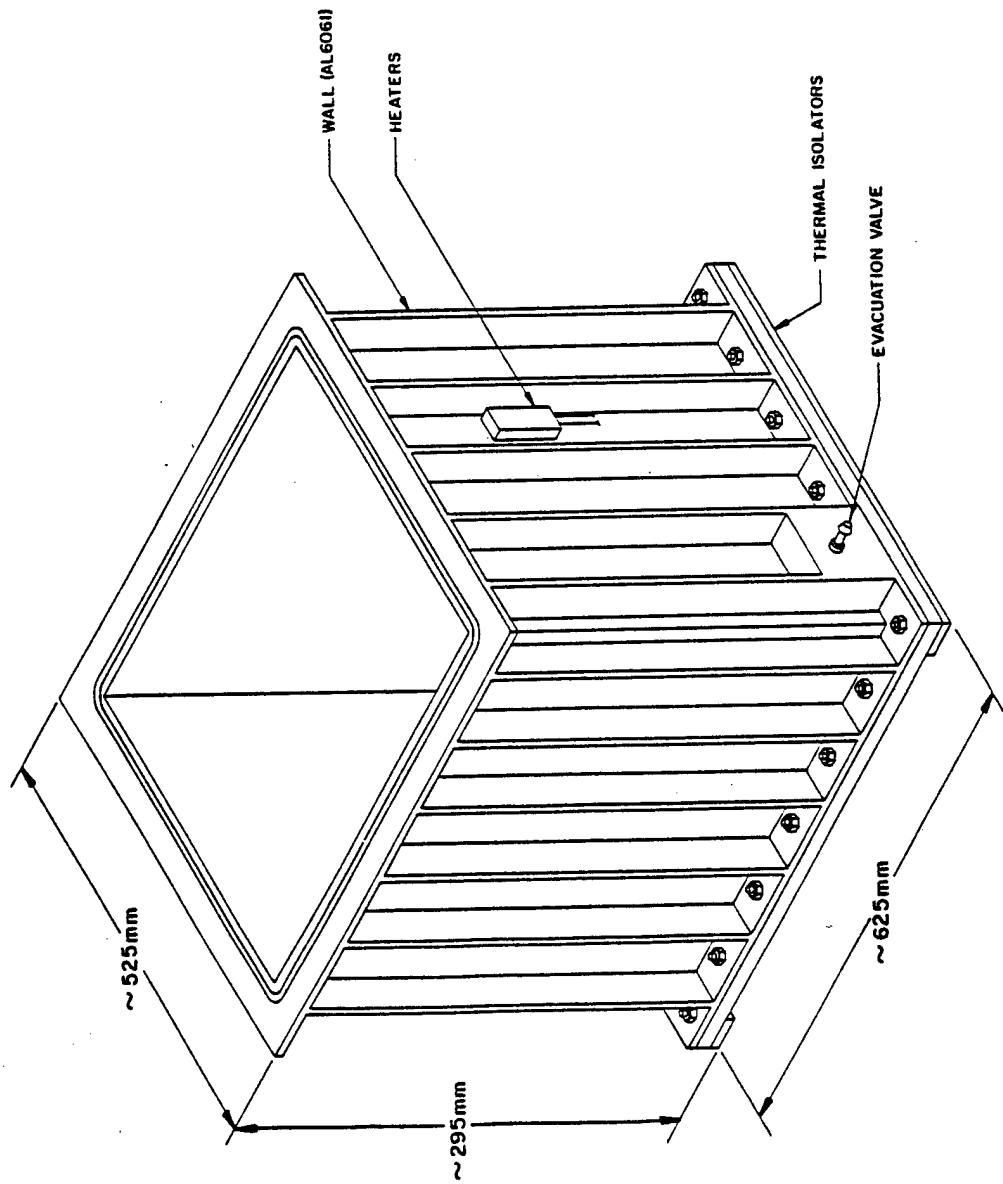
EXPERIMENT DESCRIPTION

- DETECTOR PLATES INCLUDE NUCLEAR TRACK EMULSIONS OF DIFFERENT TYPES, X-RAY FILM AND CR-39 ETCHABLE TRACK DETECTORS. THIS STACK (ALSO INCLUDING INACTIVE MATERIAL SUCH AS LUCITE AND LEAD) MUST BE PROTECTED FROM LIGHT, HEAT, HUMIDITY AND VIBRATION DAMAGE.
- THE STACK (OR EMULSION CHAMBER) IS CONTAINED IN A HERMETIC ALUMINUM BOX WHICH IS PARTIALLY EVACUATED. THE BOX HAS A HONEYCOMB LID TO REDUCE NUCLEAR INTERACTIONS OF INCOMING COSMIC RAYS.
- DIMENSIONS: 50 CM X 60 CM X 40 CM
- WEIGHT: 180 KG
- TEMPERATURE: ≤ 20°C, REDLINE 30°C
- POWER: HEATERS, THERMISTORS AND TEMPERATURE DATA RECORDER
- ORBIT: ≤ 57 DEG; ≤ 400 KM; 5-10 DAYS



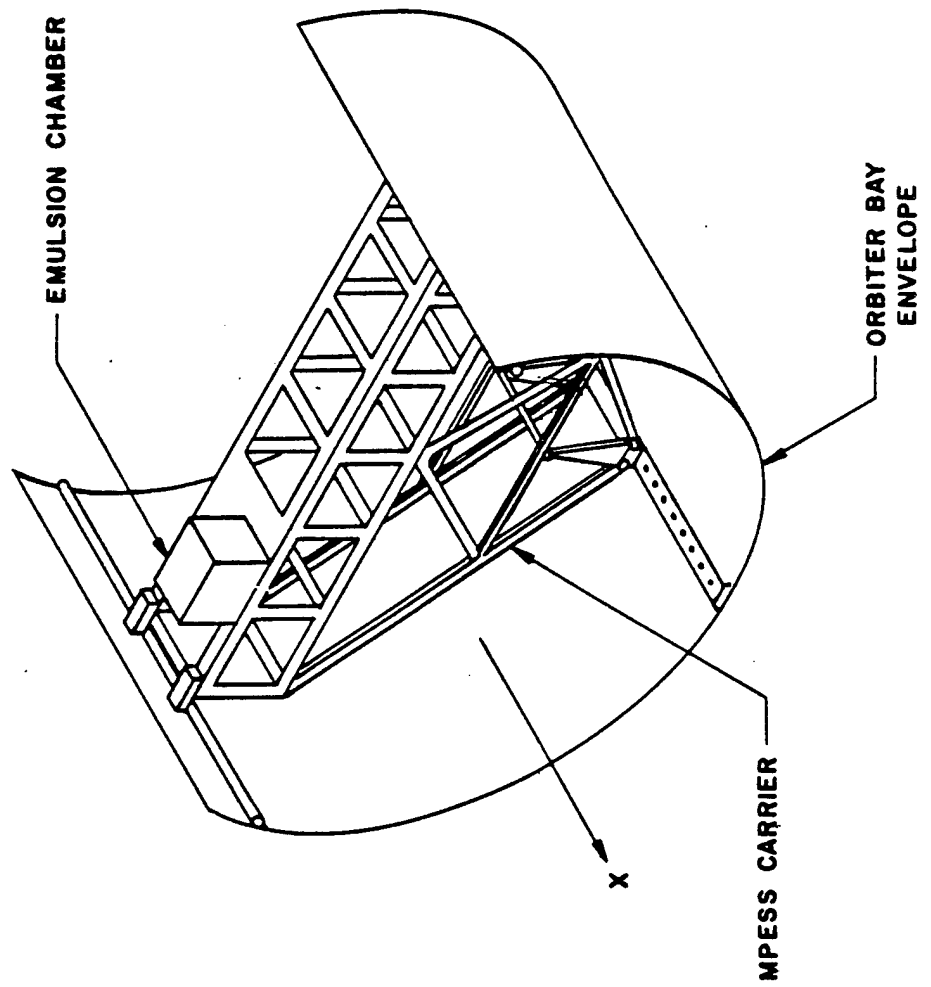
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SECTION OF EMULSION CHAMBER AND CONTAINER



CONTAINER FOR EMULSION CHAMBER

OUT-REACH	DEVELOPMENT OF EMULSION CHAMBER TECHNOLOGY	UNIVERSITY OF ALABAMA IN HUNTSVILLE



OUT-REACH	DEVELOPMENT OF EMULSION CHAMBER TECHNOLOGY	UNIVERSITY OF ALABAMA IN HUNTSVILLE

SCHEDULE

	6 MONTHS	12 MONTHS	15 MONTHS
O DESIGN			
O MECHANICAL			
O THERMAL			
O SCIENTIFIC			
O MID-TERM REVIEW			
O MSFC	Δ		
O FABRICATION OF TEST ARTICLE			
O PHASE B DESIGN REVIEW	 Δ		
O BACKGROUND STUDY			
O PREPARATION OF DRAWINGS			
O DELIVERY OF DRAWINGS, SPECIFICATIONS AND COST PLAN FOR FLIGHT INVESTIGATION			Δ

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SENSORS AND INFORMATION SYSTEMS	IN-SPACE TECHNOLOGY EXPERIMENTS WORKSHOP DECEMBER 6-9, 1988	SENSORS

**INFRARED FOCAL PLANE PERFORMANCE
IN THE SOUTH ATLANTIC ANOMALY**

FRANK JUNGA

LOCKHEED RESEARCH AND DEVELOPMENT DIVISION

**CONTRACT NO. NAS2-12898
NASA AMES RESEARCH CENTER
CRAIG MCCREIGHT**

OUTREACH	INFRARED FOCAL PLANE PERFORMANCE IN THE SOUTH ATLANTIC ANOMALY	LOCKHEED RESEARCH & DEVELOPMENT DIVISION

PROGRAM OBJECTIVES

- Construct a model to predict selected focal plane performance parameters in the South Atlantic Anomaly environment. Outputs shall include proton-induced pulse height distribution in detectors and proton induced noise
- Verify pulse height distribution calculations for several proton energies and shielding thicknesses
- Develop a detailed concept for a flight experiment

OUTREACH	INFRARED FOCAL PLANE PERFORMANCE IN THE SOUTH ATLANTIC ANOMALY	LOCKHEED RESEARCH & DEVELOPMENT DIVISION

BACKGROUND

- NASA and DOD will fly missions employing low background IR detectors. The proton environment can significantly affect detector performance

TECHNOLOGY NEED

- An accurate model is required to assess noise problems and to develop signal processing algorithms for noise reduction

NEED FOR SPACE EXPERIMENT

- We can model and verify model for effects of particle energy, geometric factors, and shielding. We cannot model noise contributions due to fluctuations in the instantaneous proton energy distribution.

OUTREACH	INFRARED FOCAL PLANE PERFORMANCE IN THE SOUTH ATLANTIC ANOMALY	LOCKHEED RESEARCH & DEVELOPMENT DIVISION

PULSE HEIGHT DISTRIBUTIONS, NOISE ANALYSIS, AND VERIFICATION

ANALYSIS INCLUDES

Chord length distribution

Proton energy distribution

Proton energy loss, variance
in energy distribution
(a parameter)

Secondary sources of ionizing
radiation (e.g. soft x-rays)

[NOVICE Code]

VERIFICATION

Measure pulse height
distributions for various
angles of incidence,
proton energy (20-60 MeV),
and type and thickness of
shielding material

Test for blooming

OUTREACH	INFRARED FOCAL PLANE PERFORMANCE IN THE SOUTH ATLANTIC ANOMALY	LOCKHEED RESEARCH & DEVELOPMENT DIVISION

ACTIVITIES TO DATE

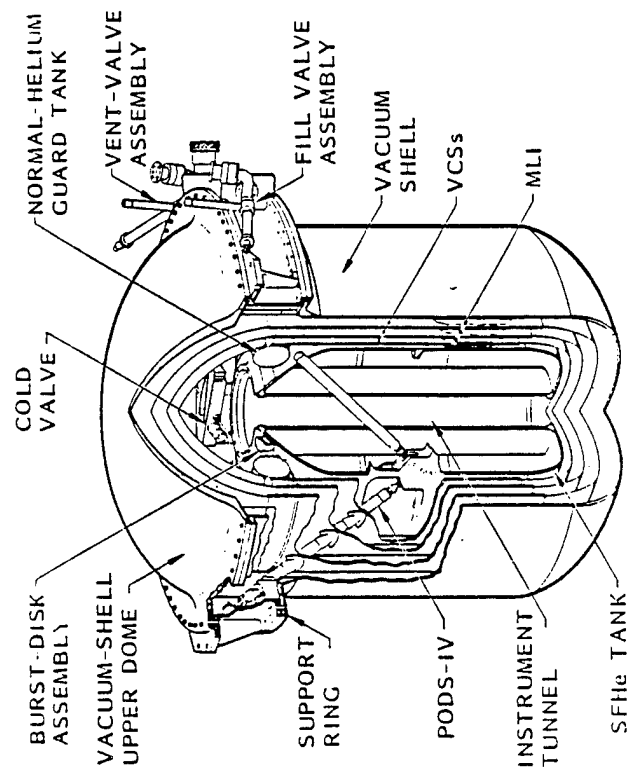
- Background material assembled for pulse height distribution and noise calculations
- Visits to UC Berkeley and Davis cyclotrons to get specifics on experiment configurations
- Designed and fabricated necessary fixtures for proton pulse height distribution experiments*
- Scheduled Davis cyclotron for Dec 7

*NASA Ames completed dewar and software modifications

OUTREACH	INFRARED FOCAL PLANE PERFORMANCE IN THE SOUTH ATLANTIC ANOMALY	LOCKHEED RESEARCH & DEVELOPMENT DIVISION

FLIGHT EXPERIMENT CONCEPT

Lockheed ID He Extended Life Dewar (HELD)



A self-contained experiment

- Data collected on tape

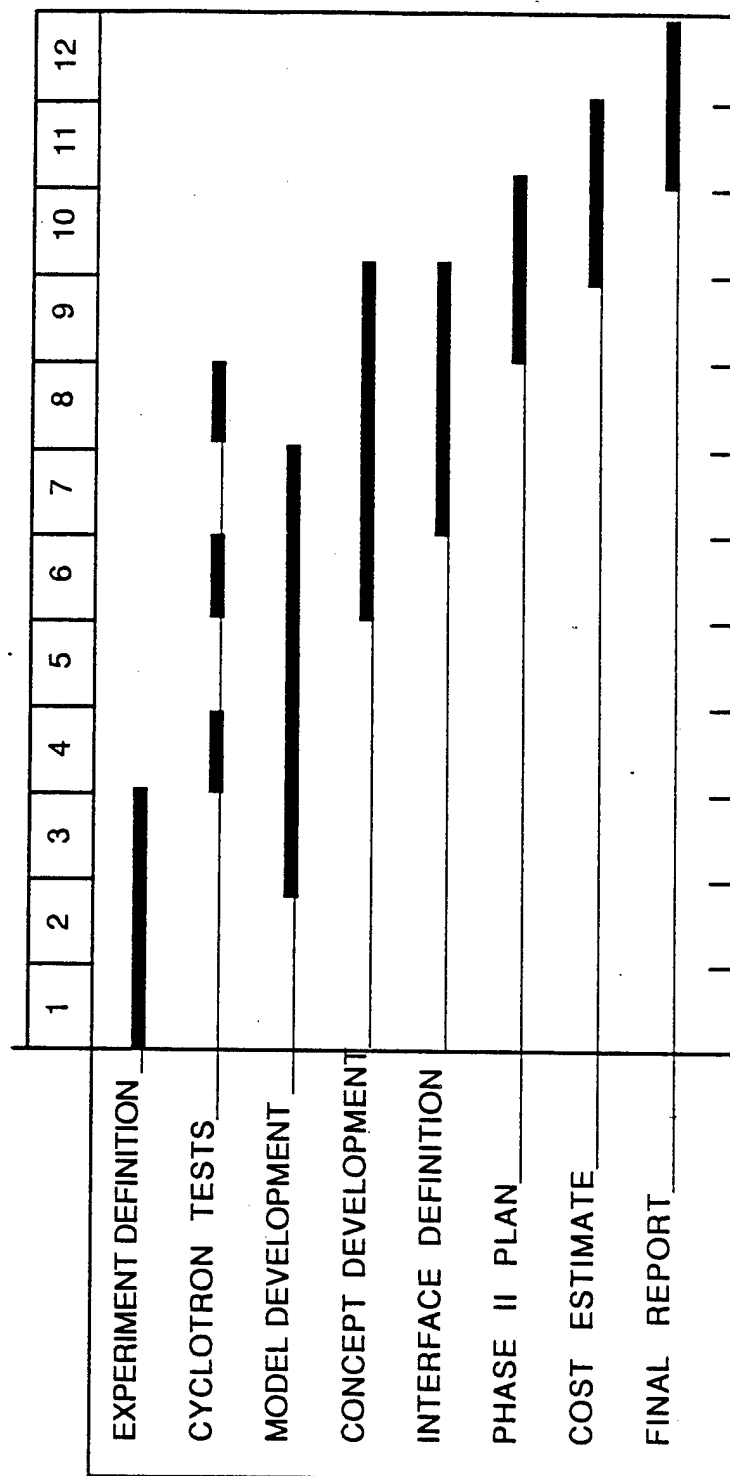
Minimum of two focal plane arrays

- One with added shielding

Several experiments to be
accomodated in dewar

OUTREACH	INFRARED FOCAL PLANE PERFORMANCE IN THE SOUTH ATLANTIC ANOMALY	LOCKHEED RESEARCH & DEVELOPMENT DIVISION

PROGRAM SCHEDULE (MONTHS AFTER GO-AHEAD)



Program Start Date: 7 September 1988

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CONSTRUCTION and IN-SPACE PERFORMANCE EVALUATION
of
HIGH STABILITY HYDROGEN MASER CLOCKS

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Cambridge, Massachusetts

Contract No. NAS8-37752
NASA Marshall Space Flight Center
Dr. R. Decher

OUTREACH EXPERIMENT DEFINITION STUDY	CONSTRUCTION and IN-SPACE PERFORMANCE EVALUATION of HIGH STABILITY HYDROGEN MASER CLOCKS	SMITHSONIAN ASTROPHYSICAL OBSERVATORY

EXPERIMENT OBJECTIVE:

- TO DEVELOP TECHNOLOGY FOR ULTRASTABLE
ATOMIC HYDROGEN MASER CLOCKS FOR LONG
DURATION SPACE-BORNE EXPERIMENTS
- TO DESIGN AND BUILD TWO FLIGHT-QUALIFIED
HYDROGEN MASERS
- TO TEST AND EVALUATE THE MASERS'
PERFORMANCE IN SPACE

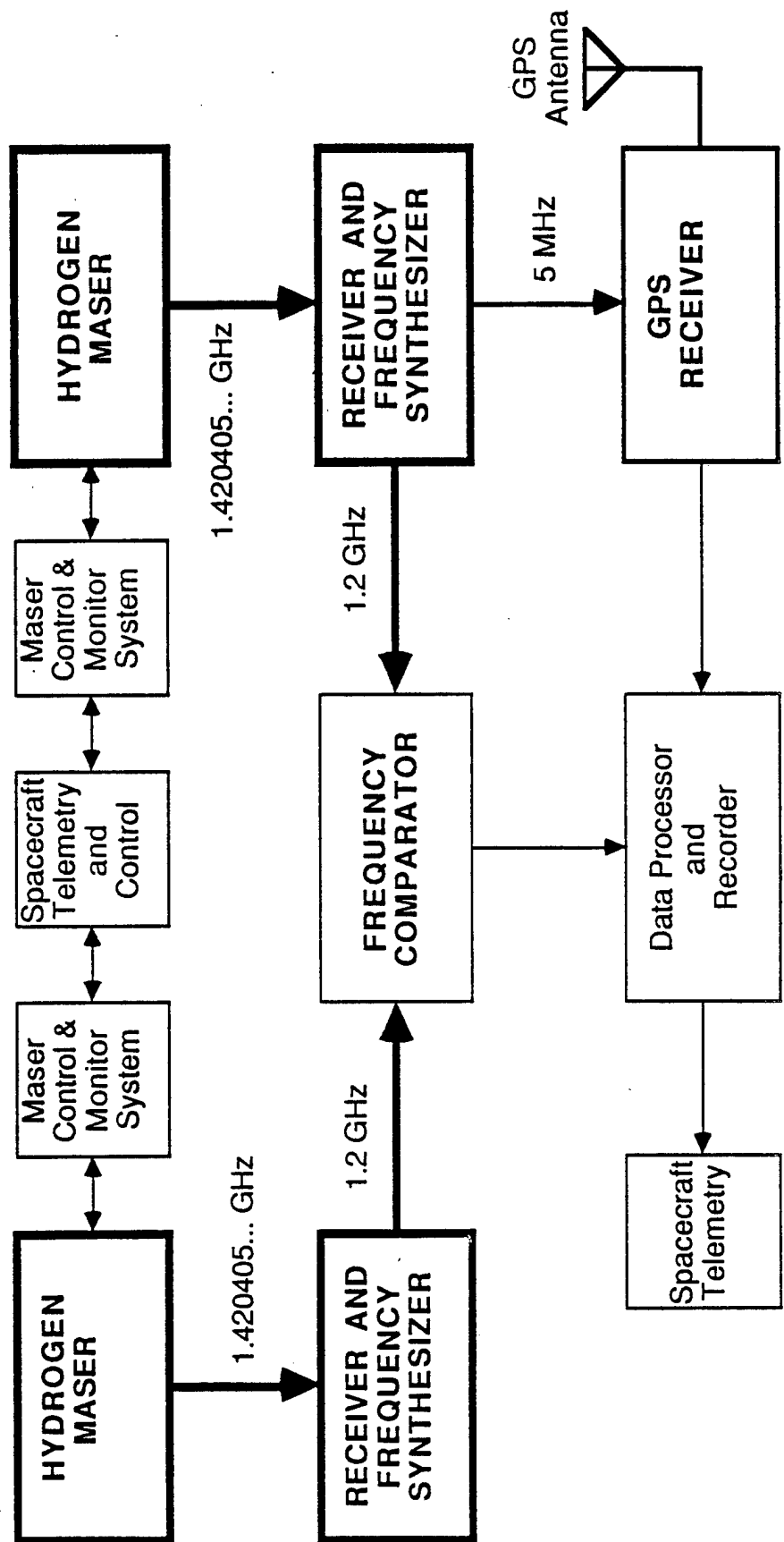
BACKGROUND

- 1976 GP-A (REDSHIFT) H-MASER DEVELOPED FOR SHORT DURATION ROCKET FLIGHT ~2 HOURS, MASER STABILITY 7×10^{-15}
- 1980-84 STUDY OF ORBITING CLOCK EXPERIMENT FOR VERY HIGH PRECISION GLOBAL TIME AND FREQUENCY TRANSFER
- 1988 GROUND BASED MASER FREQUENCY STABILITY APPROACHING 1×10^{-16} AT 10^4 SEC; THIS CAN BE REALIZED IN A SPACEWORTHY H MASER

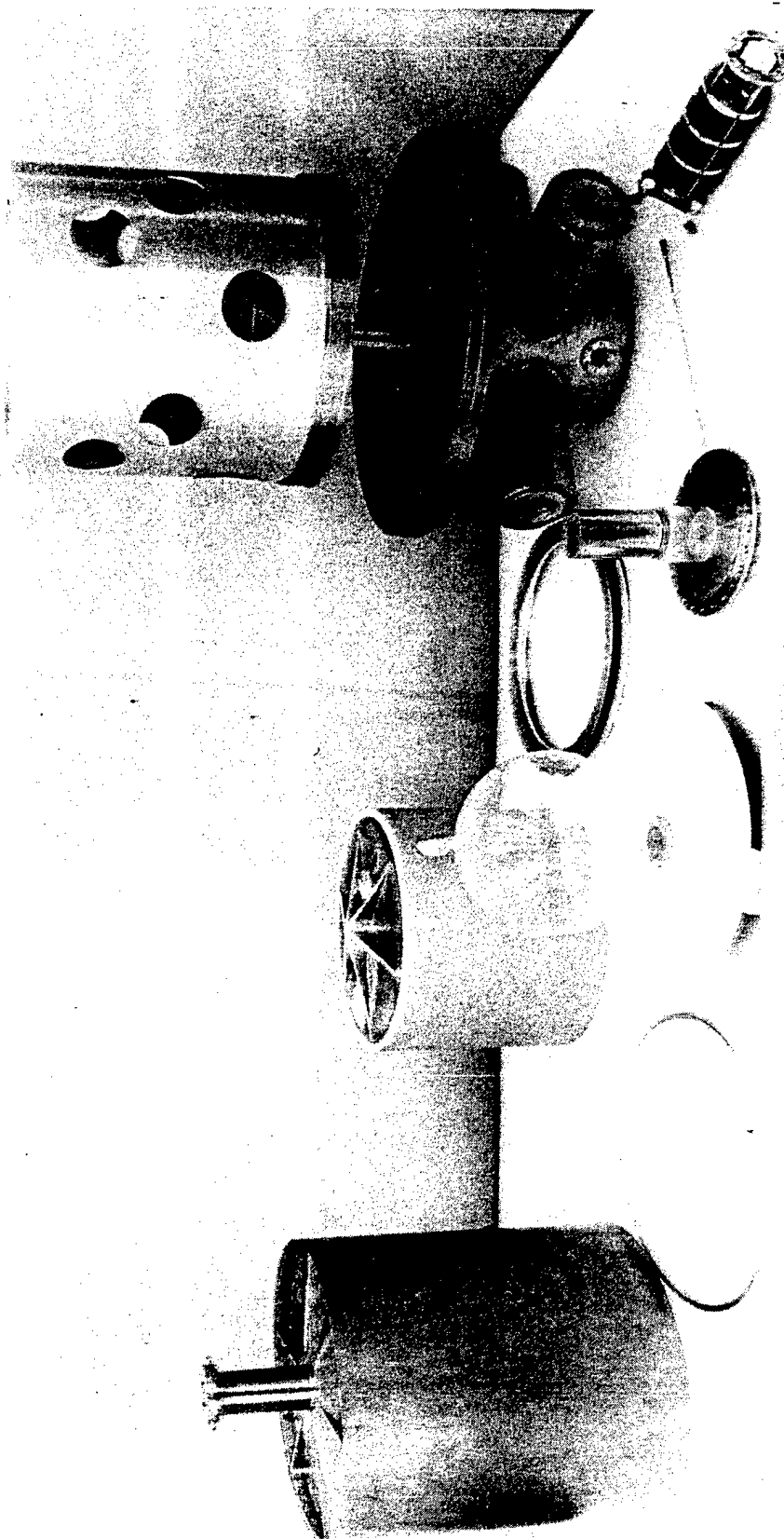
TECHNOLOGY NEEDS SATISFIED BY SPACEBORNE ULTRA-HIGH STABILITY HYDROGEN MASERS

- HIGH PRECISION SPACE-BORNE GUIDANCE AND NAVIGATION SYSTEMS
- RADIO ASTRONOMY VERY LONG BASELINE INTERFEROMETRY
- REAL-TIME HIGH PRECISION GLOBAL TIME AND FREQUENCY SYNCHRONIZATION
- GRAVITATION AND RELATIVITY PHYSICS
- SPACE-BORNE MULTISTATION TIME-CORRELATED RADAR TRACKING

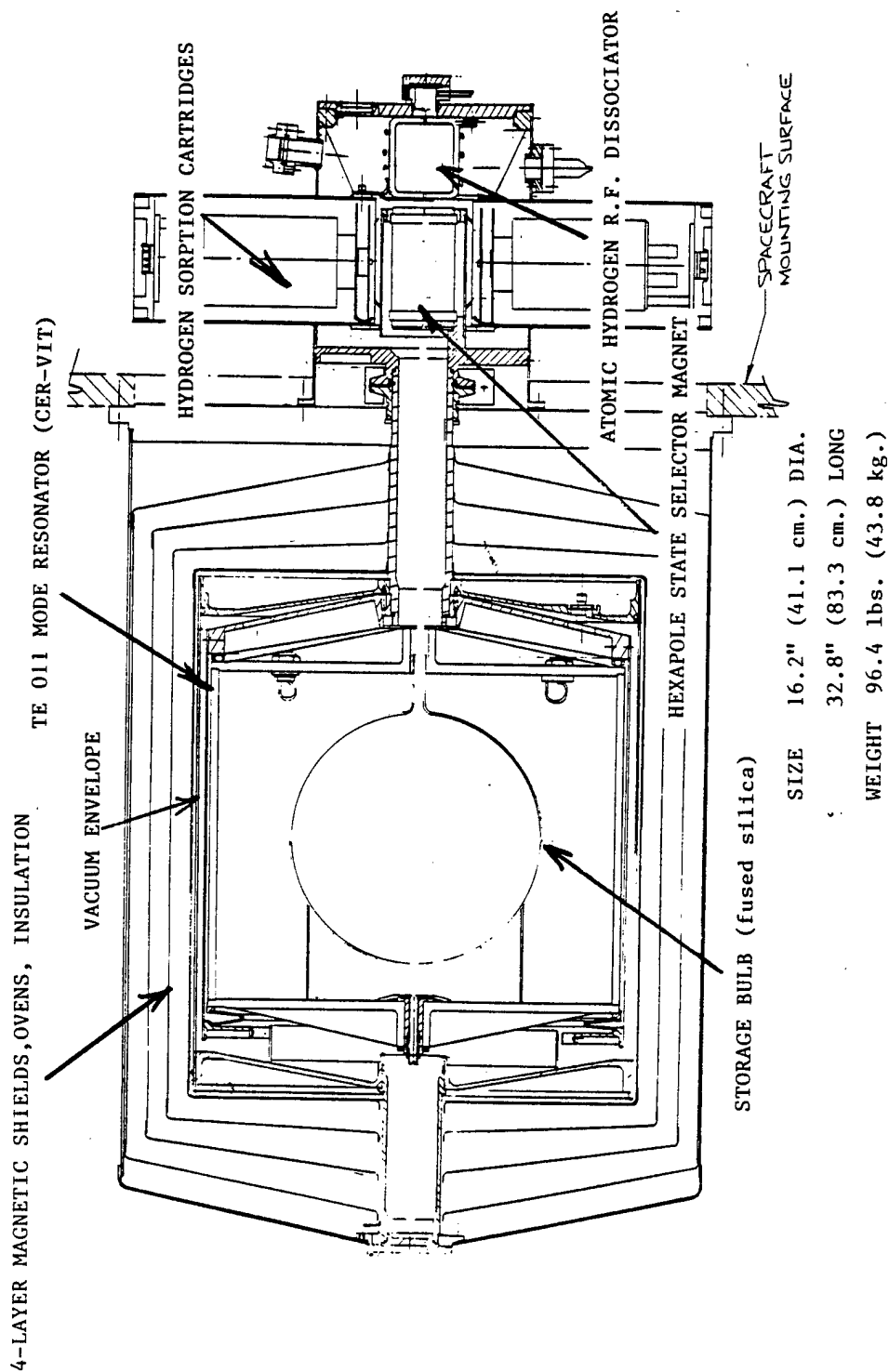
EXPERIMENT DESCRIPTION



PHOTOGRAPH OF SPACE MASER COMPONENTS



SPACE MASER DESIGN CONCEPT

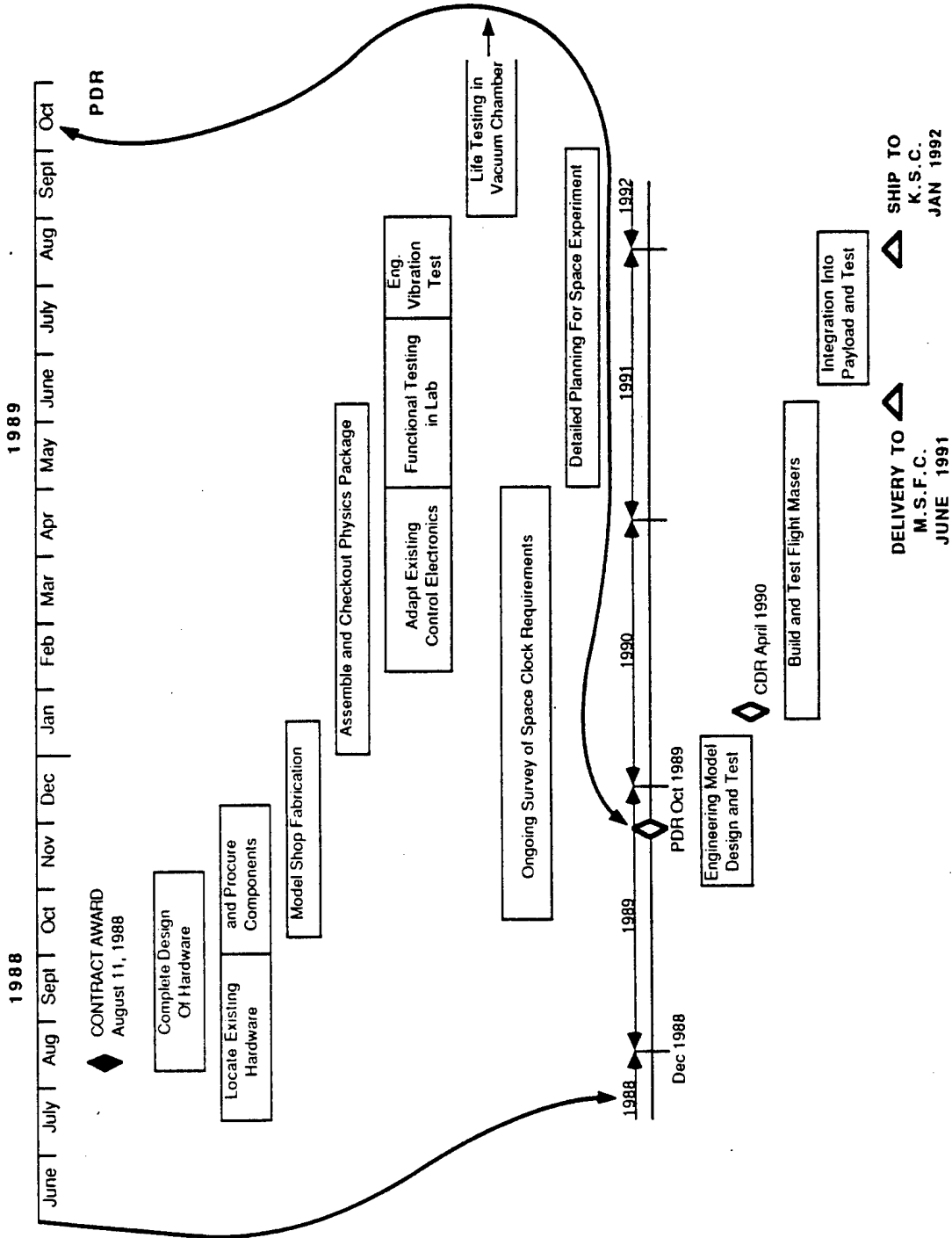


OUTREACH EXPERIMENT DEFINITION STUDY

CONSTRUCTION and IN-SPACE PERFORMANCE EVALUATION
of
HIGH STABILITY HYDROGEN MASER CLOCKS

SMITHSONIAN
ASTOPHYSICAL
OBSERVATORY

SCHEDULE OF PRESENT PROGRAM AND ITS EXTENSION TO A FLIGHT EXPERIMENT.



CONCLUSIONS AND SUMMARY

EARTH-BASED HYDROGEN MASERS HAVE ACHIEVED EXTREMELY HIGH PERFORMANCE AND STABILITY APPROACHING 1×10^{-16} . THIS TECHNOLOGY SHOULD BE ADAPTED FOR SPACE APPLICATIONS OF LONG DURATION.

- THE SPACE STATION AND POLAR ORBITER WILL REQUIRE HIGH STABILITY CLOCKS FOR
 - VLBI OPERATION OF SPACEBORNE RADIOTELESCOPES
 - WORLD WIDE TIME AND FREQUENCY COORDINATION
 - HIGH SPEED COMMUNICATIONS SYNCHRONIZATION
- HIGH PRECISION, VERY HIGH STABILITY, CLOCK SIGNALS ARE NECESSARY AS AN ON-BOARD UTILITY FOR OTHER SYSTEM APPLICATIONS.

MODERN METROLOGY DEPENDS ON THE DEFINITION OF TIME INTERVAL IN TERMS OF THE ATOMIC SECOND. DISTANCE IS NOW DEFINED BY THE VELOCITY OF LIGHT IN TERMS OF ATOMIC TIME.

ATOMIC CLOCKS PROVIDE THE MOST PRECISE MEASUREMENTS OF PHYSICAL PARAMETERS.

CHART 1

THEME: SENSORS & INFORMATION SYSTEMS	IN-SPACE TECHNOLOGY EXPERIMENTS WORKSHOP DECEMBER 6-9, 1988	SUBTHEME GROUP: F(6): SENSORS

ACCELERATION MEASUREMENT AND MANAGEMENT

Experiment Definition

Investigation Team:

- Experiment Manager: Mr. Jan A. Bijvoet, UAH*
- Fundamental Theory: Dr. Charles A. Lundquist, UAH
- Theoretical Analysis: Dr. J. Iwan D. Alexander, UAH
- Fundamentals of Dr. Ru J. Hung, UAH
- Measurements: Dr. Ernst Stuhlinger, TBE*
- Survey of Accelerometers: Mr. Dan Delong, TBE

*UAH = University of
Alabama in
Huntsville
TBE = Teledyne Brown
Engineering

Contract No: NAS1-18683
NASA Center: Langley Research Center
Contact: Robert C. Blanchard

CHART 2

OUTREACH	ACCELERATION MEASUREMENT AND MANAGEMENT	- UAH - TBE

General Experiment Objectives:

- Enhance the level of Acceleration Measurement and spatial patterning as an essential support to high quality microgravity operations.
- To bring acceleration measurement and management toward the mature status enjoyed by attitude and orbit determination & management.

CHART 3

OUTREACH	ACCELERATION MEASUREMENT AND MANAGEMENT	- UAH - TBE

Technology Need:

- Microgravity materials processes require:
 - very low acceleration disturbance levels.
 - knowledge of direction of the residual acceleration vector for experiment accommodation.
- No methodology available to determine on-orbit the center-of-mass.
- Acceleration disturbance level and vector needs to be known at a large number of experiment locations.
- Needs to be known in real time.
- Information needed in real time for control of the center of mass.

CHART 4

OUTREACH	ACCELERATION MEASUREMENT AND MANAGEMENT	- UAH - TBE

Experiment Definition Objectives:

- Develop analytical methods for in-orbit calculation of center of mass from a number of separately located 3-D accelerometers.
- Develop analytical methods for in-orbit calculation of acceleration level and acceleration vector at any selectable experiment location.
- Determine data for control of the center of mass.

OUTREACH

UAH
TBE

ACCELEROMETER MEASUREMENT AND MANAGEMENT

SURVEY OF EXISTING ACCELEROMETERS (Sheet 1 of 2)

Other Similar Uses for Accelerometers

- Missile Guidance
- Satellite Sensor Stabilization
- Seismic Motion Detection
- Orbital Experiment Instrumentation

Teledyne Brown Engineering Requested Information from the Following Organizations:

• Applied Technology Associates	• KMS Fusion	• Stanford University
• Bell Aerospace Textron	• Litton	• Sundstrand Data Control
• Bruel & Kjaer	• Payload Systems, Inc.	• Syston Donner
• C.S. Draper Laboratories	• Rockwell Defense Electronics	• Teledyne Geotech
• G.E. Space Div.	• Singer Kearfott	• U of MD Physics Dept.
• Honeywell	• Sperry Aerospace	
• IC Sensors		

OUTREACH

UAH
TBE

ACCELEROMETER MEASUREMENT AND MANAGEMENT

SURVEY OF EXISTING ACCELEROMETERS (Sheet 2 of 2)

Specifications Requested Were:

- Measure 10^{-7} to 10^{-2} g_0
- Frequency response of 10⁻⁴ to 50 Hz
- Accommodate a noise spectrum of up to 10^{-2} g_0 from 1 to 50 Hz
- A method of calibrating the sensor

Conclusions:

- Currently existing sensors may be suitable for our needs, pending testing
- Sensor bias and drift characteristics will interfere with the low amplitude, low frequency measurements
- Testing and calibration will be difficult in a one g_0 environment
- A new type of sensor may be more appropriate for this application

CHART 6

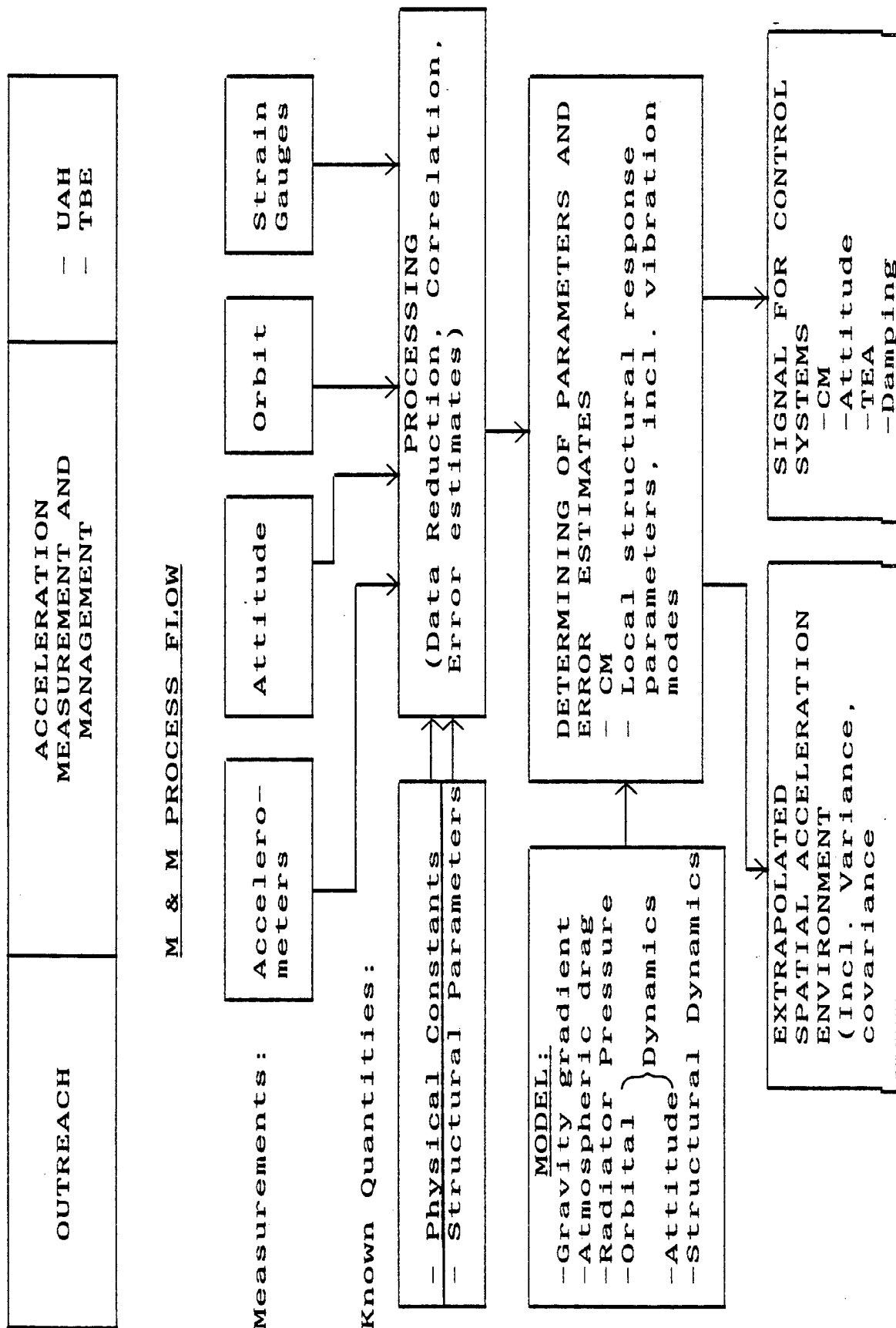


CHART 7.1

OUTREACH	ACCELERATION MEASUREMENT AND MANAGEMENT	- UAH - TBE

POTENTIAL SHUTTLE FLIGHTS FOR PILOT EXPERIMENTATIONS

Flight, Orbiter	Date	Relevant Payload	Carrier	Low-g Flight?	Accelerometers*
32, C	Nov 89				H, O
35, C	Mar 90	Astro-1	2SL-PAL	yes?	H, O
40, C	Jun 90	SLS-1	SL-LM	?	S?, H, O
44, C	Dec 90	Atlas-1, MSL-3?	2SL-PAL	yes	S?, H, O
45, A	Jan 91	TSS-1	SL-PAL, + MPSS		TBD
47, C	Apr 91	IML-1	SL-LM	yes	S, H, O
48, A	May 91	EURECA-IL		yes	TBD
49, C	Jul 91	S/L-J	SL-LM	yes	S, H, O
52, C	Dec 91	S/L-D2	SL-LM+USS	yes	H, O + TBD
55, C	Mar 92	USML-1	SL-LM+MPSS	yes	2S, H, O
56, A	Apr 92	ORFEUS	SPAS	yes	TBD

*S = SAMS = Space Acceleration Measurement System (Le R.C.)

H = HIRAP = High Resolution Accelerometer Package (JSC, La R.C.)

O = OARE = Orbital Acceleration Research Experiment (JSC, La R.C.)

CHART 7.2

OUTREACH	ACCELERATION MEASUREMENT AND MANAGEMENT	- UAH - TBE

POTENTIAL SHUTTLE FLIGHTS (Continued)

Flight, Orbiter	Date	Relevant Payload	Carrier	Low-g Flight?	Accelero- meters*
57, D	May 92	<u>USMP-1</u>	MSL+MPSS	yes	TBD
59, C	Jul 92	SLS-2	SL-LM	?	S?, H.O
60, A	Jul 92	<u>ISF-1</u>		<u>yes</u>	TBD
63, C	Oct 92	<u>IML-2</u>	SL-LM	yes	S?, H.O
65, D	Nov 92	<u>MSL-4</u>	MPSS	yes	S?
68, A	Feb 93	<u>ISF-2</u>		<u>yes</u>	TBD
70, OV-105	Apr 93	<u>EURECA-2L</u>		<u>yes</u>	TBD
73, C	Jul 93	<u>USML-2</u>	SL-LM+MPSS	yes	2S?, H.O
74, OV-105	Aug 93	AAFE	2SL-PAL	?	S (Mod.)?
75, A	Sep 93	GP-B1	SL-PAL	yes	TBD
?	?	<u>MSL-5</u>	MPSS	yes	S?
?	?	<u>MSL-6</u>	MPSS	yes	S?

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SENSOR & INFORMATION SYSTEMS	IN-SPACE TECHNOLOGY EXPERIMENTS WORKSHOP DECEMBER 6-9, 1988	SENSOR SYSTEMS

DYNAMIC SPACECRAFT ATTITUDE
DETERMINATION WITH GPS

by

Dr. Duncan B. Cox, Jr.
Mayflower Communications Company, Inc.
80 Main Street, Reading, MA 01867
617-942-2666

Contract No. NAS5-30358
NASA/GSFC
Dr. Seymour Kant

OUTREACH	DYNAMIC SPACECRAFT ATTITUDE DETERMINATION WITH GPS	MAYFLOWER COMMUNICATIONS

EXPERIMENT OBJECTIVE

Determine the feasibility of using NAVSTAR GPS signals to accurately measure very small differences in antenna locations in multiple antenna arrays.

- o Determine spacecraft orbit, attitude, and flexure.

Consider shading of antennas by spacecraft structures.

Utilize optimum estimation filters, including models of spacecraft dynamics and potentially available inertial sensors.

- o Measure very slow ground motions due to geodynamics.

Utilize data obtained by continuously monitoring GPS signals at multiple sites, including stable baselines as well as potentially unstable ones.

Estimate ionospheric and tropospheric delays and multipath perturbations.

OUTREACH	DYNAMIC SPACECRAFT ATTITUDE DETERMINATION WITH GPS	MAYFLOWER COMMUNICATIONS

BACKGROUND

NAVSTAR Global Positioning System (GPS)

Signals soon available continuously world-wide, to LEO and beyond

Likely to be widely used for spacecraft navigation

Phase information can be used to measure lengths and bearings of short baselines with subcentimeter accuracies.

Allows determination of attitude and flexure of spacecraft with multiple antennas.

Allows determination of geodynamic motions of GPS-instrumented ground sites.

OUTREACH	DYNAMIC SPACECRAFT ATTITUDE DETERMINATION WITH GPS	MAYFLOWER COMMUNICATIONS

TECHNOLOGY NEEDS

GPS-derived attitude data can be used for initial pointing of spacecraft subsystems, such as laser radars and laser communications systems. But technical issues must be resolved before mission applications are undertaken.

Spacecraft structures obscure the views of satellites and cause multipath interference.

A Geodynamic Laser Ranging System (GLRS) demonstration can benefit from having independent GPS measurements of terrestrial baselines with subcentimeter accuracies.

A system design employing low-cost, weather-tolerant, terrestrial equipment and advanced algorithms needs to be developed and demonstrated. The system should be integrated appropriately with the GLRS system.

OUTREACH	DYNAMIC SPACECRAFT ATTITUDE DETERMINATION WITH GPS	MAYFLOWER COMMUNICATIONS

EXPERIMENT DESCRIPTION

Instrumented space vehicle

Three GPS antennas, one GPS receiver, one high-accuracy clock, one digital controller, one data recorder.

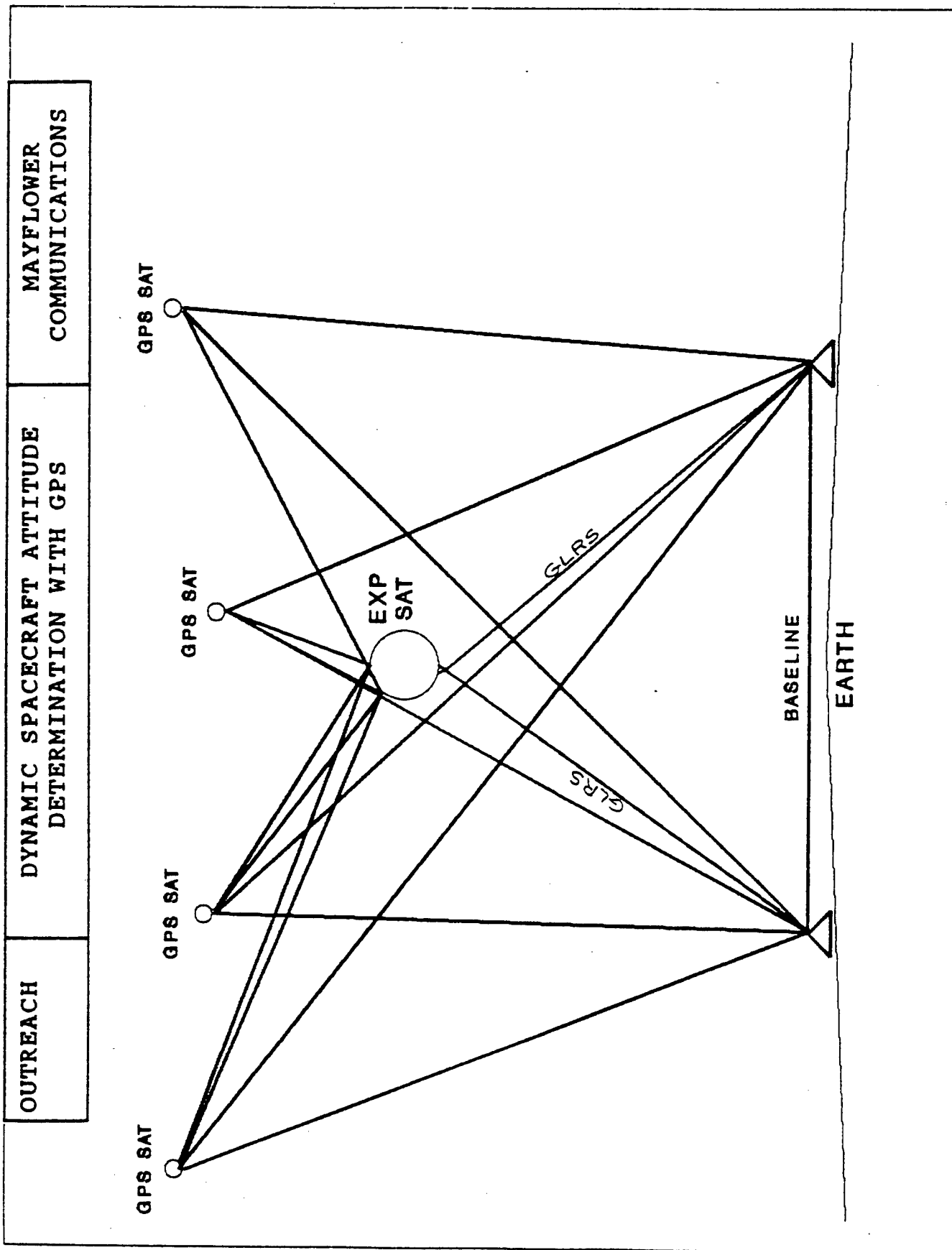
One independent attitude determination subsystem, preferably part of a GLRS experiment. (Note that GPS receivers are likely to be utilized by GLRS for orbit determination.)

Record raw GPS pseudorange and phase data, and independent attitude data for post-flight processing. Include inertial sensor data if available.

Instrumented terrestrial range

A GPS antenna, receiver, and recorder at each of two GLRS sites.

Compare GPS attitude and baseline data with independent results.



OUTREACH	DYNAMIC SPACECRAFT ATTITUDE DETERMINATION WITH GPS	MAYFLOWER COMMUNICATIONS

SCHEDULE

TASK DESCRIPTION	O	N	D	J	F	M	A	M	J	J	A	S
System Description	--	--	--	--								
Algorithm development				--	--	--	--					
Hardware selection				--	--	--	--					
Performance analysis								--	--	--		
Experiment planning								--	--	--	--	
Final report											--	--

OUTREACH	DYNAMIC SPACECRAFT ATTITUDE DETERMINATION WITH GPS	MAYFLOWER COMMUNICATIONS

SUMMARY

GPS signals probably can be used simply and at low cost to determine the attitudes of spacecraft, and bending of spacecraft members, to milliradian accuracies.

GPS signals probably can be used with low cost equipment for determination of slow geodynamic motions of terrestrial baselines to subcentimeter accuracies.

An experiment is proposed in which GPS would synergistically support a GLRM experiment.

Utilizing GLRM-spacecraft attitude data to corroborate GPS attitude data.

Utilizing GPS data to corroborate GLRM baseline data.

Using GPS data for satellite orbit estimation, to the benefit of both experiments.

Sensors & Information Systems	IN-SPACE TECHNOLOGY EXPERIMENTS WORKSHOP DECEMBER 6-9, 1988	SENSORS

Stanford University-NASA Laser In-space Technology Experiment

SUMMIT

PRINCIPAL INVESTIGATORS
A Martin Buoncrisiani
 Langley Research Center
 National Research Council
Robert L Byer
 Stanford University

Art Newcomb
 Instrument Manager

INREACH	SUNLITE	<i>Langley Research Center</i>

OBJECTIVE:

To provide ultra-stable, solid-state laser oscillators for future applications in space based systems. The self powered SUNLITE instrument will use the vibration free, microgravity environment in or about the orbiting Shuttle to test the stability and Schawlow-Townes linewidth limit of specially configured monolithic Non-Planar Ring Oscillators (NPRO).

BACKGROUND:

The availability of diode lasers, as pump sources, provides the opportunity for development of small, stable, long-life all solid-state laser sources. The monolithic Non-Planar Ring Oscillator (NPRO), developed at Stanford under NASA/OAST sponsorship, promises to satisfy scientific, medical and industrial applications requiring coherent narrow linewidth sources. Immediate benefits are promised for spacecraft operations and remote sensing applications.

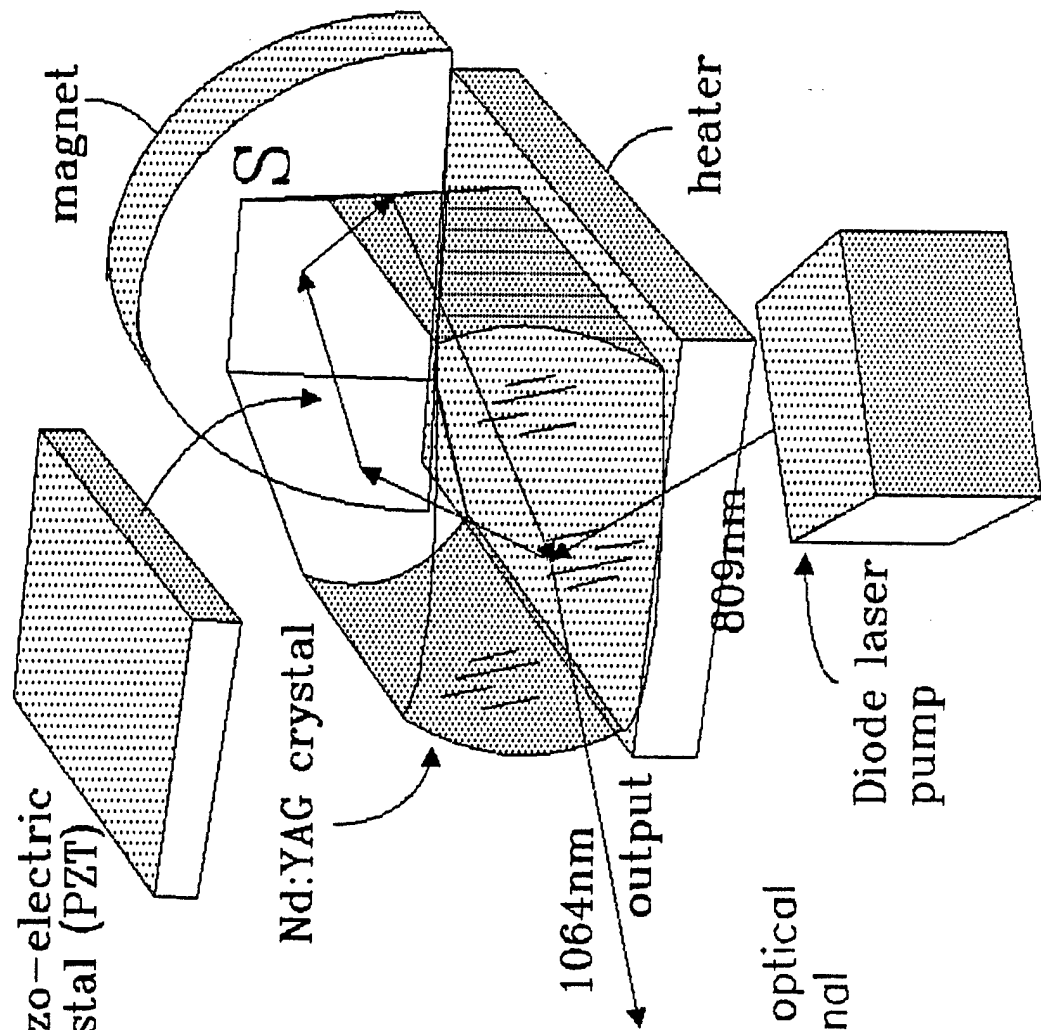
Improved techniques in frequency control are used to lock the NPRO to external cavities and have yielded linewidths down to about 150 Hz. Resultant linewidth measurements are limited by noise induced by sources within the lab environment. Reducing these sources to practical limits will leave gravity, mechanical and acoustically coupled vibration as limiting factors in laboratory experiments. The Shuttle experiment will provide the environment needed to further examine linewidth and stability limitations.

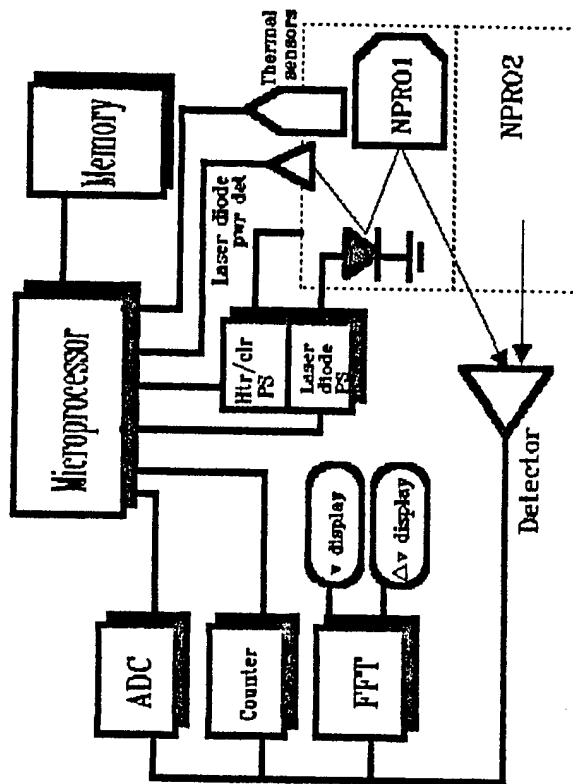
The NPR0 Module

The Nd:YAG laser is tuned by modulating the voltage across the PZT squeezing or stretching the crystal.

The laser crystal is specially ground containing all the elements of the laser cavity taking advantage of total internal reflection.

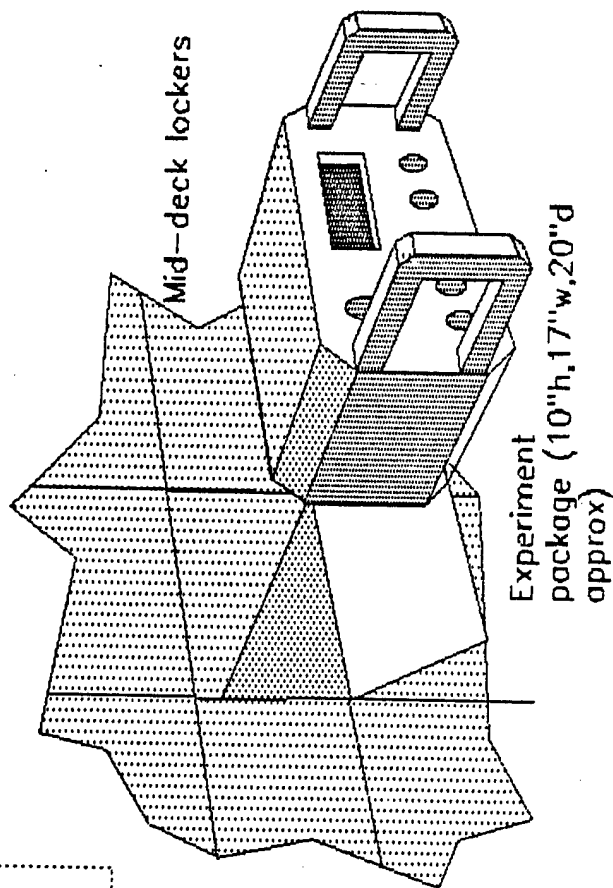
The magnet functions as an optical diode to assure a unidirectional light path.





DESCRIPTION

The experiment consists of 3 NPROs in heterodyne pairs using photodetection for examination and recording of difference signals.

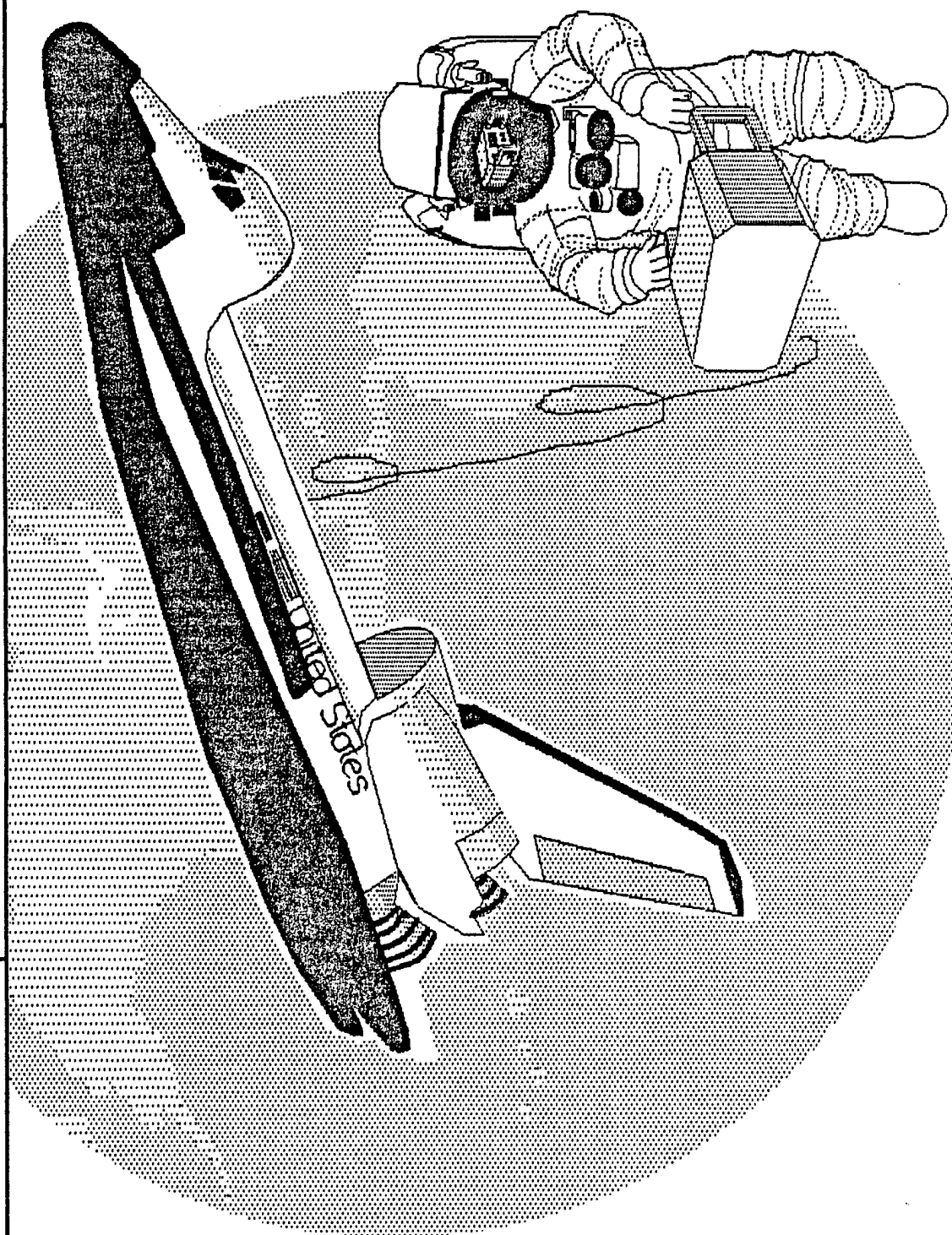


The self contained unit will be stored in a Shuttle mid-deck locker. The experiment timeline takes about an hour, a warm-up period followed by short data taking periods. Data is stored in solid state memory for dump after the return flight.

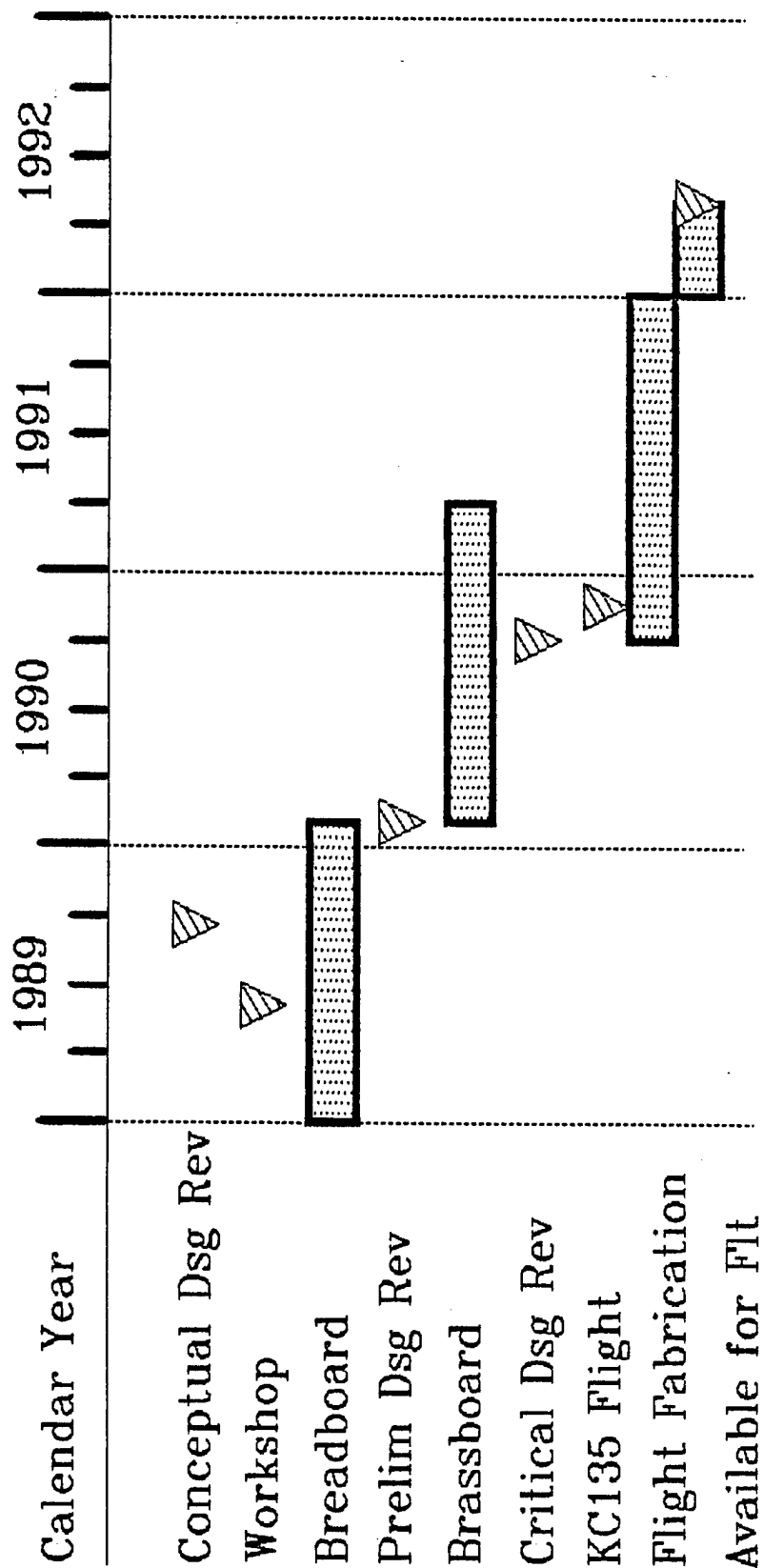
*Langley
Research Center*

SUNLITE

INREACH



SCHEDULE



7. IN-SPACE SYSTEMS

IN-SPACE SYSTEMS	IN-SPACE TECHNOLOGY EXPERIMENTS WORKSHOP DECEMBER 6-9, 1988	MAINTENANCE, REPAIR, AND FIRE SAFETY

DEFINITION OF EXPERIMENTS TO INVESTIGATE FIRE SUPPRESSANTS IN MICROGRAVITY

**DR. JAMES J. REUTHER
BATTELLE COLUMBUS DIVISION**

**CONTRACT NO. NAS3-25362
NASA LEWIS RESEARCH CENTER
MR. ROBERT FRIEDMAN**

OUTREACH PROJECT	DEFINITION OF EXPERIMENTS TO INVESTIGATE FIRE SUPPRESSANTS IN MICROGRAVITY	BATTELLE COLUMBUS DIVISION

EXPERIMENT OBJECTIVE

- Define specific in-space technology experiment(s) to identify, evaluate, and develop effective fire suppressants for the microgravity environment. Fire suppression technology is broadly defined as the technology both to prevent ignition through atmosphere control and to extinguish smoldering and flaming combustion once initiated.

OUTREACH PROJECT	DEFINITION OF EXPERIMENTS TO INVESTIGATE FIRE SUPPRESSANTS IN MICROGRAVITY	BATTELLE COLUMBUS DIVISION

BACKGROUND/TECHNOLOGY NEED

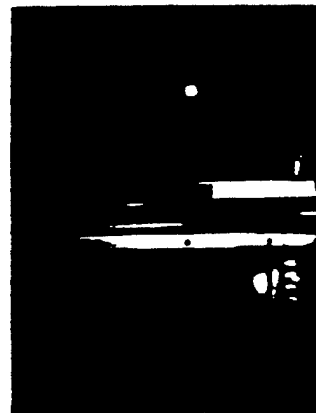
- A preliminary analysis by Battelle of the combustion situation under microgravity conditions revealed that spacecraft fire suppression may be more difficult than that for 1-G fires on Earth. Specifically, fire suppressants that are routinely and rather universally used on Earth may not be as effective, or may even be ineffective, in spacecraft fire situations.
- Because there may not be proven techniques developed to extinguish fires in space, crews and hardware of future manned space missions may be at risk.

OUTREACH PROJECT	DEFINITION OF EXPERIMENTS TO INVESTIGATE FIRE SUPPRESSANTS IN MICROGRAVITY	BATTELLE COLUMBUS DIVISION

ZERO GRAVITY COMBUSTION

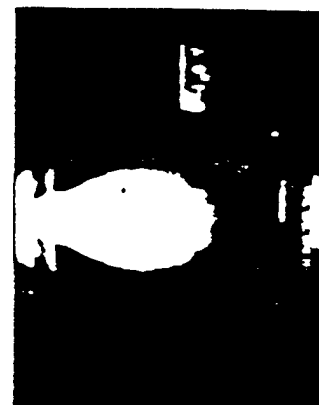


EARTH GRAVITY



ZERO GRAVITY

GASES



EARTH GRAVITY



ZERO GRAVITY

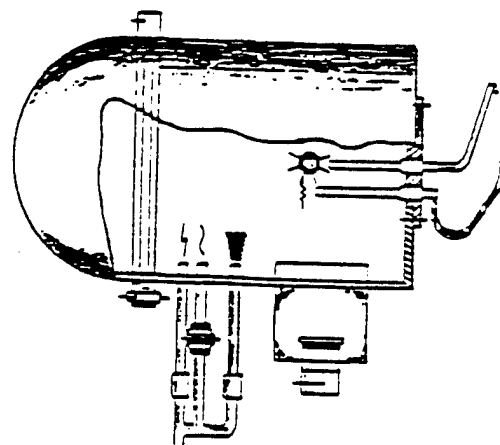
SOLIDS

OUTREACH PROJECT	DEFINITION OF EXPERIMENTS TO INVESTIGATE FIRE SUPPRESSANTS IN MICROGRAVITY	BATTELLE COLUMBUS DIVISION

EARLY PROGRESS

- Determination of the extent to which the effectiveness and/or mode of action of terrestrial fire suppressants are altered by the spacecraft environment.
- Formulation of guidelines with which to identify terrestrial agents that have the potential for acting as effective spacecraft fire suppressants.

OUTREACH PROJECT	DEFINITION OF EXPERIMENTS TO INVESTIGATE FIRE SUPPRESSANTS IN MICROGRAVITY	BATTELLE COLUMBUS DIVISION

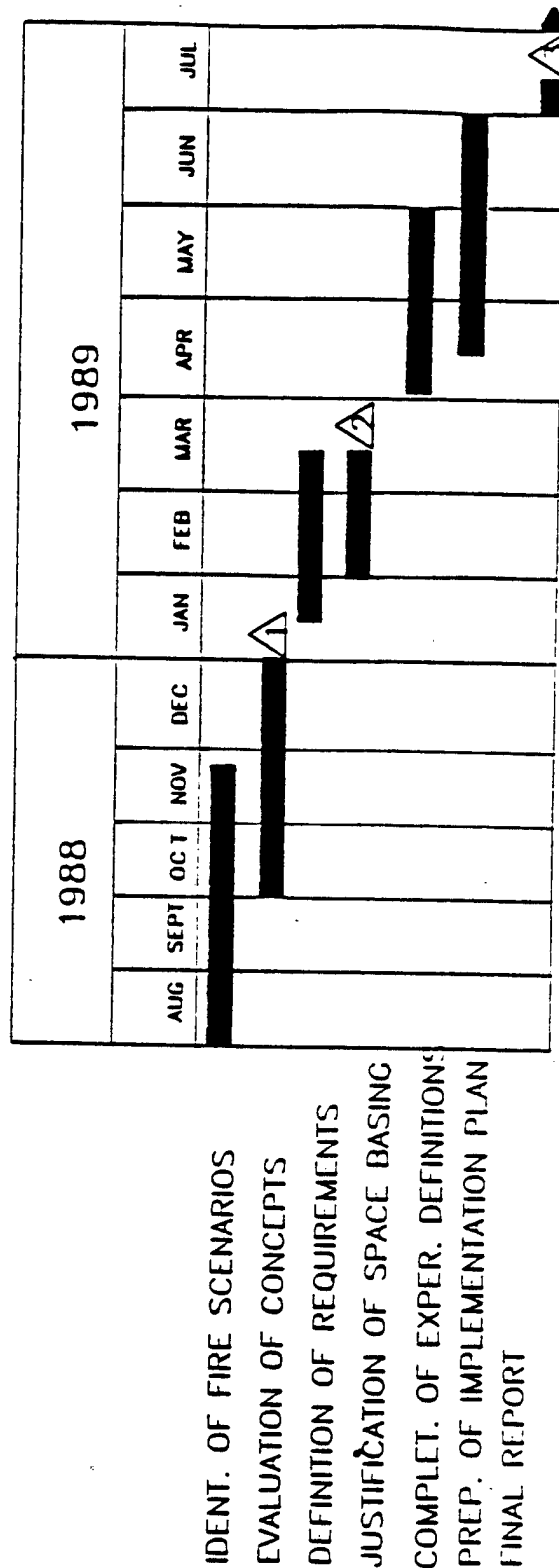


EXPERIMENT DESCRIPTION

- The apparatus will provide a means by which to simulate various flame situations representative of plausible spacecraft fire scenarios after which various means will be used to deliver and evaluate the suppression effectiveness of various agents.

OUTREACH PROJECT	DEFINITION OF EXPERIMENTS TO INVESTIGATE FIRE SUPPRESSANTS IN MICROGRAVITY	BATTELLE COLUMBUS DIVISION

PROJECT SCHEDULE



1. TASK 1 APPROVAL
2. TASK 2 APPROVAL
3. FINAL REPORT TO NASA REVIEW

OUTREACH PROJECT	DEFINITION OF EXPERIMENTS TO INVESTIGATE FIRE SUPPRESSANTS IN MICROGRAVITY	BATTELLE COLUMBUS DIVISION

SUMMARY/CONCLUDING REMARKS

- The mission of the project is to identify those technologies that quickly and permanently extinguish spacecraft fires, with the action taken being no more life or mission threatening than the fire itself.

IN-SPACE SYSTEMS	IN-SPACE TECHNOLOGY EXPERIMENTS WORKSHOP DECEMBER 6-9, 1988	MAINTENANCE, REPAIR, AND FIRE SAFETY

RISK-BASED FIRE SAFETY EXPERIMENT DEFINITION

PRINCIPAL INVESTIGATOR
 GEORGE APOSTOLAKIS
 UNIVERSITY OF CALIFORNIA, LOS ANGELES

SUBCONTRACTOR AMERICAN SPACE TECHNOLOGY, INC. SANTA MONICA, CALIFORNIA	CONTRACT NO. NAS 8--37750 MARSHALL SPACE FLIGHT CENTER J. AUSTIN

OUTREACH EXPERIMENT DEFINITION STUDY	RISK-BASED FIRE SAFETY EXPERIMENT DEFINITION	UCLA

EXPERIMENT OBJECTIVE

EXPAND THE UNDERSTANDING OF PROCESSES AND PHENOMENA IMPORTANT TO THE ASSESSMENT OF RISKS ASSOCIATED WITH FIRES IN SPACECRAFT.

- OBSERVE THE MECHANISMS OF FLAME PROPAGATION BETWEEN TWO SOLID OBJECTS AND THE COMPETING PROCESSES OF DETECTION AND SUPPRESSION.
- OBSERVE THE GENERATION, MOTION, AND ADVERSE IMPACT OF COMBUSTION PRODUCTS.
- CONTRIBUTE TO THE DEVELOPMENT OF PROBABILISTIC RISK ASSESSMENT METHODOLOGY FOR SPACECRAFT.

OUTREACH EXPERIMENT DEFINITION STUDY	RISK-BASED FIRE SAFETY EXPERIMENT DEFINITION	UCLA

BACKGROUND

- QUANTITATIVE RISK ASSESSMENT IS PLAYING AN INCREASINGLY IMPORTANT ROLE IN IDENTIFYING SIGNIFICANT RISKS AND JUSTIFYING MITIGATING ACTIONS (SEE ALSO NMI 8070.4)
- PRA METHODOLOGY QUANTIFYING THE FIRE RISK IN NUCLEAR POWER PLANTS HAS BEEN DEVELOPED AT UCLA.

TECHNOLOGY NEEDS

- TO INTEGRATE BASIC KNOWLEDGE ACQUIRED IN PREVIOUS MICROGRAVITY RESEARCH TO INVESTIGATE SYSTEM LEVEL PHENOMENA
- TO EXPAND BASIC FIRE-SAFETY KNOWLEDGE

OUTREACH EXPERIMENT DEFINITION STUDY	RISK-BASED FIRE SAFETY EXPERIMENT DEFINITION	UCLA

OUTLINE OF FIRE RISK ASSESSMENT

1. IDENTIFICATION OF "CRITICAL" LOCATIONS AND ASSESSMENT OF THE FREQUENCY OF FIRES.
2. ESTIMATION OF FIRE GROWTH TIMES AND COMPETING DETECTION AND SUPPRESSION TIMES.
3. RESPONSE OF THE SYSTEM.

$$Q = Fr\{T_G < T_D + T_S \mid FIRE\}$$

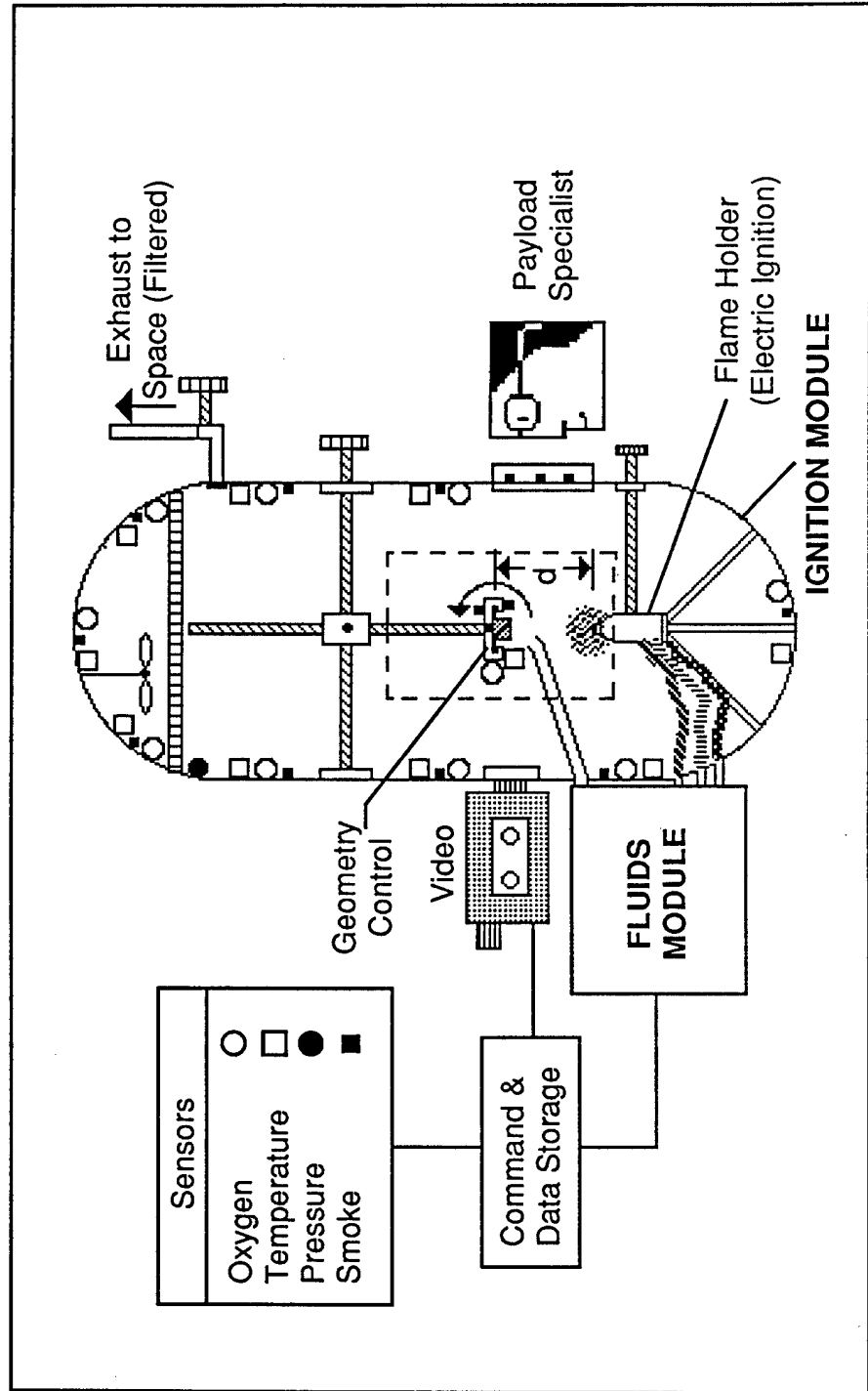
$$1 + 2 + 3 \Rightarrow \lambda_D = \sum \lambda_j Q_{D|j} Q_{D|D,j}$$

**OUTREACH
EXPERIMENT
DEFINITION STUDY**

**RISK-BASED FIRE SAFETY
EXPERIMENT DEFINITION**

UCLA

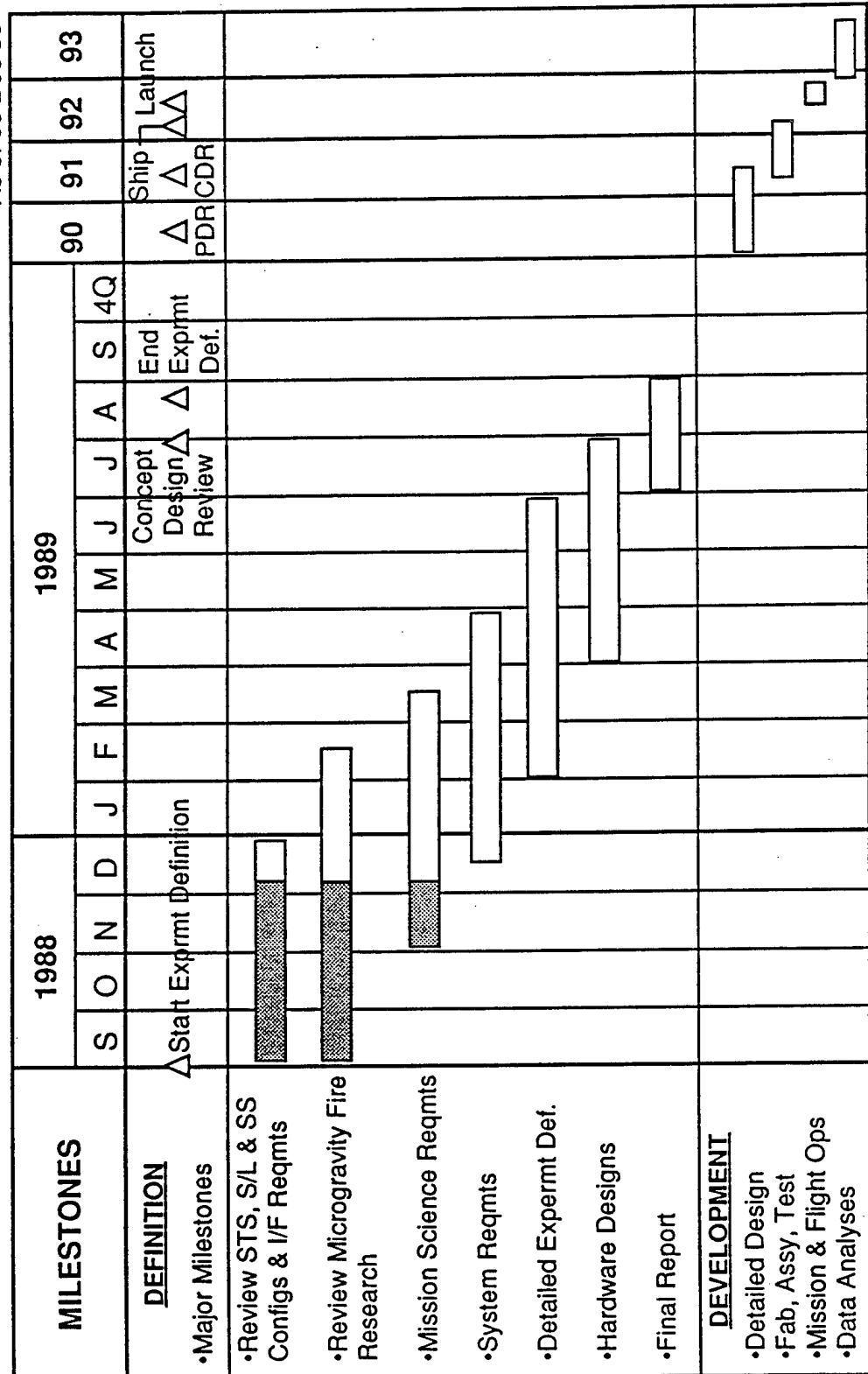
Preliminary Schematic



OUTREACH EXPERIMENT DEFINITION STUDY	RISK-BASED FIRE SAFETY EXPERIMENT DEFINITION	UCLA

Program Master Schedule

As of 06 Dec 88



**IN-SPACE
SYSTEMS**

**IN-SPACE TECHNOLOGY EXPERIMENTS WORKSHOP
DECEMBER 6-9, 1988**

**MATERIALS
PROCESSING**

PLASMA ARC WELDING IN-SPACE

**BORIS RUBINSKY
DEPARTMENT OF MECHANICAL ENGINEERING
UNIVERSITY OF CALIFORNIA, BERKELEY
BERKELEY, CA 94720**

**CONTRACT NO. NAS1-18686
NASA LANGLEY RESEARCH CENTER
DR. JOHN BUCKLEY**

OUT-REACH	PLASMA ARC WELDING IN-SPACE	UNIVERSITY OF CALIFORNIA, BERKELEY

EXPERIMENT OBJECTIVE

TO DEVELOP A FUNDAMENTAL UNDERSTANDING OF THE HEAT TRANSFER, MASS TRANSFER AND FLUID FLOW PROCESSES THAT OCCUR DURING PLASMA ARC WELDING IN A LOW-GRAVITY AND LOW PRESSURE ENVIRONMENT. TO DEVELOP CORRELATIONS WITH ANALYTICAL MODELS. THIS UNDERSTANDING WILL BE APPLIED TO:

- THE IDENTIFICATION OF THE OPTIMAL PARAMETERS FOR PLASMA ARC WELDING IN SPACE.
- THE DESIGN OF LOW WEIGHT TASK SPECIFIC PLASMA ARC WELDING SYSTEMS.

BACKGROUND/TECHNOLOGY NEEDS

- COMPUTER MODEL OF THE PLASMA ARC WELDING PROCESS FOR THE IDENTIFICATION OF WELDING PARAMETERS.
- ANALYTICAL AND EXPERIMENTAL METHOD FOR THE ANALYSIS OF THE EXPERIMENTAL DATA RETRIEVED FROM THE IN-SPACE EXPERIMENT.
- EXPERIMENTAL SYSTEMS FOR VERIFICATION OF THE ABOVE METHODS IN GROUND-BASED LABORATORIES.

OUT-REACH	PLASMA ARC WELDING IN-SPACE	UNIVERSITY OF CALIFORNIA, BERKELEY

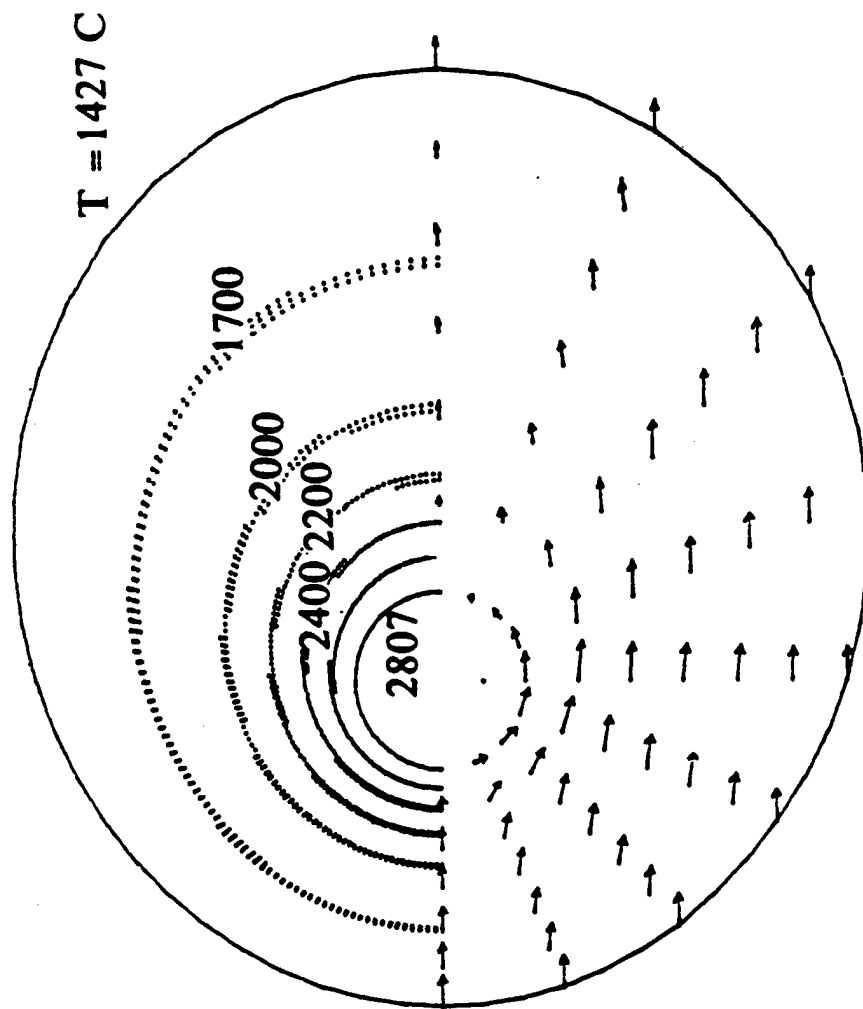
COMPUTER MODEL

A FINITE ELEMENT COMPUTER MODEL WILL PROVIDE THE ABILITY TO DETERMINE THE SHAPE OF THE LIQUID REGION AND THE TEMPERATURE DISTRIBUTION IN THE SOLID REGION AS A FUNCTION OF GRAVITY AND AIR PRESSURE.

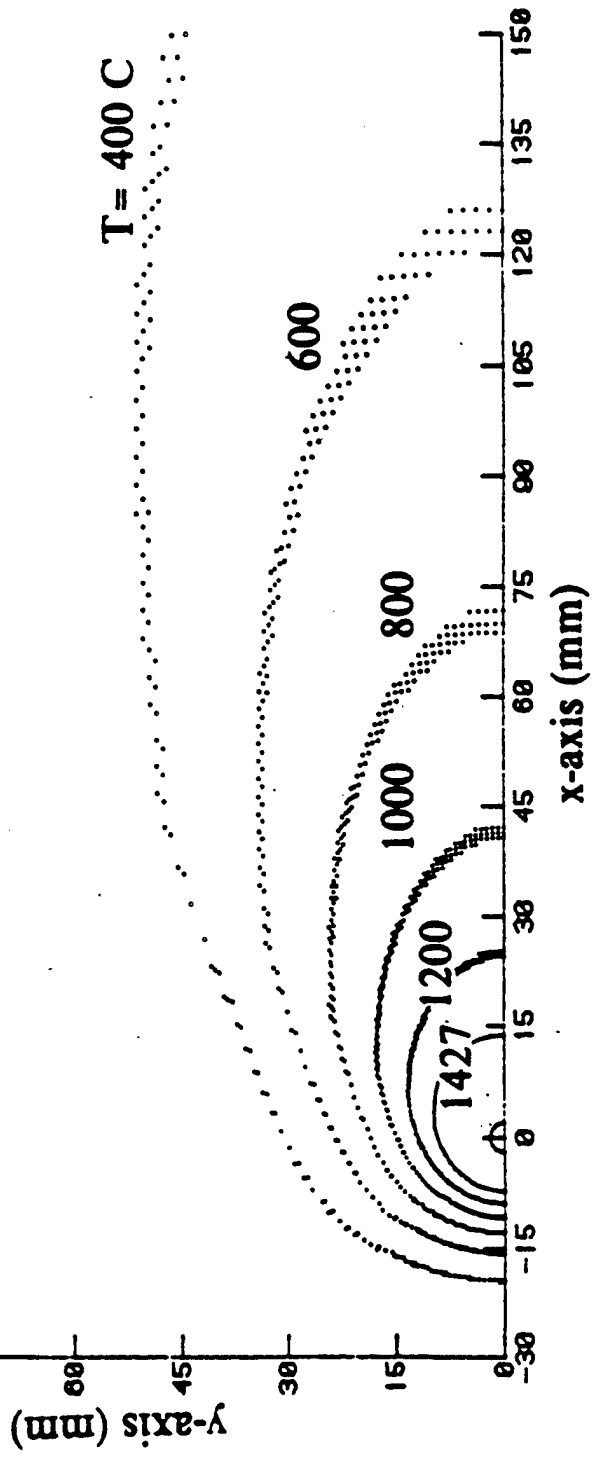
ASSUMPTIONS USED IN THE STUDY INCLUDE:

- THE PROCESS IS QUASI-STATIONARY AS VIEWED IN A FRAME OF REFERENCE MOVING WITH THE PLASMA-TORCH.
- THE MOLTEN LIQUID IS NEWTONIAN AND INCOMPRESSIBLE.
- THE HEAT TRANSFER AND FLUID FLOW CORRELATIONS FOR THE FLOW OF PLASMA ARE TAKEN FROM KNOWN EXPERIMENTAL DATA FOR FLOW OF PLASMAS IN TUBES.
- MATERIAL PROPERTIES ARE TEMPERATURE DEPENDENT.

Velocity and temperature distributions
in the molten pool, $U = 0.5$ mm/sec



Temperature distribution in the solid

 $U = 0.5 \text{ mm/sec}$ 

ANALYTICAL/EXPERIMENTAL METHOD FOR DATA ANALYSIS

AN INVERSE FINITE ELEMENT COMPUTER PROGRAM WILL PROVIDE THE ABILITY TO DETERMINE THE TEMPERATURE FIELD AND THE POSITION OF THE SOLID-LIQUID INTERFACE DURING WELDING USING CONTINUOUS TEMPERATURE AND HEAT FLUX MEASUREMENTS TAKEN ON THE OUTER SURFACE OF THE WORKPIECE, AWAY FROM THE WELD REGION. THE METHOD COULD ALSO PROVIDE REAL TIME CONTROL OVER THE QUALITY OF THE WELDING PROCESS.

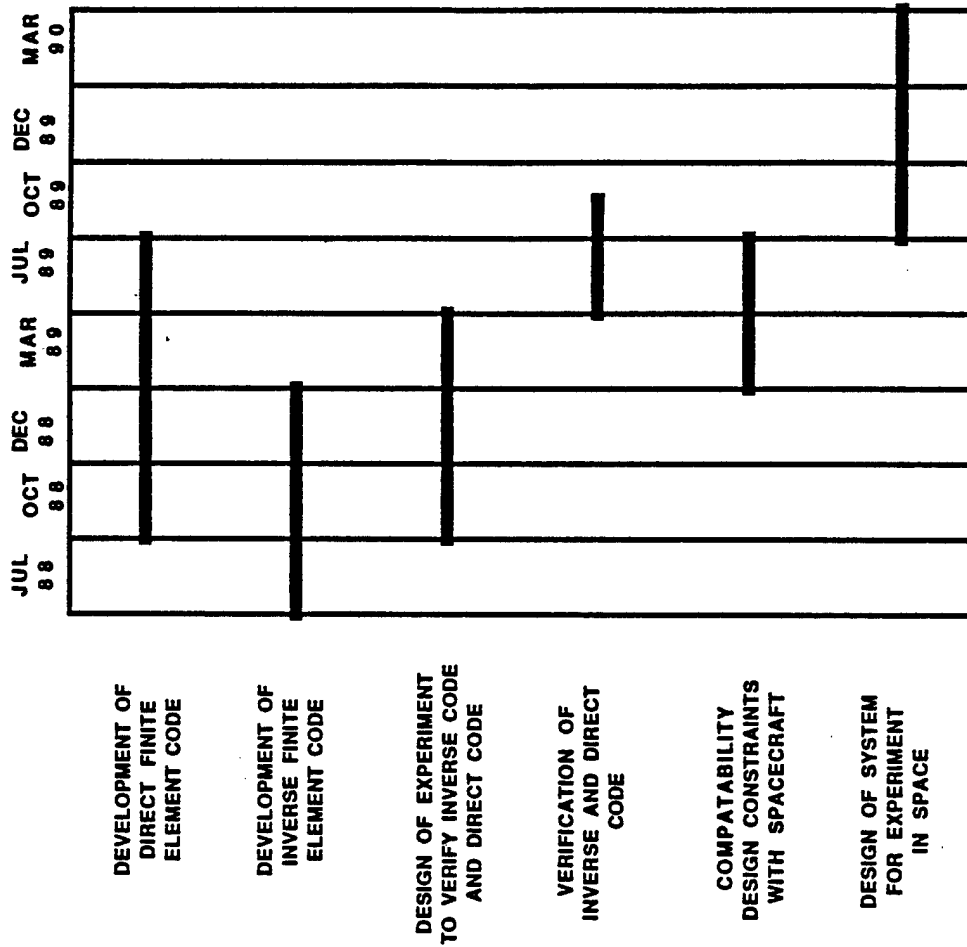
OUT-REACH	PLASMA ARC WELDING IN-SPACE	UNIVERSITY OF CALIFORNIA, BERKELEY

ON GROUND LABORATORY EXPERIMENTS

THE DIRECT AND INVERSE FINITE ELEMENT COMPUTER CODES
WILL BE VERIFIED USING A COMMERCIAL PLASMA ARC WELDING SYSTEM

THROUGH:

- THERMOCOUPLE TEMPERATURE MEASUREMENTS.
- HIGH POWER FLASH X-RAY PHOTOGRAPHY.
- METALURGICAL CROSS SECTIONS.



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In-Space Systems	In-Space Technology Experiments Workshop December 6-9, 1988	Materials Processing

Extra-Vehicular Activity Welding Experiment

**Gary Schnittgrund
Rocketdyne Division
Rockwell International Corporation**



**Contract No. NAS8-37753
NASA Marshall Space Flight Center
Arthur C. Nunes**

Outreach Experiment Definition Study	Extra-Vehicular Activity Welding Experiment	Rockwell International Rocketdyne Division

Experiment Objective

Generate data to assess flight crew capability to perform on-orbit EVA welding operations

- Investigate equipment requirements
- Investigate crew/equipment & crew/process interaction
- Investigate weld automation
- Evaluate process/material compatibility
- Define critical human factors

Outreach Experiment Definition Study	Extra-Vehicular Activity Welding Experiment	Rockwell International Rocketdyne Division

Background

- Soviets welding in space since 1965
- Welding in vacuum demonstrated by Rocketdyne
- “Enabling” for Pathfinder missions

Technology Needed

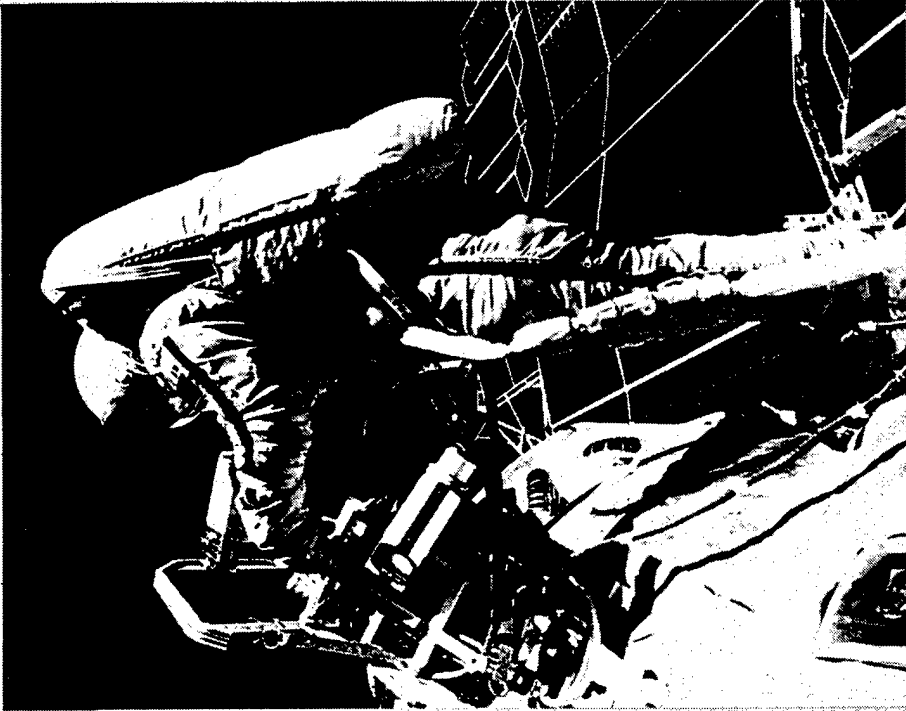
- Welding is a versatile joining technique for diverse materials
- Welding applicable to contingency repair or in-space construction

Need for space experiment

- Extended duration of space flight gives environment integrated weld data
- Welding process sensitive to human factors

Outreach Experiment Definition Study	Extra-Vehicular Activity Welding Experiment	Rockwell International Rocketdyne Division

**Russian Astronaut Welding
in Space (1986)**



Outreach Experiment Definition Study	Extra-Vehicular Activity Welding Experiment	Rockwell International Rocketdyne Division

Experiment Description

Issues

- Equipment requirements
- Process interactions
- Materials effects
- Human factors

On-Orbit Tasks

- Manual GTA welding
- Semiautomatic in-place GTA tube welding
- Various materials, configurations, orientations, parameters

Baseline Data

- KC-135 low-G tube welding
- Gas can (G-169) tube welding experiment
- Pressure-suited manual welding tests
- KC-135 manual welding tests
- Laboratory process development

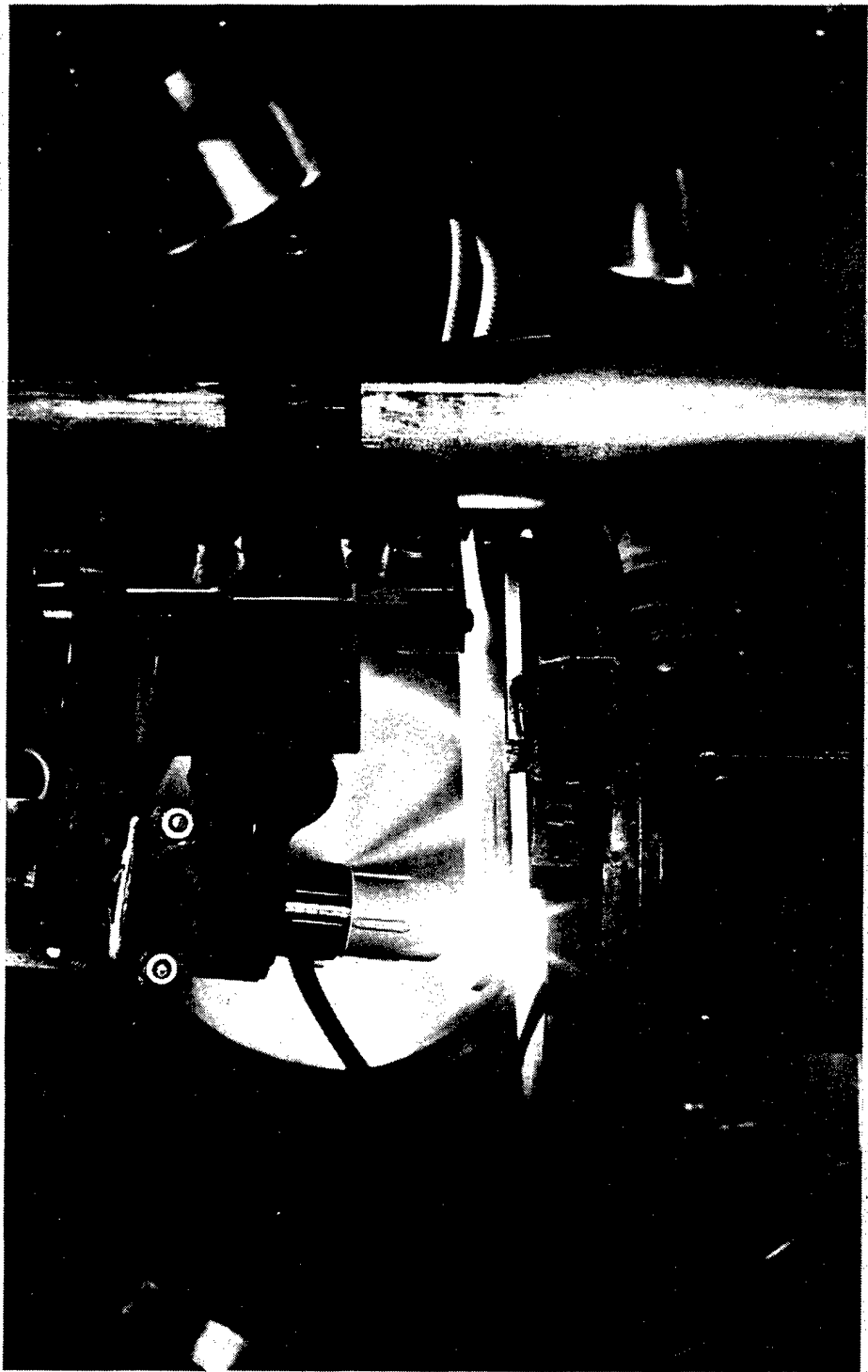
Outreach Experiment Definition Study	Extra-Vehicular Activity Welding Experiment	Rockwell International Rocketdyne Division

Tungsten Inert Gas (TIG) Vacuum Welding Apparatus



Outreach Experiment Definition Study	Extra-Vehicular Activity Welding Experiment	Rockwell International Rocketdyne Division

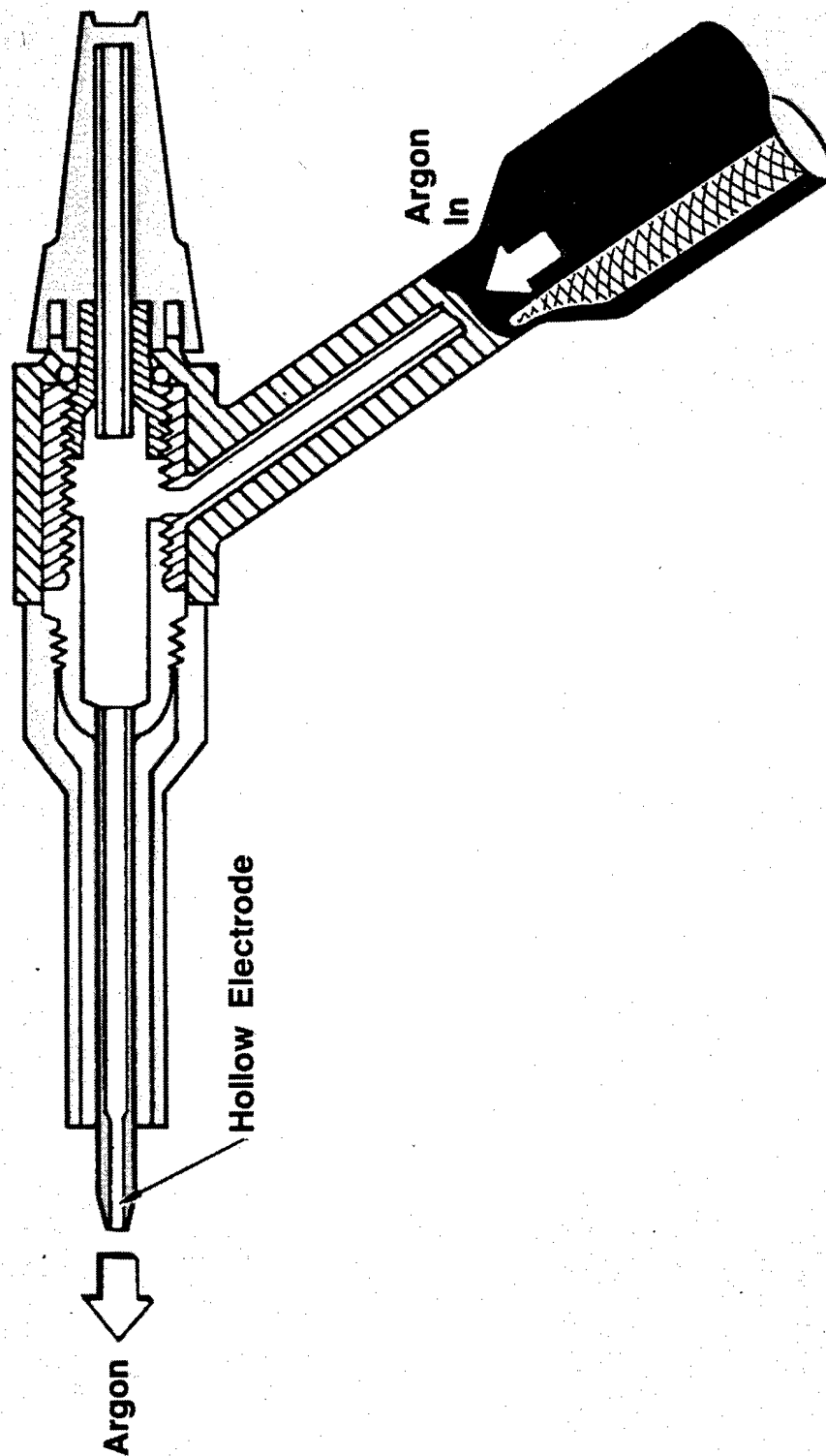
Tungsten Inert Gas Vacuum Welding Experiment



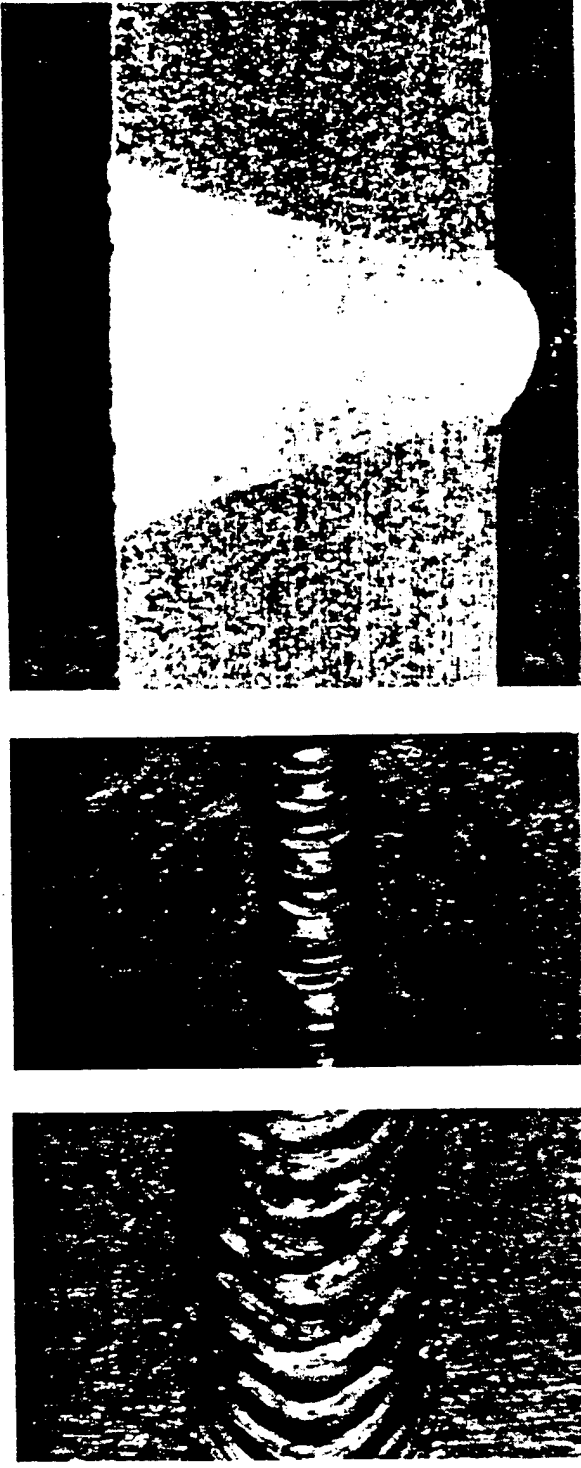
Rockwell International
Rocketdyne Division

SC88C-8-23
2772m/3

Rocketdyne Vacuum GTAW Torch



**Automatically Pulsed Single Pass
Full Penetration Vacuum GTA Weld
Material 304SS**



Travel
Direction
↑

Appearance of Top Bead	Appearance of Bottom Bead	Cross-Section
6.9X Mag.	6.9X Mag.	9X Mag.
Top Width = 0.229 in., Bottom Width = 0.090 in.		

Outreach Experiment Definition Study	Extra-Vehicular Activity Welding Experiment	Rockwell International Rocketdyne Division

KC-135 Welding Flight Experiments

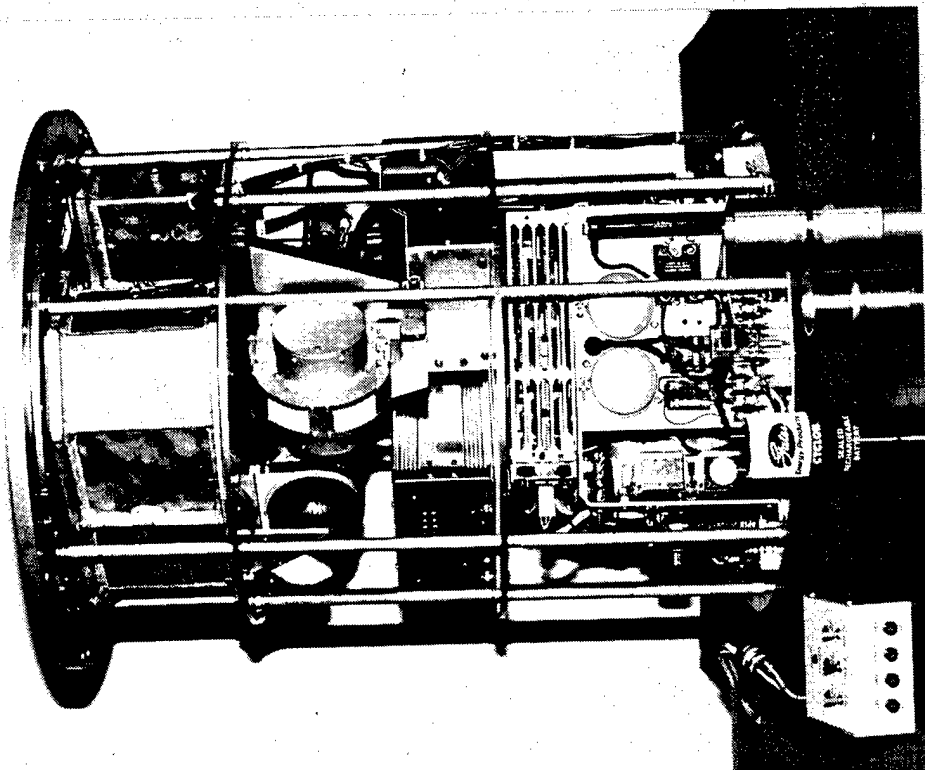


Outreach
Experiment
Definition Study

Extra-Vehicular Activity Welding Experiment

Rockwell International
Rocketdyne Division

Rockwell International/Cal Poly Gas Can Welding Experiment

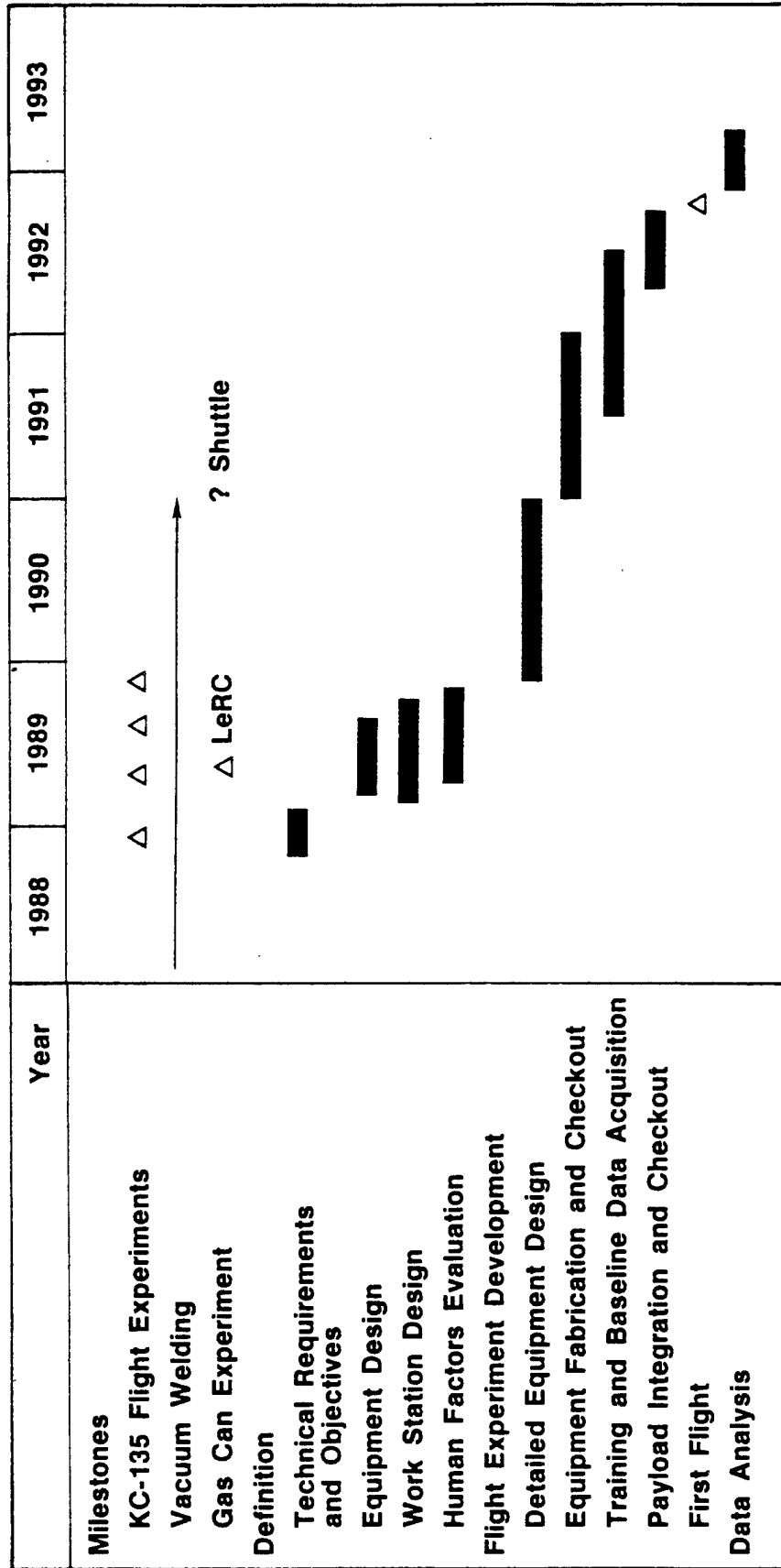


 Rockwell International
Rocketdyne Division

SC88C-8-27
2772m/12

Outreach Experiment Definition Study	Extra-Vehicular Activity Welding Experiment	Rockwell International Rocketdyne Division

Master Schedule



IN-SPACE SYSTEMS	IN-SPACE TECHNOLOGY EXPERIMENTS WORKSHOP DECEMBER 6-9, 1988	MATERIALS PROCESSING

ON-ORBIT ELECTRON BEAM WELDING EXPERIMENT

WILLIAM HOOPER

MARTIN MARIETTA MANNED SPACE SYSTEMS

CONTRACT NAS8-37756
MARSHALL SPACE FLIGHT CENTER
ARTHUR NUNES

OUTREACH EXPERIMENT DEFINITION STUDY	ONORBIT ELECTRON BEAM WELDING EXPERIMENT	MARTIN MARIETTA MANNED SPACE SYSTEMS

EXPERIMENT OBJECTIVE

DESIGN AN EXPERIMENT THAT WILL DEMONSTRATE THAT THE ELECTRON BEAM PROCESS CAN SAFELY PRODUCE HIGH INTEGRITY WELDS IN THE SPACE ENVIRONMENT.

SPECIFICALLY ADDRESS THE EXPERIMENT DESIGN TO THE REPAIR OF MICROMETEOROID STRIKE DAMAGE TO STRUCTURAL PANELS AND THE TYPE OF ALLOY SPECIFIED FOR THE SPACE STATION STRUCTURES.

PROVIDE FOR CORRELATION BETWEEN SPACE-DERIVED AND GROUND-BASED DATA

OUTREACH EXPERIMENT DEFINITION STUDY	ONORBIT ELECTRON BEAM WELDING EXPERIMENT	MARTIN MARIETTA MANNED SPACE SYSTEMS

BACKGROUND

PRIOR WORK

- D-56R: ONORBIT WELDING AND CUTTING
- M-42R: LONG TERM SPACE EXPOSURE OF METALS
- M-01S: SPACE DEBRIS AND METEOROID PROTECTION
- M-05S: MANNED SPACECRAFT EVA REPAIR

DEMONSTRATES

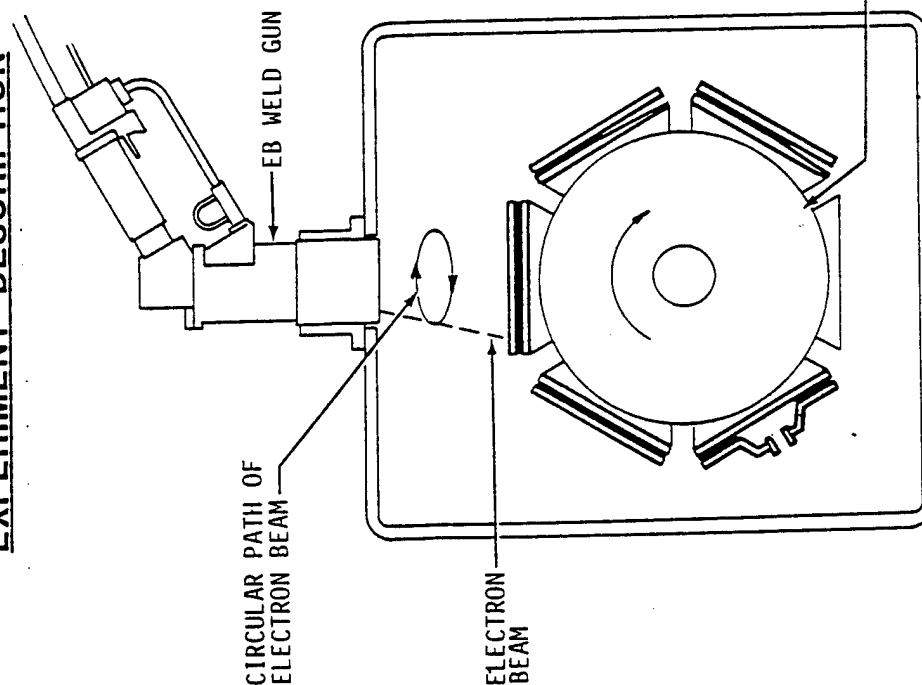
- LONG TERM RISK OF PENETRATION DAMAGE
- TYPE OF DAMAGE
- COMPATIBILITY OF EB WELDING PROCESS WITH EVA REPAIR

TECHNOLOGY NEED

- CANNOT PREDICT EB WELD BEAD PUSH-THROUGH CAPACITY
IN ABSENCE OF GRAVITY EFFECTS
- SOLIDIFICATION CHARACTERISTICS OF WELD BEAD METAL IN
MICROGRAVITY AND EFFECT ON WELD PROPERTIES

OUTREACH EXPERIMENT DEFINITION STUDY	ONORBIT ELECTRON BEAM WELDING EXPERIMENT	MARTIN MARIETTA MANNED SPACE SYSTEMS

EXPERIMENT DESCRIPTION



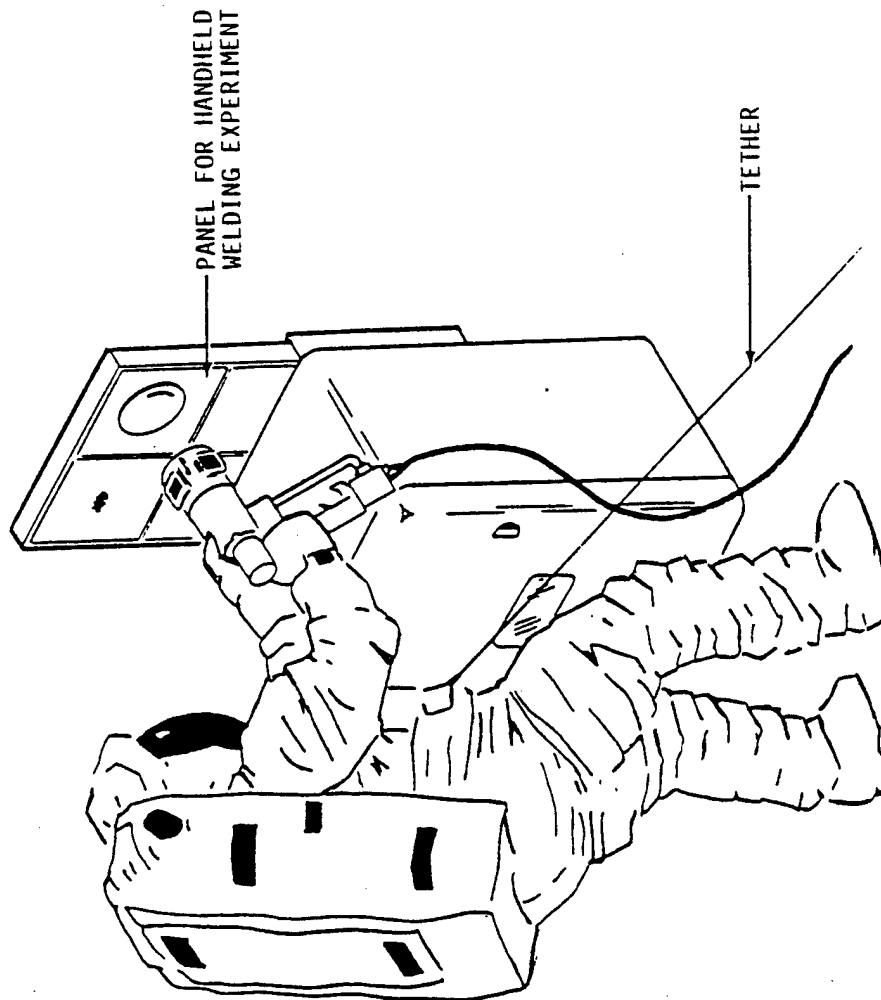
- SIX WELD PANEL CONFIGURATIONS AND WELD SCHEDULES ARE DEVELOPED
- ONE SET OF SIX PANELS IS WELDED IN GROUND-BASED EXPERIMENT
- AN IDENTICAL SET IS MOUNTED FOR ONORBIT EXPERIMENT
- ONORBIT ENCLOSURE IS PORTED TO SPACE: THE AUTOMATED CYCLE OF WELDS IS REPEATED
- THE OPTIONAL HAND-HELD WELDING EXPERIMENT IS COMPLETED
- PROPERTIES OF ONORBIT WELDED AND GROUND-LEVEL WELDED PANELS ARE COMPARED

**OUTREACH
EXPERIMENT
DEFINITION STUDY**

ONORBIT ELECTRON BEAM WELDING EXPERIMENT

MARTIN MARIETTA

MANNED SPACE SYSTEMS

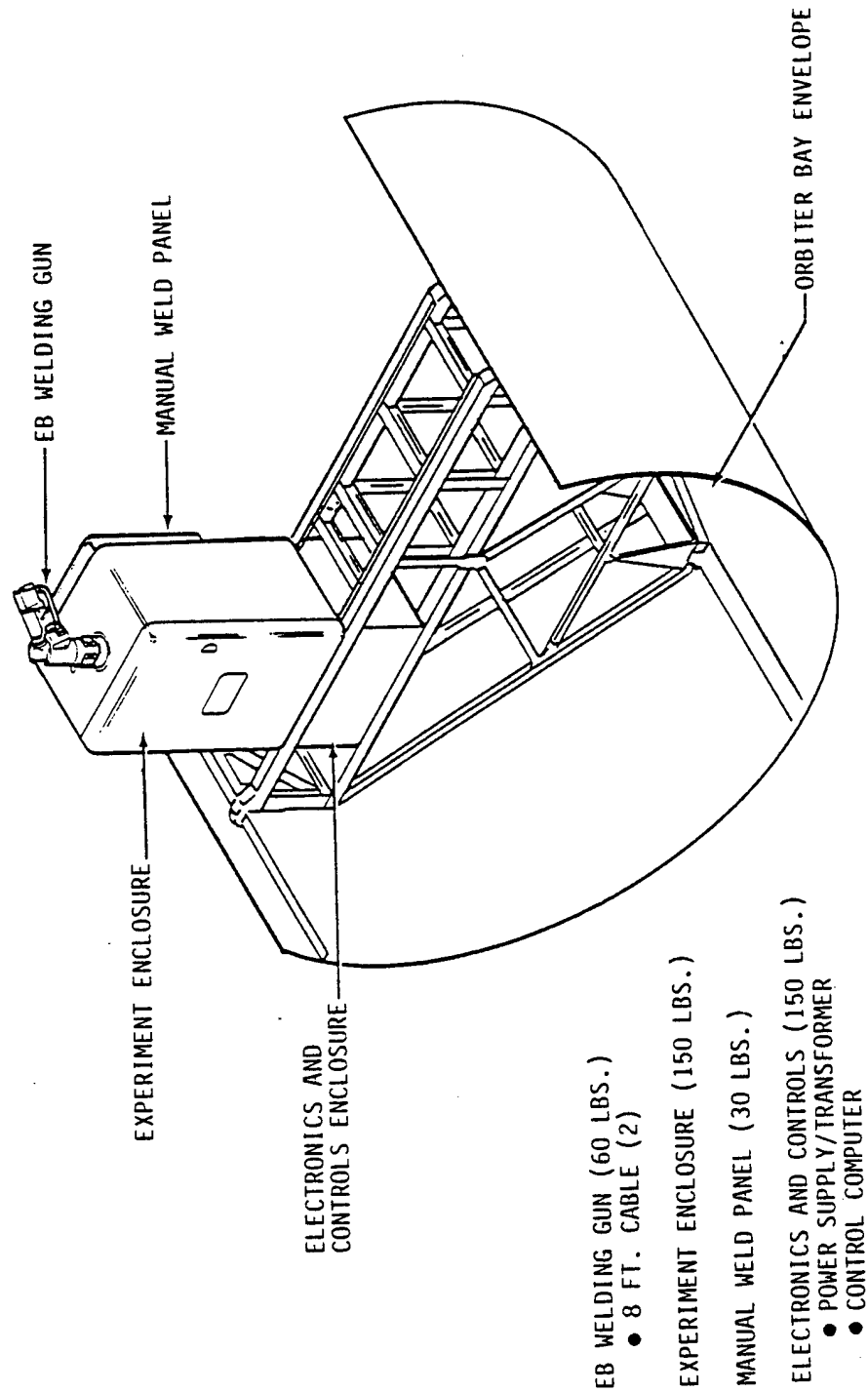


OUTREACH EXPERIMENT DEFINITION STUDY

ONORBIT ELECTRON BEAM WELDING EXPERIMENT

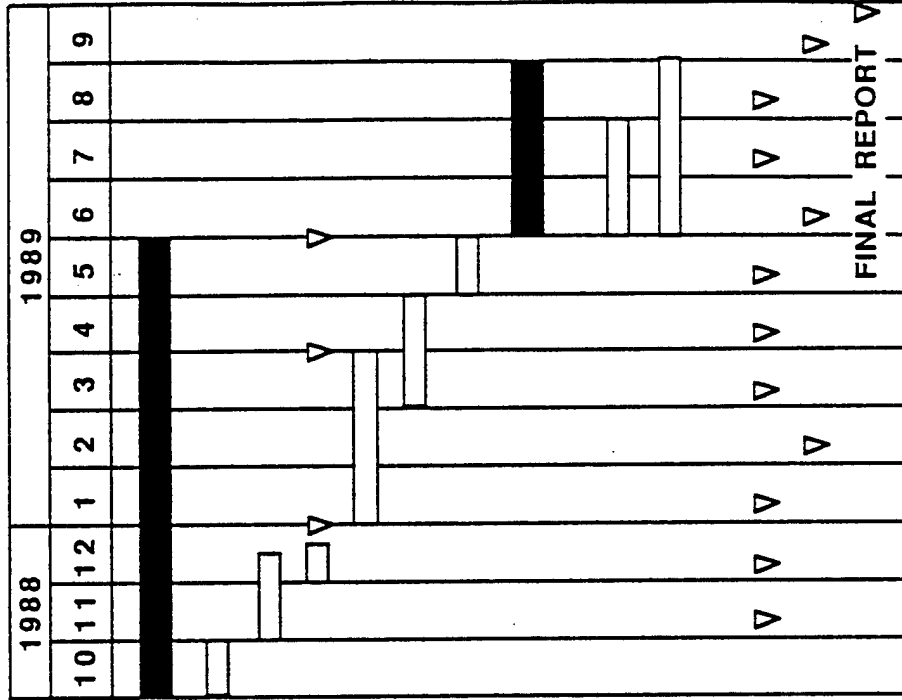
MARTIN MARIETTA

MANNED SPACE SYSTEMS



OUTREACH EXPERIMENT DEFINITION STUDY	ONORBIT ELECTRON BEAM WELDING EXPERIMENT	MARTIN MARIETTA MANNED SPACE SYSTEMS

MASTER SCHEDULE



CONCEPTUAL DESIGN STUDY TASKS

- 1) DEVELOP OBJECTIVES FOR A SPECIFIC EXPERIMENT
- 2) DEFINE EXPERIMENT REQUIREMENTS
- 3) VERIFY EXPERIMENT REQMTS COMPATIBLE W/ORBITER
- 4) PERFORM EXPERIMENT DESIGN
- 5) EQUIPMENT TRADE STUDIES-SELECT OPTION
- 6) INTEGRATE EXPERIMENT & EQUIPMENT SELECTION

EXPERIMENT IMPLEMENTATION PLAN STUDY TASKS

- 7) FUNCTIONAL DIAGRAM
- 8) IMPLEMENTATION PLAN & COSTS

CONCEPTUAL DESIGN STUDY TASKS

- MONTHLY REPORTS
- PROGRESS REVIEWS

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IN-SPACE SYSTEMS	IN-SPACE TECHNOLOGY EXPERIMENTS WORKSHOP DECEMBER 6 - 9, 1988	MATERIALS PROCESSING

LASER WELDING IN SPACE

Principal investigators:
 Gary L. Workman, Ph. D.
 William F. Kaukler, Ph. D.
 University of Alabama in Huntsville

Contract No. NAS9 - 17962
 Johnson Space Center
 Contact: Jay Bennett

OUT-REACH	LASER WELDING IN SPACE	University of Alabama in Huntsville

EXPERIMENT OBJECTIVES

To develop a conceptual understanding of the significant characteristics of laser welding for space applications, including the following:

Operational characteristics of a laser welder in a micro gravity environment.

Correlations between ground-based welds and those performed in low-gravity.

This understanding will be used to develop an optimal design for a space based laser welding facility which can be used for assembly or repair of space structures.

OUT-REACH	LASER WELDING IN SPACE	University of Alabama in Huntsville

BACKGROUND/TECHNOLOGY NEEDS

- Need for In - flight Experiment
 - To develop experience in welding operations in Space where processes and materials can behave differently
 - To evaluate suitability of laser power and beam delivery systems for Space Systems operation.
 - To determine overall man-process interactions and required level of automation for operations aboard a space structure.

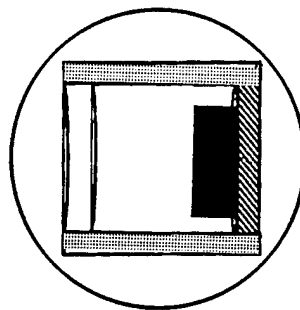
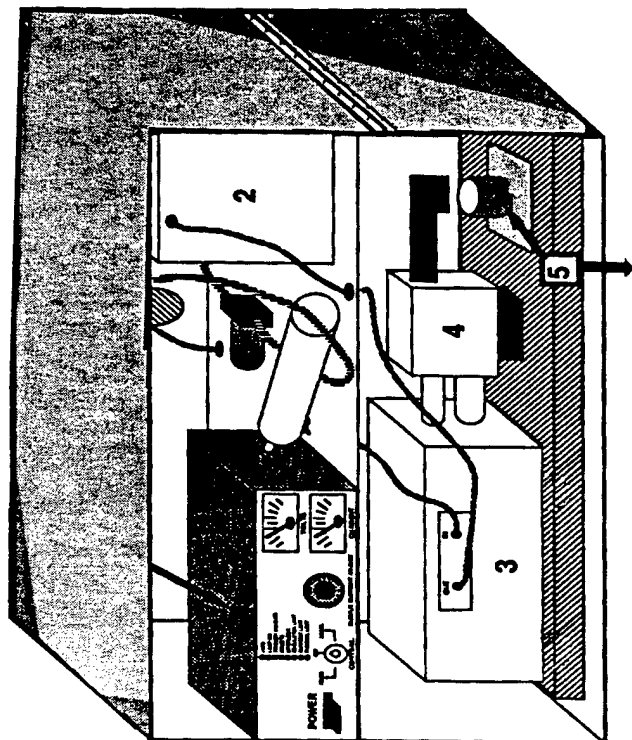
- Essential Technology Advancements
 - High efficiency solid - state lasers.
 - Alternate sources of pumping. (solar)
 - Robotized fiber - optic beam coupling system.
 - Demonstrations of materials joining capability other than metals.

OUT-REACH	LASER WELDING IN SPACE	University of Alabama in Huntsville

EXPERIMENT DESCRIPTION

The space based laser welding facility will be used to weld tubular components using a solid-state laser with a fiber-optic beam delivery system. Variable weld parameters will include weld material, laser energy, and weld speed. Temperature measurements adjacent to the weld seam will be used correlate processing parameters of each sample. Ground based metallurgical and weld strength analysis will be used to determine consistency in the overall weld process and the reliability of the space based welds.

Current version of
the KC-135 laser
welding experimental
apparatus.



Sample chamber
under vacuum

Laser welding experiments as performed here on the NASA KC-135 are used to obtain information about weld solidification and heat transfer in a microgravity environment.



SCHEDULE

TASK	88	89	90	91	92

Ground Based Experiment Definition

Laser Sources Evaluation	██████████	██████████			
Determine Weld Parameters	██████████	██████████	██████████	██████████	██████████
Metallurgical Analysis	██████████	██████████	██████████	██████████	██████████
KC- 135 Experimentation	██████████	██████████	██████████	██████████	██████████

Space Experiment Definition

Space System Design		██████████			
Fabrication		██████████	██████████		
Flight Test and Qualification			██████████	██████████	
Space Based Experiments					██████████

Current Contract	██████████				
Future Efforts		██████████	██████████	██████████	██████████

OUT-REACH	LASER WELDING IN SPACE	University of Alabama in Huntsville

SUMMARY

Laser welding experiments have been performed on the KC-135 aircraft resulting in a preliminary definition for a space based welding facility using a solid-state laser with fiber-optic delivery system and solar pumping for an alternate source of energy.

IN-SPACE SYSTEMS	IN-SPACE TECHNOLOGY EXPERIMENTS WORKSHOP DECEMBER 6-9, 1988	MATERIALS PROCESSING

LIQUID ENCAPSULATED FLOAT ZONE REFINING OF GALLIUM ARSENIDE

EDWARD BAROCELA
McDonnell Douglas Astronautics Company

CONTRACT NO. NAS3-25360
NASA LEWIS RESEARCH CENTER
ARNON CHAIT

OUTREACH EXPERIMENT DEFINITION STUDY	LIQUID ENCAPSULATED FLOAT ZONE REFINING OF GALLIUM ARSENIDE	<i>McDonnell Douglas Astronautics Company</i>

EXPERIMENT OBJECTIVE

DEMONSTRATE THE FEASIBILITY OF A NEW FLOAT ZONE REFINING PROCESS
THAT TAKES ADVANTAGE OF MICROGRAVITY TO PRODUCE DEFECT-FREE SEMICONDUCTORS.

- INVESTIGATE THE BENEFITS OF CONTAINERLESS PROCESSING ON GALLIUM
ARSENIDE CRYSTAL QUALITY.
- DEMONSTRATE THE FEASIBILITY OF USING A FREE SURFACE ENCAPSULANT
IN MICROGRAVITY.
- TEST THE STABILITY OF AN ENCAPSULATED GALLIUM ARSENIDE FLOATING ZONE.

OUTREACH EXPERIMENT DEFINITION STUDY	LIQUID ENCAPSULATED FLOAT ZONE REFINING OF GALLIUM ARSENIDE	<i>McDonnell Douglas Astronautics Company</i>

BACKGROUND

COMPOUND SEMICONDUCTORS PLAY AN INCREASINGLY IMPORTANT ROLE IN AEROSPACE TECHNOLOGY.

- HIGH SPEED COMPUTERS ● RADIATION HARDENED ELECTRONICS
- SOLID STATE LASERS ● OPTICAL DETECTORS

TECHNOLOGY NEED

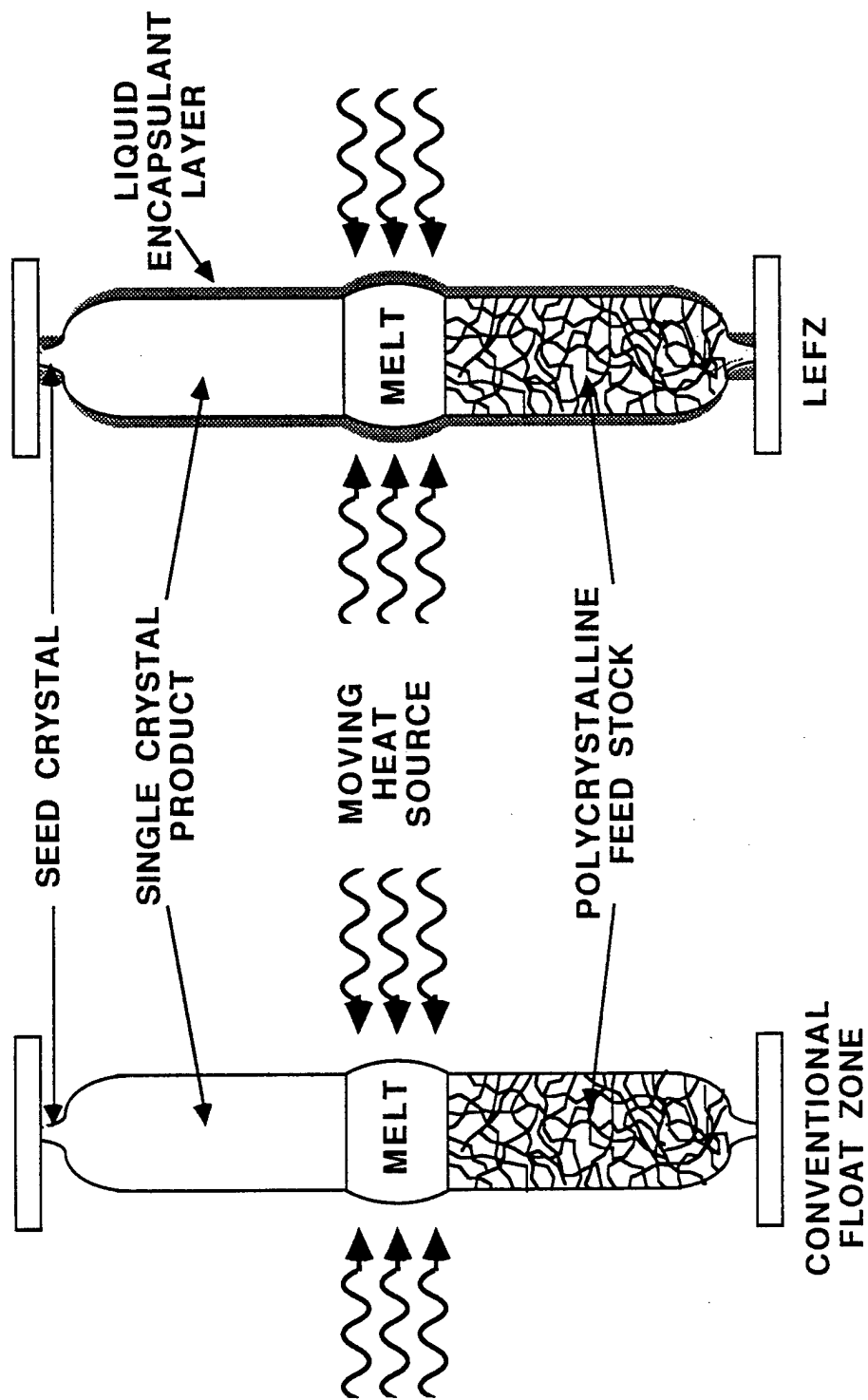
- GROWING CRYSTALS OF COMPOUND SEMICONDUCTORS IS DIFFICULT IN THE PRESENCE OF GRAVITATIONAL EFFECTS.
- CONTAINER WALLS INTRODUCE CRYSTAL STRAIN AND CHEMICAL CONTAMINANTS.
- HIGH DENSITY IC'S REQUIRE LOW DOPANT CONCENTRATIONS: LIQUID ENCAPSULATION PREVENTS CONTAMINATION FROM FURNACE COMPONENTS.

NEED FOR SPACE EXPERIMENT

- GALLIUM ARSENIDE CANNOT BE FLOAT ZONE PROCESSED IN GRAVITY.
- FREE SURFACE ENCAPSULANT WOULD FLOW IN GRAVITY.

OUTREACH EXPERIMENT DEFINITION STUDY	LIQUID ENCAPSULATED FLOAT ZONE REFINING OF GALLIUM ARSENIDE	McDonnell Douglas Astronautics Company

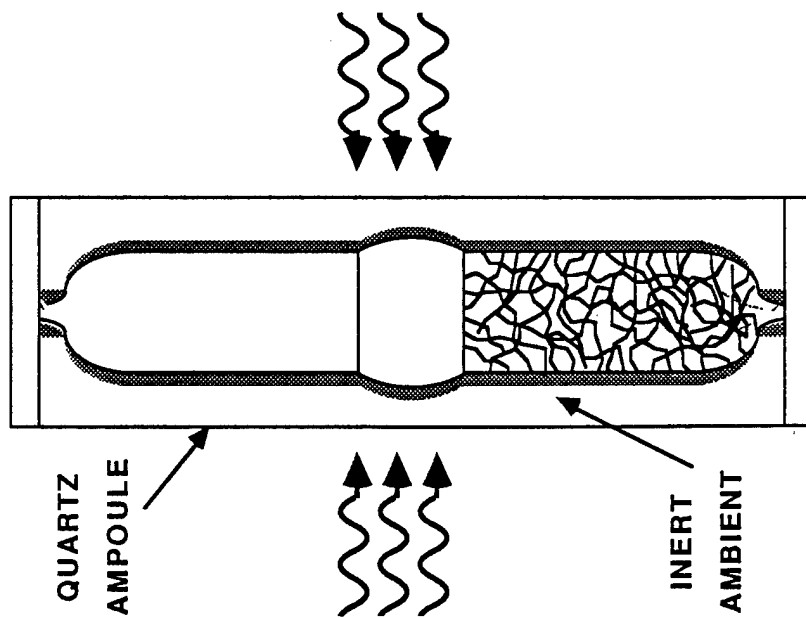
PROCESS DESCRIPTION



OUTREACH EXPERIMENT DEFINITION STUDY	LIQUID ENCAPSULATED FLOAT ZONE REFINING OF GALLIUM ARSENIDE	McDonnell Douglas Astronautics Company

EXPERIMENT DESCRIPTION

- A ROD OF GALLIUM ARSENIDE IS COATED WITH A THIN LAYER OF BORON TRIOXIDE ENCAPSULANT.
- THE SAMPLE ROD IS SEALED INTO A QUARTZ AMPOULE, WHICH IS FILLED WITH DRY NITROGEN OR ARGON.
- THE SAMPLE IS FLOAT ZONE PROCESSED IN MICROGRAVITY.
- THERMAL AND OPTICAL OBSERVATIONS ARE MADE ON ORBIT TO DOCUMENT THE PROCESS. THESE OBSERVATIONS WILL BE ANALYZED TO ASSESS THE BEHAVIOR OF THE COMBINED LIQUID ENCAPSULANT-MOLTEN SEMICONDUCTOR SYSTEM AND THE SOLID-LIQUID INTERFACE.
- THE SAMPLE WILL BE COMPARED ON THE GROUND WITH TERRESTRIALLY GROWN MATERIAL.



OUTREACH EXPERIMENT DEFINITION STUDY	LIQUID ENCAPSULATED FLOAT ZONE REFINING OF GALLIUM ARSENIDE	<i>McDonnell Douglas Astronautics Company</i>

THERMAL MODELING - NEAR TERM TASKS

- **REFINE BASELINE OPERATING PARAMETERS TO OPTIMIZE:**
 - ELECTRICAL POWER CONSUMPTION
 - PEAK TEMPERATURE
 - THERMAL GRADIENTS

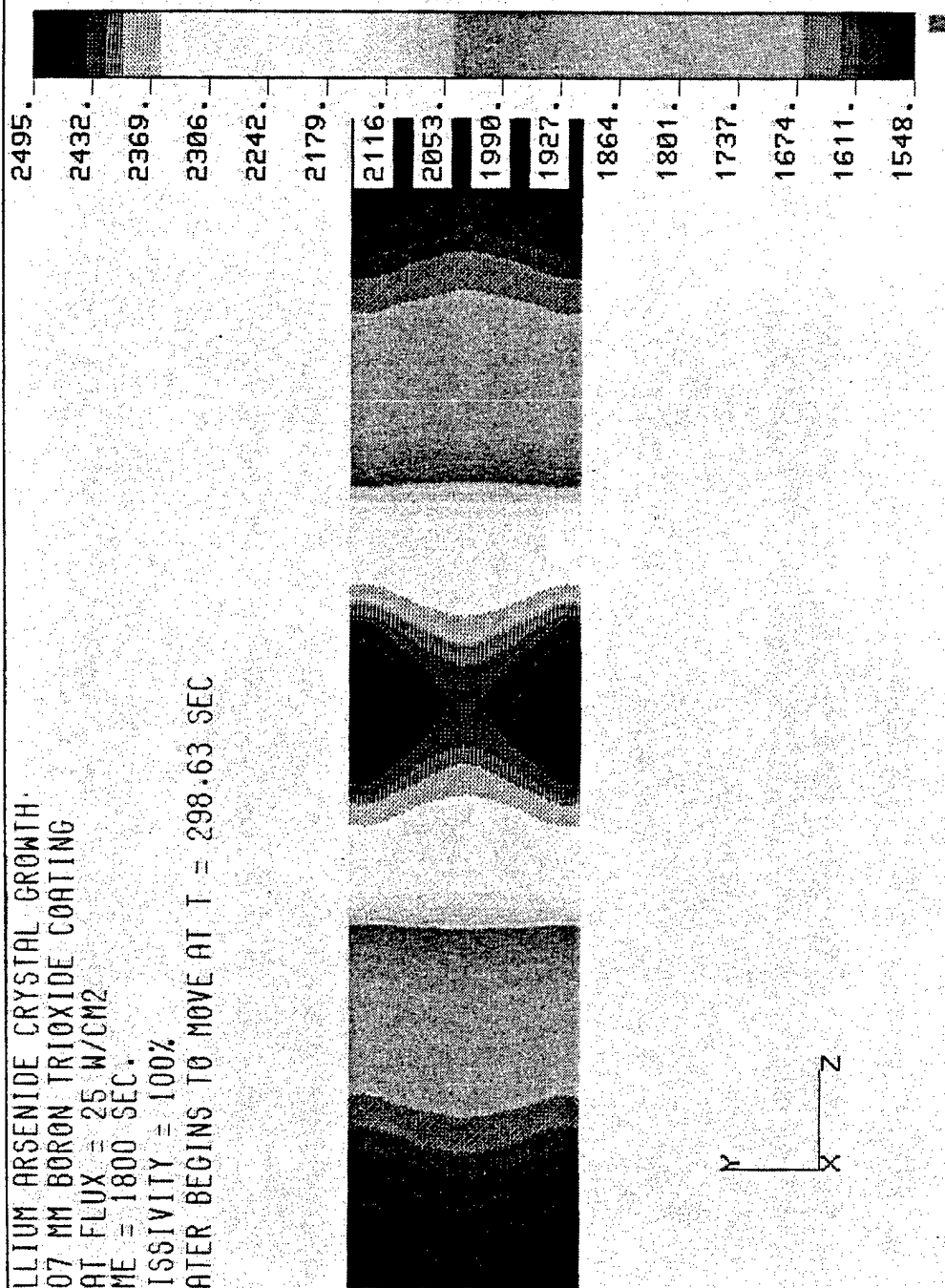
- **ESTABLISH REQUIREMENTS FOR COATING PROCESS BY INVESTIGATING THE EFFECTS OF:**
 - DIFFERENT ENCAPSULANT THICKNESSES
 - ENCAPSULANT THICKNESS NONUNIFORMITIES
 - PINHOLES IN THE ENCAPSULANT

OUTREACH
EXPERIMENT
DEFINITION STUDY

LIQUID ENCAPSULATED FLOAT ZONE REFINING
OF GALLIUM ARSENIDE

McDonnell Douglas
Astronautics Company

GALLIUM ARSENIDE CRYSTAL GROWTH
1.07 MM BORON TRIOXIDE COATING
HEAT FLUX = 25 W/CM²
TIME = 1800 SEC.
EMISSIVITY = 100%
HEATER BEGINS TO MOVE AT T = 298.63 SEC



OUTREACH EXPERIMENT DEFINITION STUDY	LIQUID ENCAPSULATED FLOAT ZONE REFINING OF GALLIUM ARSENIDE	McDonnell Douglas Astronautics Company

MASTER SCHEDULE

	1988				1989				1990				1991				1992			
	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
TECHNICAL REQUIREMENTS AND OBJECTIVES																				
HARDWARE CONCEPT																				
PROJECT PLAN																				
SYSTEM DESIGN																				
FABRICATION AND ASSEMBLY																				
TEST AND FLIGHT QUALIFICATION																				
PAYLOAD INTEGRATION AND CHECK OUT																				
FIRST FLIGHT																				

IN-SPACE SYSTEMS	IN-SPACE TECHNOLOGY EXPERIMENTS WORKSHOP DECEMBER 6-9, 1988	MATERIALS PROCESSING

VAPOR CRYSTAL GROWTH TECHNOLOGY

357

FRANZ E. ROSENBERGER
FRANCIS C. WESSLING

CENTER FOR MICROGRAVITY AND MATERIALS RESEARCH
THE UNIVERSITY OF ALABAMA IN HUNTSVILLE
WITH SUPPORT FROM
BOEING COMMERCIAL SPACE DEVELOPMENT

CONTRACT NO. NAS3-25361
NASA LEWIS RESEARCH CENTER
WALTER DUVAL

OUTREACH	VAPOR CRYSTAL GROWTH TECHNOLOGY	 CMMR UAH

EXPERIMENT OBJECTIVE

Develop a novel vapor growth technology that results in increased flexibility in the control of the process parameters for high quality crystal growth in space and on earth.

Emphasis on:

- Advantageous crystal nucleation and growth location
- Growth of a controlled number (preferably one) of single crystals
- Reduced mechanical interaction between ampoule and crystal, in particular during cooldown
 - higher structural quality
- Continuous removal of volatile impurities
 - higher purity
- Increased growth rates

OUTREACH	VAPOR CRYSTAL GROWTH TECHNOLOGY	 CMMR UAH

BACKGROUND/TECHNOLOGY NEED

NASA-and ESA-sponsored researchers, and workers in the USSR have been conducting vapor growth experiments in space.

Crystal growth from vapors has many advantages over other techniques.

All low gravity vapor growth experiments have been carried out in closed ampoules and traditional heating geometries, thus resulting in

- little control of number of size of crystals grown,
- relatively low growth rates

➤ particularly important in view of limited experiment time
in space

Despite these shortcomings, vapor growth in space has yielded very promising results.

**To take full advantage of microgravity conditions
for vapor crystal growth a novel technology is needed.**

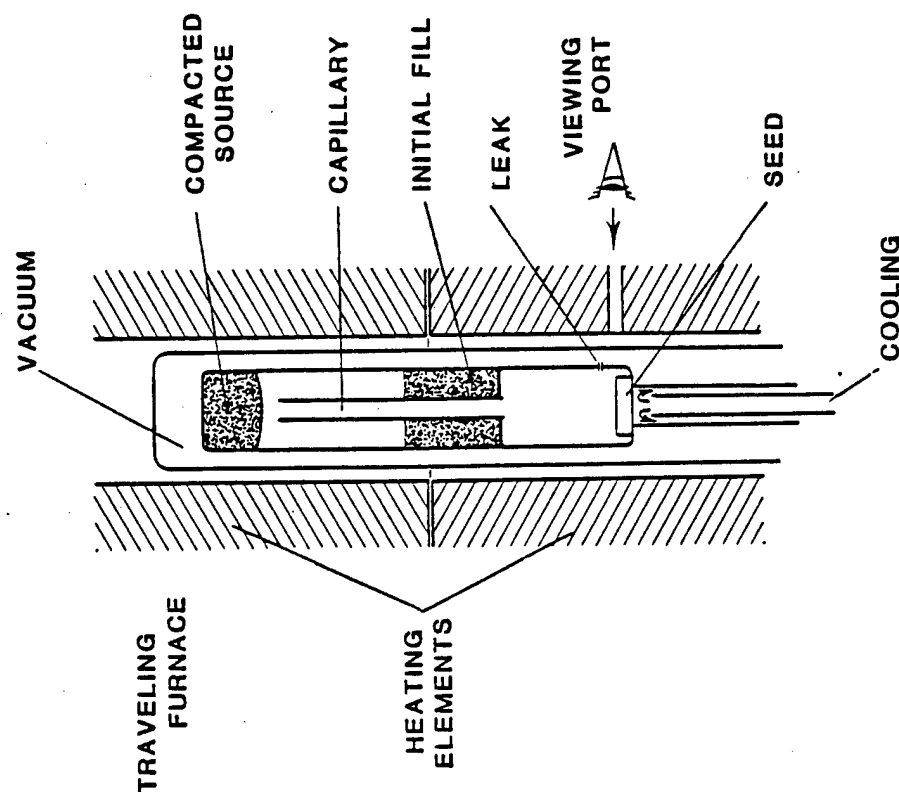
OUTREACH	VAPOR CRYSTAL GROWTH TECHNOLOGY	 CMMR UAH

EXPERIMENT DESCRIPTION

Essential Elements of Congruent (Diffusionless)

Growth Technique:

- Semi-closed (leaky) ampoule
- Predetermined (viscous) transport rates and minimization of rate fluctuations
- No sealing of ampoule required
- Initial purification of source material
- Continuous purification, but possible stoichiometry shifts
- Predetermined crystal location, size and orientation
- Observability and, hence, controllability of seeding
- Temperature profile readily adjustable and, hence, expedient determination of optimum growth conditions



OUTREACH	VAPOR CRYSTAL GROWTH TECHNOLOGY	 CMMR UAH

TASK SCHEDULE/PRODUCTS

'88 '89 '90
O N D J F M A M J J A S O N D J F M

EXPERIMENT TECHNICAL REQUIREMENTS

Definition of Experiment Requirements _____
Choice of Specific Crystal Material _____
Supporting Research _____
Modelling of heat transfer, thermometry _____
Modelling of vapor transport conditions _____
Prototype System and Experiments _____
Component design, building and/or procurement _____
System assembly and testing _____
Development of (semi-automated) growth procedure _____
Technical Requirements Report _____

EXPERIMENT CONCEPTUAL DESIGN (For Phase II)

Definition of Specific In-Space Technology Experiment _____
Identification of Support Equipment Requirements _____
Hardware Accommodation Study _____
Engineering Trade Study _____
Functional Diagram _____

8. HUMANS IN SPACE

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HUMANS IN SPACE	IN-SPACE TECHNOLOGY EXPERIMENTS WORKSHOP DECEMBER 6-9, 1988	HUMAN PERFORMANCE

ENHANCEMENT OF IN-SPACE OPERATIONS USING SPATIAL PERCEPTION AUDITORY REFERENCING (SPAR)

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ROBERT H.I. BLANKS, Ph.D., JOIE P. JONES, Ph.D., & YASUHIRO TORIGOE, Ph.D.

UNIVERSITY OF CALIFORNIA, IRVINE

&

WILLIAM DOUGLAS, M.D. & HERB KELLY

MCDONNELL DOUGLAS ASTRONAUTICS CO, HUNTINGTON BEACH

CONTRACT NO. NAS2 - 12834
NASA AMES RESEARCH CENTER
ELIZABETH M. WENZEL

OUTREACH DEFINITION STUDY	IN-SPACE TECHNOLOGY EXPERIMENTS WORKSHOP DECEMBER 6-9, 1988	University of California Irvine McDonnell Douglas Astronautics Co.

OBJECTIVES:

DETERMINE THE FEASIBILITY OF USING DIRECTIONALLY CODED AUDITORY TRANSMISSION FOR THE
ENHANCEMENT OF IN-SPACE OPERATIONS BY PROVIDING DIRECTIONALLY CODED SOUND FOR:

1) ADVANCED LIFE SUPPORT

- * DIRECTIONALLY CODED PROXIMITY / THREAT ALERT
- * AUDITORY DISPLAY OF AIR LOCKS, CO-WORKERS EVA, ROBOTICS AND PARTS
- * IMPROVED ASTRONAUT VIGILANCE, JUDGEMENT AND WORK EFFICIENCY EVA

2) DIAGNOSTIC AND DATA SYSTEM (ALGORITHMS)

- * KINEMATIC REFERENCING OF EVA ASTRONAUTS, ROBOTS AND MATERIALS
- * PROVIDE DIRECTIONAL INFORMATION TO SAFETY OFFICERS
 - ON BOARD
 - SPACE STATION CONTROL FACILITY

3) LIFE SUPPORT AND SAFETY

- * TREATMENT STRATEGY FOR SPACE ADAPTATION SYNDROME

4) OTHER BENEFITS

- * IMPROVED QUALITY OF AUDITORY COMMUNICATIONS
- * CUSTOMIZED ENTERTAINMENT FOR ASTRONAUTS

OUTREACH DEFINITION STUDY	IN-SPACE TECHNOLOGY EXPERIMENTS WORKSHOP DECEMBER 6-9, 1988	University of California Irvine McDonnell Douglas Astronautics Co.

BACKGROUND:

- * NATURAL SOUND CONVEYS THE DIRECTION, DISTANCE AND "SIZE" OF THE SOURCE
- * DIRECTIONAL CUES ARE LOST WHEN SOUND IS HEARD OVER EARPHONES
- * SOUND CAN BE ELECTRONICALLY PROCESSED, FOR TRANSMISSION OVER EARPHONES, TO
REINSTATE DIRECTIONAL CUES
- * SOUND PROCESSING CAN BE:
 - VIRTUAL (E.G., VOICES HEARD AS COMING FROM THE DIRECTION OF PERSON SPEAKING)
 - CODED (E.G., TONES INDICATING LOCATION OF AIRLOCKS, ROBOTS, PARTS OR
GEOCENTRIC REFERENCE)
- * MINIMUM TRAINING IS REQUIRED TO EXTRACT DIRECTIONAL CUES FROM PROCESSED SOUND
TRANSMISSIONS

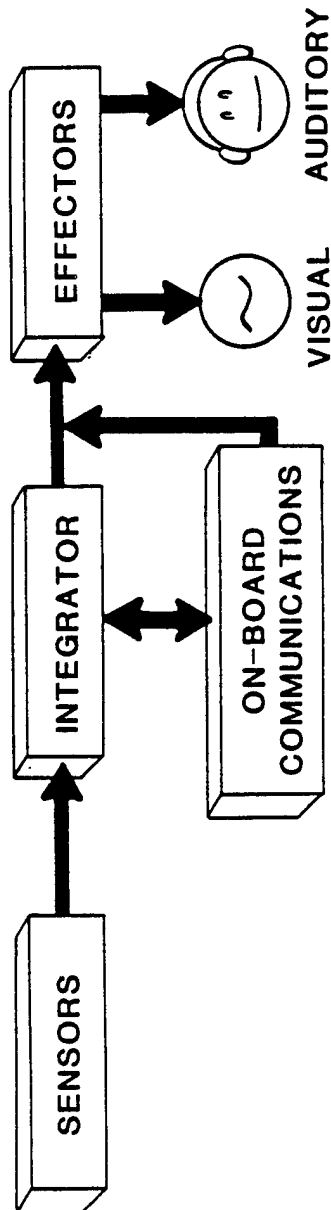
OUTREACH DEFINITION STUDY	IN-SPACE TECHNOLOGY EXPERIMENTS WORKSHOP DECEMBER 6-9, 1988	University of California Irvine McDonnell Douglas Astronautics Co.

TECHNOLOGY REQUIRED FOR SOUND LOCALIZATION:

- * KINEMATIC REFERENCING (SENSOR SYSTEMS) ASTRONAUT BODY AND HEAD POSITION,
ROBOTS AND PARTS
- * OPTIMUM SOUND SYSTEM, HELMET AND HEADPHONE DESIGN
- * INTERFACE TO COMPUTER SYSTEMS/COMMUNICATIONS

NEED FOR SPACE EXPERIMENT:

- * CONSTRUCTION AND MAINTENANCE OF SPACE STATION REQUIRES UNPRECEDENTED AMOUNTS OF
EVA ACTIVITY
- * THE BENEFITS OF DIRECTIONALLY CODED SOUND ON ASTRONAUT PERFORMANCE EVA (IMPROVED
SAFETY, WORK EFFICIENCY, VIGILANCE) ARE BEST ASSESSED OPERATIONALLY AND
UNDER MICROGRAVITY CONDITIONS
- * SPACE ADAPTATION SYNDROME (SAS) WILL BE A PROBLEM GIVEN FREQUENT CREW CHANGES FOR
CONSTRUCTION AND SERVICING OF THE STATION
- * TREATMENT STRATEGIES FOR SAS MUST ULTIMATELY BE TESTED IN MICROGRAVITY OF SPACE



**THREE DIMENSIONAL REFERENCING
OF ASTRONAUT HEAD POSITION &
ORIENTATION RE. SPACECRAFT
ACHIEVED BY:**

- 1) ON-BOARD INERTIAL
NAVIGATION SYSTEMS
- 2) UPGRADE OF "COMMON
TRACKING SYSTEM" TO INCLUDE
ASTRONAUT POSITION &
ORIENTATION
- 3) NEW APPLICATION FOR
LOCAL NAVIGATION SYSTEMS

- * LASER DOCKING SYSTEM
- * FIBER OPTIC INERTIAL
GYROSCOPES

STAND ALONE

**HARDWARE/FIRMWARE SYSTEM
SINGLE BOARD - MULTIPROCESSOR**

**EVA: SMALL CONTROLLER
BOARD ON EMU**

**IVA/GROUND CONTROL:
INTERFACE/ADD-ON TO
ON-BOARD COMPUTER
SYSTEM**

**FULL COMPATIBILITY WITH
ON-BOARD /GROUND CONTROL
SYSTEMS**

*** AUDITORY DISPLAY OF:**

- 1) **WARNING SIGNALS**
(O₂ LEVELS, PROXIMITY ALERT)
- 2) **ACOUSTICAL POINTING**
(AIRLOCKS, PARTS, ETC.)
- 3) **3-D SOUND**
(CODED TRANSMISSIONS BETWEEN
ASTRONAUTS AND SAFETY OFFICER)

**SIMULTANEOUS VISUAL DISPLAY FOR
BENEFIT OF ON-BOARD SAFETY OFFICER**

- * DISPLAY MODES 1 & 2 COULD BE
ACHIEVED WITH FIXED SPEAKER IN EMU
HELMET OR VIA EAR INSERTS. 3-D
SOUND (3 ABOVE) REQUIRES FIXED
MULTIPLE SPEAKERS OR HEAD PHONES

OUTREACH DEFINITION STUDY	IN-SPACE TECHNOLOGY EXPERIMENTS WORKSHOP DECEMBER 6-9, 1988	University of California Irvine McDonnell Douglas Astronautics Co.

SCHEDULE

1988 1989

MONTHS	6	7	8	9	10	11	12	1	2	3	4	5
1. EVALUATE COMMERCIAL SOUND SYSTEM	■	■										
2. EVALUATE SPAR TECHNOLOGY	■	■	■	■	■	■	■	■	■	■	■	■
3. EVALUATE EXISTING SENSOR TECHNOLOGY			■	■	■	■	■	■	■	■	■	■
4. BUILD AND ASSEMBLE PROTOTYPE			■	■	■	■	■	■	■	■	■	■
5. SOFTWARE DEVELOPMENT			■	■	■	■	■	■	■	■	■	■
6. BENCH TEST 4 & 5 ABOVE FOR EXPERIMENTS			■	■	■	■	■	■	■	■	■	■
7. PSYCHOACOUSTIC EXPERIMENTS			■	■	■	■	■	■	■	■	■	■
8. UNDERWATER ORIENTATION EXPERIMENTS			■	■	■	■	■	■	■	■	■	■
9. MODIFY PROTOTYPE (UNDERWATER EXP.)			■	■	■	■	■	■	■	■	■	■
10. PREPARE DOCUMENTATION TO NASA			■	■	■	■	■	■	■	■	■	■

DEFINITION OF A MICROBIOLOGICAL MONITOR FOR APPLICATION IN SPACE VEHICLES

Melvin V. Kilgore, Jr.

Kenneth E. Johnson Research Center

and

Robert J. Zahorchak, Ph. D.

Department of Biological Sciences

Consortium for the Space Life Sciences
The University of Alabama in Huntsville
Huntsville, Alabama 35899

Contract No. 9-17963
Johnson Space Center
Duane Pierson, Ph. D.

EXPERIMENT OBJECTIVES:

PHASE I

- Identify and Evaluate current methodologies for microbial monitoring
- Determine the Feasibility of Developing the Hardware for Space Applications
- Develop a Method for the Application of Microbiological Monitoring in Space
- Develop a Conceptual Design and Functional Diagram
- Prepare a Cost Estimate Regarding the Development Phase
- Define the Experimental Parameters to be Evaluated on Future STS Missions

PHASE II

- Thorough Evaluation of the Candidate Methodologies
- Development of Prototype Hardware
- Extensive Ground Based Evaluation of Hardware and Methodology
- In Flight Experiments

BACKGROUND

- **Necessity for Microbiology Monitoring**
Closed System Environment
Increased Duration Missions
Increased Distances
Potential for Immuno Compromised Crew
Experiments and Hardware
- **Unique Requirements**
Microgravity Conditions
Multiple Sample Handling
Power, Weight, Volume
Analysis Time
- **Current Methodologies**
Particulate Detection
Culture Techniques
Indicator Organisms
- **Specifications**
Water
Air
Surfaces

TECHNOLOGY NEED

- No Commonly used Near Real Time Monitor Currently Available

JUSTIFICATION

- Assurance of Performance
- Bacterial Physiology Significantly Different in Space

EXPERIMENT DESCRIPTION:

PHASE I

- Definition and Design of a Near Real-Time Microbiological Monitor for Space Applications

PHASE II

- Development and Evaluation of Performance of a Microbiological Monitor Under Microgravity and Other Conditions Imposed by Space

CRITERIA FOR FLIGHT EXPERIMENT

- Should Provide Information Required for the Development of a RTMM
- Should Demonstrate Proof of Concept Under Microgravity Conditions
- Should be Self Contained and Require Little Crew Support
- Experimental Design Should be such that Results/Products can be Analyzed/Retrieved on the Ground

TECHNICAL APPROACH

METHOD EVALUATION AND TRADE STUDIES

- **Technical**
 - Primary
 - Sensitivity
 - Time
 - Maturity
 - Applications
- **Feasibility**
 - Precision
 - Compatibility
 - Complexity
 - Development

Secondary

- **Engineering**
 - Power
 - Weight
 - Volume
 - Expendables
- **Cost**

EXTENSIVE GROUND BASED EVALUATION OF METHODOLOGY

DEVELOPMENT OF PROTOTYPE AND GROUND BASED STUDIES

PROOF OF CONCEPT (IN FLIGHT)

EVALUATION OF HARDWARE (IN FLIGHT)

CHARACTERISTICS OF A NEAR REAL TIME MICROBIOLOGICAL MONITOR

- It Should be Adaptable to Water, Air and Surfaces
- It Should be Reliable and Require Little Maintenance
- It Should be Rapid
- It Should be Self-Contained and Require Minimum Crew Support
- It Should provide for Crew and Ground Support Interactions
- It Should Lend itself to Improvements and Modifications toward both Quantitative and Qualitative Monitor
- It Should be ready for Incorporation Aboard SS Freedom

SCHEDULE

PHASE I		PHASE II											
1988		1989				1990				1991			
J	J	A	S	O	N	D	J	F	M	A	M	J	J
A	A	M	J	J	A	S	O	N	D	J	F	M	A
S	O	N	D	J	F	M	A	M	J	J	A	S	O
O	N	D	J	F	M	A	M	J	J	A	S	O	N
N	D	J	F	M	A	M	J	J	A	S	O	N	D
D	J	F	M	A	M	J	J	A	S	O	N	D	J
J	F	M	A	M	J	J	A	S	O	N	D	J	F
F	M	A	M	J	J	A	S	O	N	D	J	F	M
M	J	J	A	S	O	N	D	J	F	M	A	M	J
J	J	A	S	O	N	D	J	F	M	A	M	J	J

REVIEW

DESIGN

EVALUATION

DEFINITION

DEVELOPMENT

FLIGHT EXPERIMENT

SUMMARY OF RESULTS

- Identified Approximately 30 Methodologies having Potential Application to Microbiological Monitoring
- Approximately One-third of these met the Primary Requirements
- Five Highest Candidates from Secondary Screening choosen for Further Evaluation
- Engineering Trade Studies Currently Underway
- Feasability Studies Currently Underway
- Conceptual Design and Functional Diagrams

HUMANS IN SPACE	IN-SPACE TECHNOLOGY EXPERIMENTS WORKSHOP DECEMBER 6 - 9, 1988	CLOSED LOOP LIFE SUPPORT

DESIGN OF A CLOSED LOOP NUTRIENT SOLUTION DELIVERY SYSTEM FOR CELSS (CONTROLLED ECOLOGICAL LIFE SUPPORT SYSTEMS) APPLICATION

**PRINCIPAL INVESTIGATOR:
AFFILIATION:**

DR. STEVEN H. SCHWARTZKOPF
LOCKHEED MISSILES & SPACE CO.
SUNNYVALE, CALIFORNIA 94088

**CO-INVESTIGATOR:
AFFILIATION:**

MR. MEL W. OLESON
BOEING AEROSPACE CO.
SEATTLE, WASHINGTON 98124

**CENTER CONTACT:
AFFILIATION:**

DR. HATICE S. CULLINGFORD
NASA-JOHNSON SPACE CENTER
HOUSTON, TEXAS 77058
CONTRACT # NAS9-17981

OUTREACH PROGRAM	DESIGN OF A CLOSED LOOP NUTRIENT SOLUTION DELIVERY SYSTEM FOR CELSS (CONTROLLED ECOLOGICAL LIFE SUPPORT SYSTEMS) APPLICATION	LMSC / JSC

EXPERIMENT OBJECTIVE (PHASE I)

TO DEVELOP A CONCEPTUAL DESIGN FOR A CLOSED-LOOP
FLUID HANDLING SYSTEM THAT IS CAPABLE OF MONITORING,
CONTROLLING, AND SUPPLYING NUTRIENT SOLUTION TO HIGHER
PLANTS UNDER MICRO-GRAVITY ENVIRONMENTAL CONDITIONS
IN A CELSS APPLICATION

OUTREACH PROGRAM	DESIGN OF A CLOSED LOOP NUTRIENT SOLUTION DELIVERY SYSTEM FOR CELSS (CONTROLLED ECOLOGICAL LIFE SUPPORT SYSTEMS) APPLICATION	LMSC / JSC

BACKGROUND/TECHNOLOGY NEED

THE TRANSFER, STORAGE AND CONTROL OF LIQUIDS UNDER MICRO-GRAVITY CONDITIONS IS A UBIQUITOUS PROBLEM FOR SPACE FLIGHT. FOR ADVANCED LIFE SUPPORT (CELSS) APPLICATIONS, THE HANDLING OF FLUIDS AND THE CONTROL OF FLUID COMPOSITION ARE TWO OF THE MAJOR PROBLEMS.

THE TECHNOLOGY TO SOLVE THESE PROBLEMS WILL LEAD TO A SIGNIFICANT REDUCTION IN THE AMOUNTS OF LIFE-SUSTAINING MATERIALS CARRIED ON MANNED MISSIONS; THUS DECREASING THE ECONOMIC COST OF THESE MISSIONS.

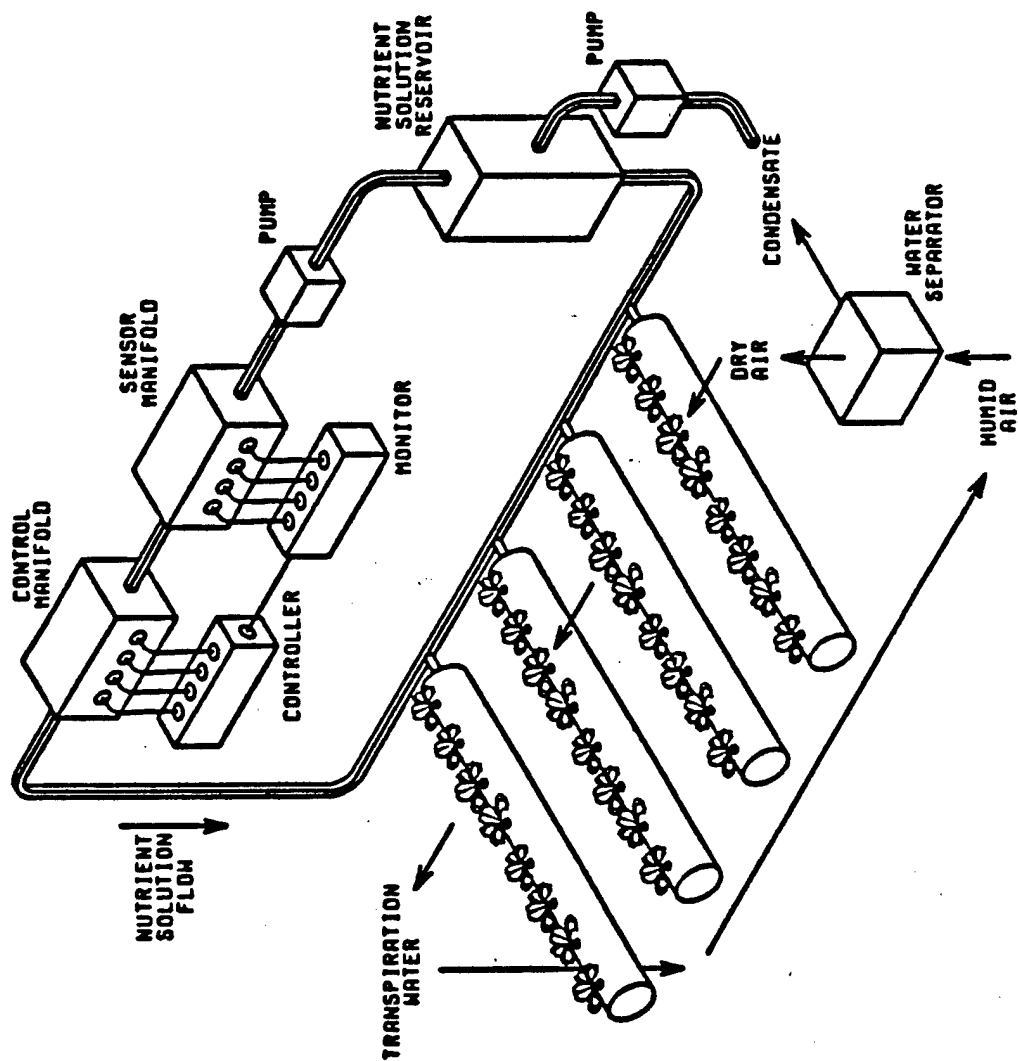
OUTREACH PROGRAM	DESIGN OF A CLOSED LOOP NUTRIENT SOLUTION DELIVERY SYSTEM FOR CELSS (CONTROLLED ECOLOGICAL LIFE SUPPORT SYSTEMS) APPLICATION	LMSC / JSC

EXPERIMENT DESCRIPTION

THE PROTOCOL OF THIS EXPERIMENT IS DESIGNED TO:

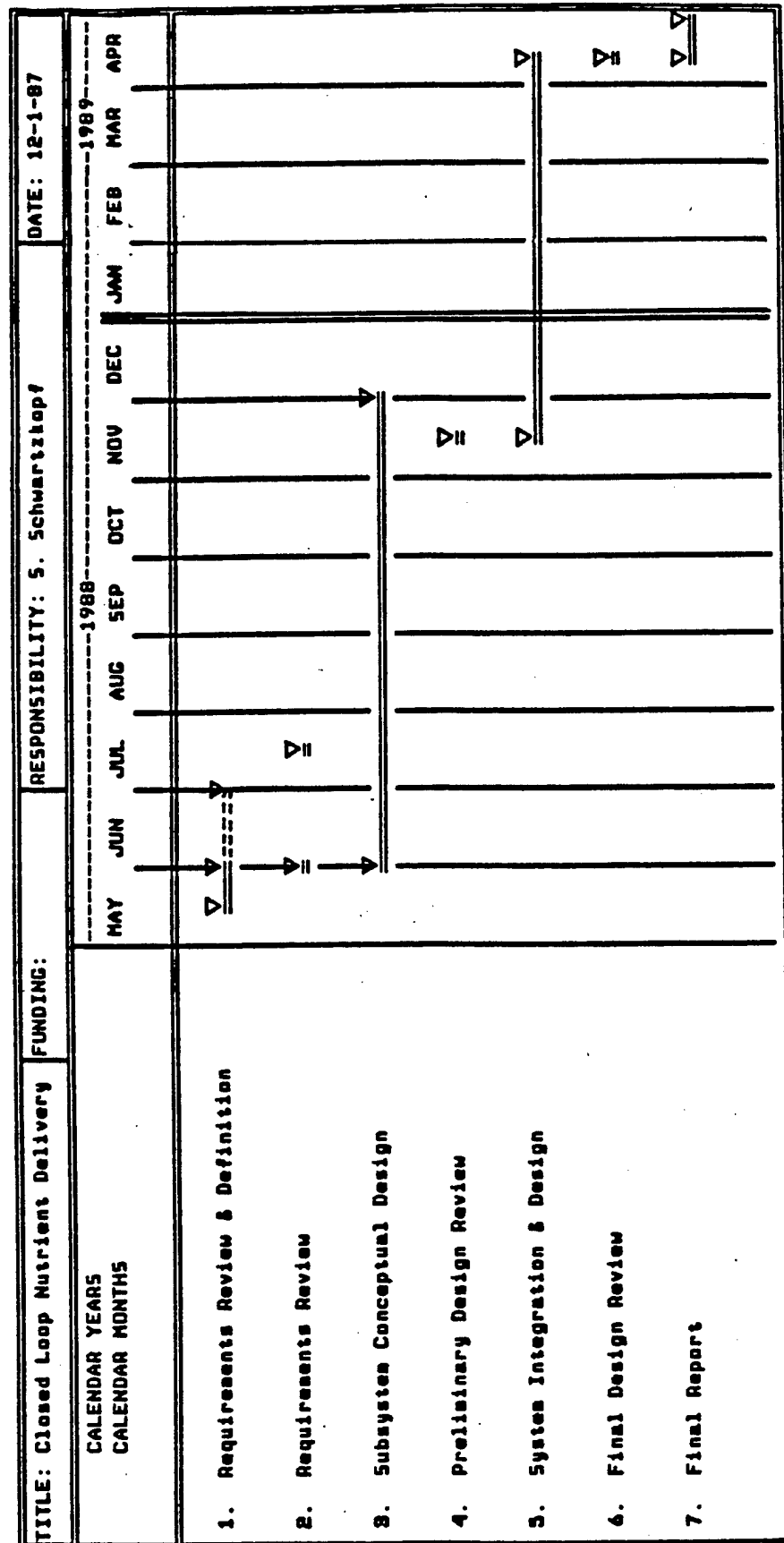
- 1) MEASURE SOLUTION MONITORING CAPABILITIES UNDER
MICRO-GRAVITY CONDITIONS**
- 2) MEASURE SOLUTION COMPOSITION CONTROL CAPABILITIES
UNDER MICRO-GRAVITY CONDITIONS**
- 3) MEASURE THE CAPABILITY OF THREE DIFFERENT NUTRIENT
SOLUTION DELIVERY/RECOVERY SYSTEMS TO PROVIDE
WATER AND NUTRIENTS TO HIGHER PLANTS UNDER MICRO-
GRAVITY CONDITIONS**
- 4) MEASURE THE CAPABILITY TO CONDENSE, COLLECT AND
RECYCLE WATER VAPOR**

CONCEPT DRAWING



OUTREACH PROGRAM	DESIGN OF A CLOSED LOOP NUTRIENT SOLUTION DELIVERY SYSTEM FOR CELSS (CONTROLLED ECOLOGICAL LIFE SUPPORT SYSTEMS) APPLICATION	LMSC / JSC

PROJECT SCHEDULE



HUMANS IN SPACE	IN-SPACE TECHNOLOGY EXPERIMENTS WORKSHOP DECEMBER 6-9, 1988	CLOSED LOOP LIFE SUPPORT

IMPACT OF LOW GRAVITY ON WATER ELECTROLYSIS OPERATION

385

Franz H. Schubert

Life Systems, Inc.

24755 Highpoint Road
Cleveland, Ohio 44122
(216) 464-3291

NAS9-17966
Johnson Space Center
Mr. Albert Behrend

OUTREACH	IMPACT OF LOW-GRAVITY ON WATER ELECTROLYSIS OPERATION	<i>Life Systems, Inc.</i>

EXPERIMENT OBJECTIVE

Investigate ways a low-G environment may improve static feed water electrolysis (SFE) performance based on the hydrophobic/philic cell components, and fluid and thermal flows within the cell. The results will be used to improve static feed electrolysis process efficiency for:

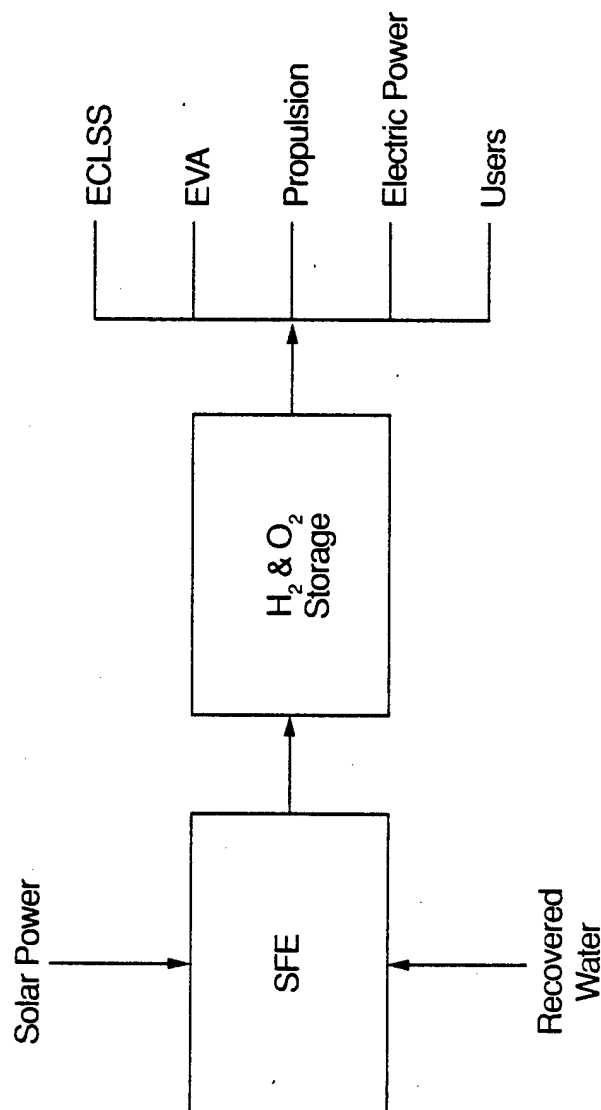
- Life Support
- Propulsion
- EMU O₂ Bottle Recharge
- Energy Storage
- Industry

OUTREACH	IMPACT OF LOW-GRAVITY ON WATER ELECTROLYSIS OPERATION	<i>Life Systems, Inc.</i>

BACKGROUND/TECHNOLOGY NEED

- Hydrogen and Oxygen (H/O) are key to survival for humans in deep space
- Static Feed Electrolysis (SFE) is a key technology for H/O based economy
- Electrochemical processes are key to industrialization of space

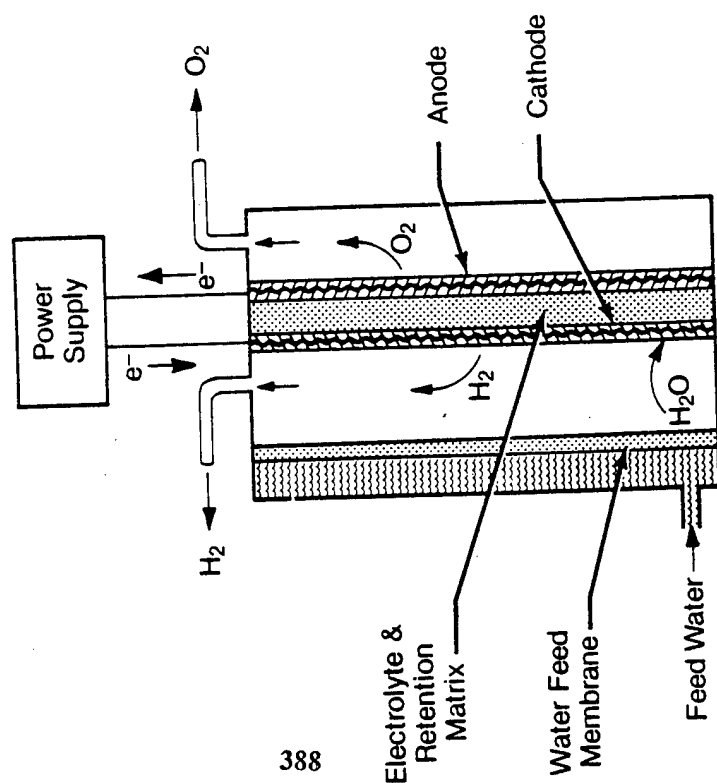
387



OUTREACH	IMPACT OF LOW-GRAVITY ON WATER ELECTROLYSIS OPERATION	<i>Life Systems, Inc.</i>

EXPERIMENT DESCRIPTION

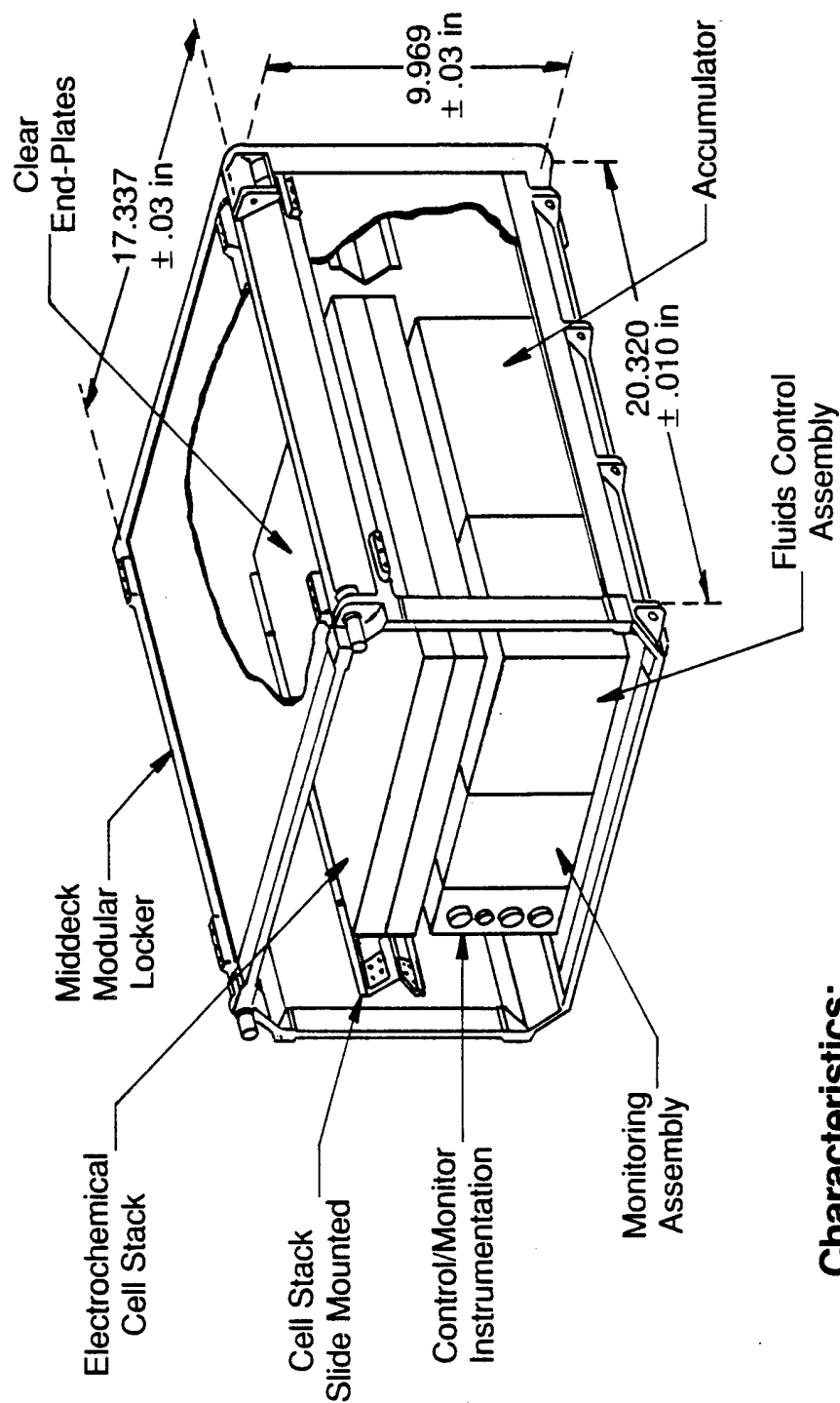
The experiment apparatus will provide the ability to study the two major processes which occur within an SFE. The first is the electrochemical process of water electrolysis in an alkaline electrolyte. The second process is the static addition of water to the cell and diffusion to the electrolysis site. The experiment will be self-contained except for a power supply requirement. Conventional instrumentation including pressure and temperature sensors will be required.



OUTREACH

WATER ELECTROLYSIS EXPERIMENT PACKAGING

Life Systems, Inc.



Characteristics:

Dimensions, in: 9 x 16 x 20

Weight, lb : 30

OUTREACH	IMPACT OF LOW-GRAVITY ON WATER ELECTROLYSIS OPERATION	Life Systems, Inc.

MASTER SCHEDULE

	88	89	90	91	92	93	94	95	96	97
Formal Reviews		PDR △	CDRSafety △△				Ship to KSC △	Ship to KSC △		
System Design										
Fabrication and Assembly										
Testing										
Mission & Flight Operations										
Data Analyses									(a)	
Refurbishment										

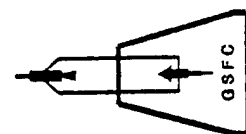
(a) Experiment equipment can be refurbished (and modified, if necessary) and flown again to investigate other areas of electrochemical phenomena in low gravity.

EXPERIMENT INTEGRATION PROCESS PRESENTATIONS

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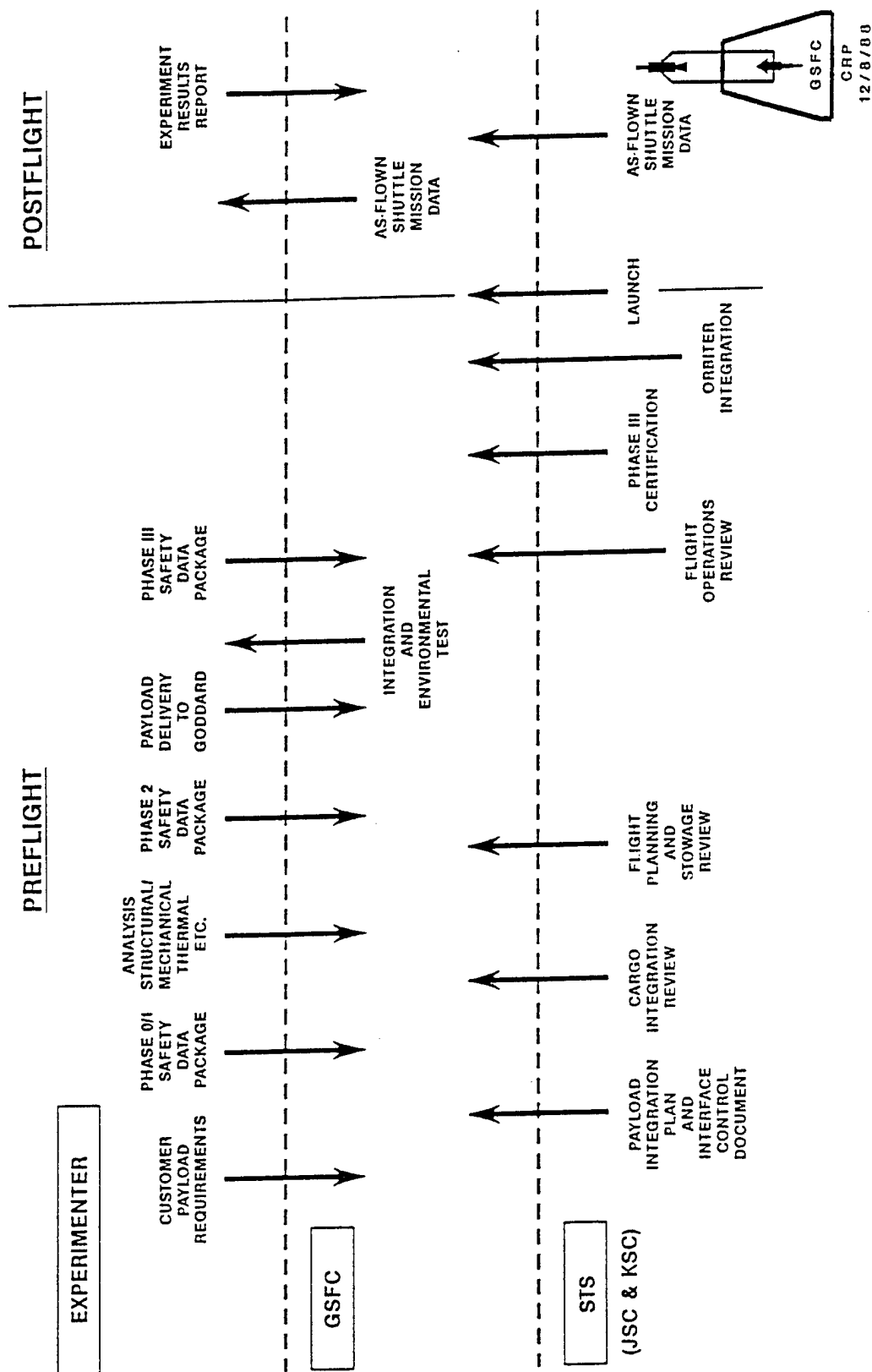
PAYLOAD INTEGRATION OVERVIEW

CLARKE R. PROUTY
SPECIAL PAYLOADS DIVISION
GODDARD SPACE FLIGHT CENTER



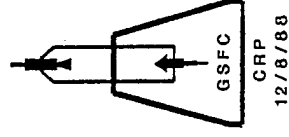
CRP
12/8/88

In-Step Payload Milestones



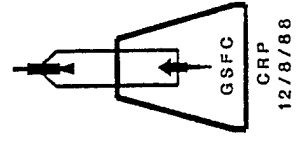
Payload Requirements

- Mid-Deck Payloads
PIP
- Complex Autonomous Payloads (CAP)
Payload Accommodation Requirements (PAR)
- Hitchhiker Payloads
Customer Payload Requirements (CPR)



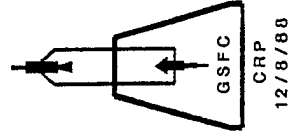
Payload Requirements

- Experiment Description
- Hardware Description
- Operational Scenario



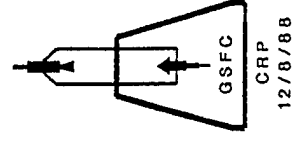
Support

- Mission Manager
- Safety Officer
- Integration
- Pre and Post Flight



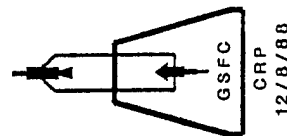
Safety Review And Certification

- Phase 0
Informal - Identify Hazards
- Phase I
Formal - Assess Preliminary Design
Evaluate preliminary hazard controls,
Verification methods
- Phase II
Assess Final Design
Concur on hazard controls,
Safety verification Methods



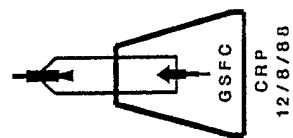
Safety Review And Certification

- Phase III
Formal - Approve Safety Assessment Report
Review Safety Compliance Data Package
Identify Open Safety Items



NASA Documents

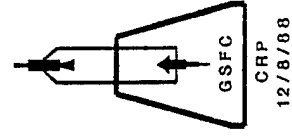
- PIP
- PIP Annexes
- ICD



Payload Integration

Carrier

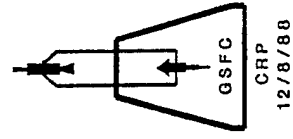
- Mid - Deck Payloads
JSC
- CAP Payloads
GSFC, KSC
- Hitchhiker Payloads
GSFC, KSC



Payload Integration

Carrier

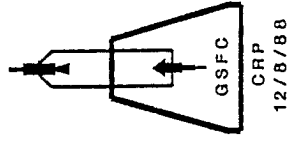
- Fit Checks and Assembly Loading consumables
- Final testing
- System Checkout

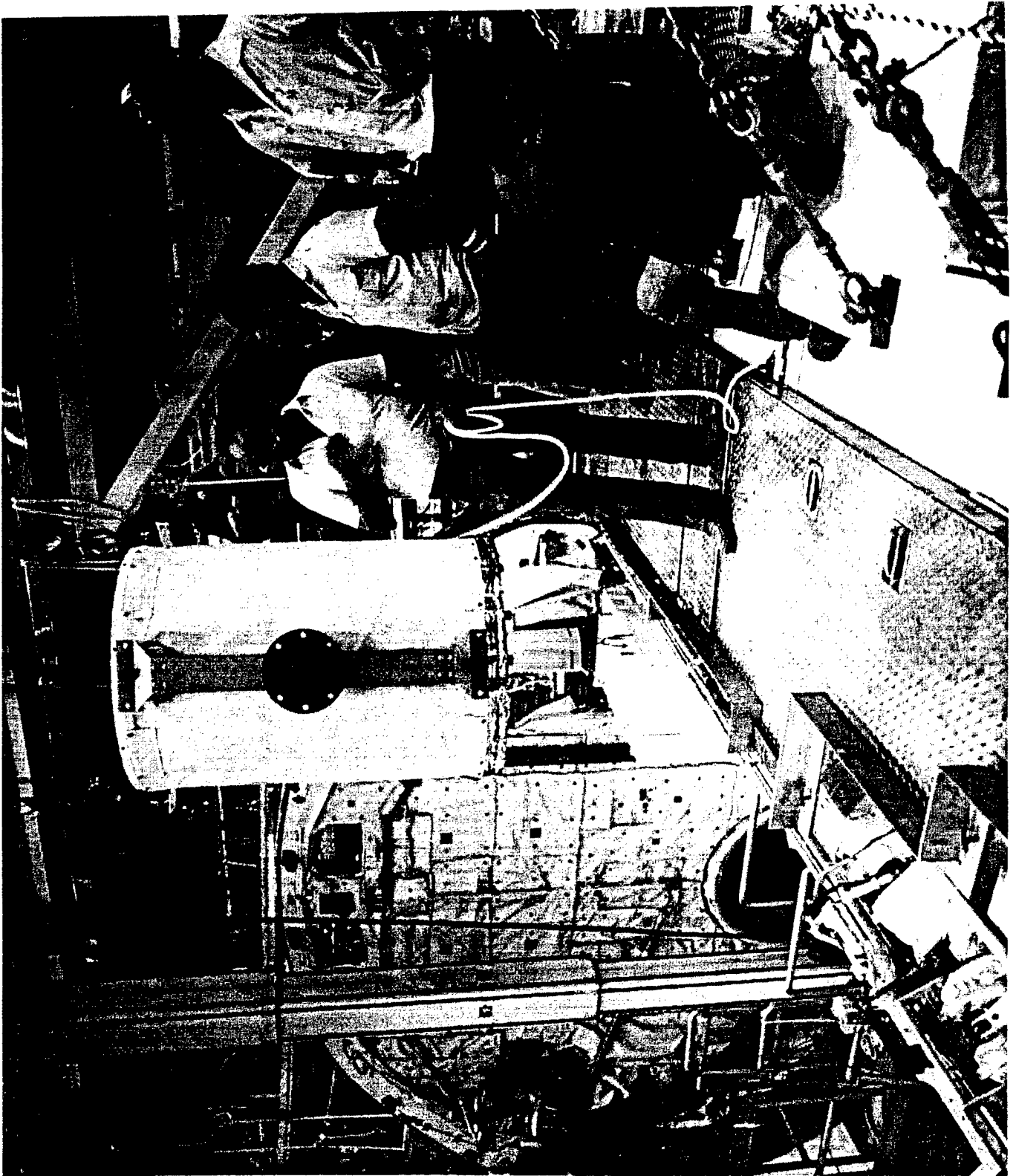


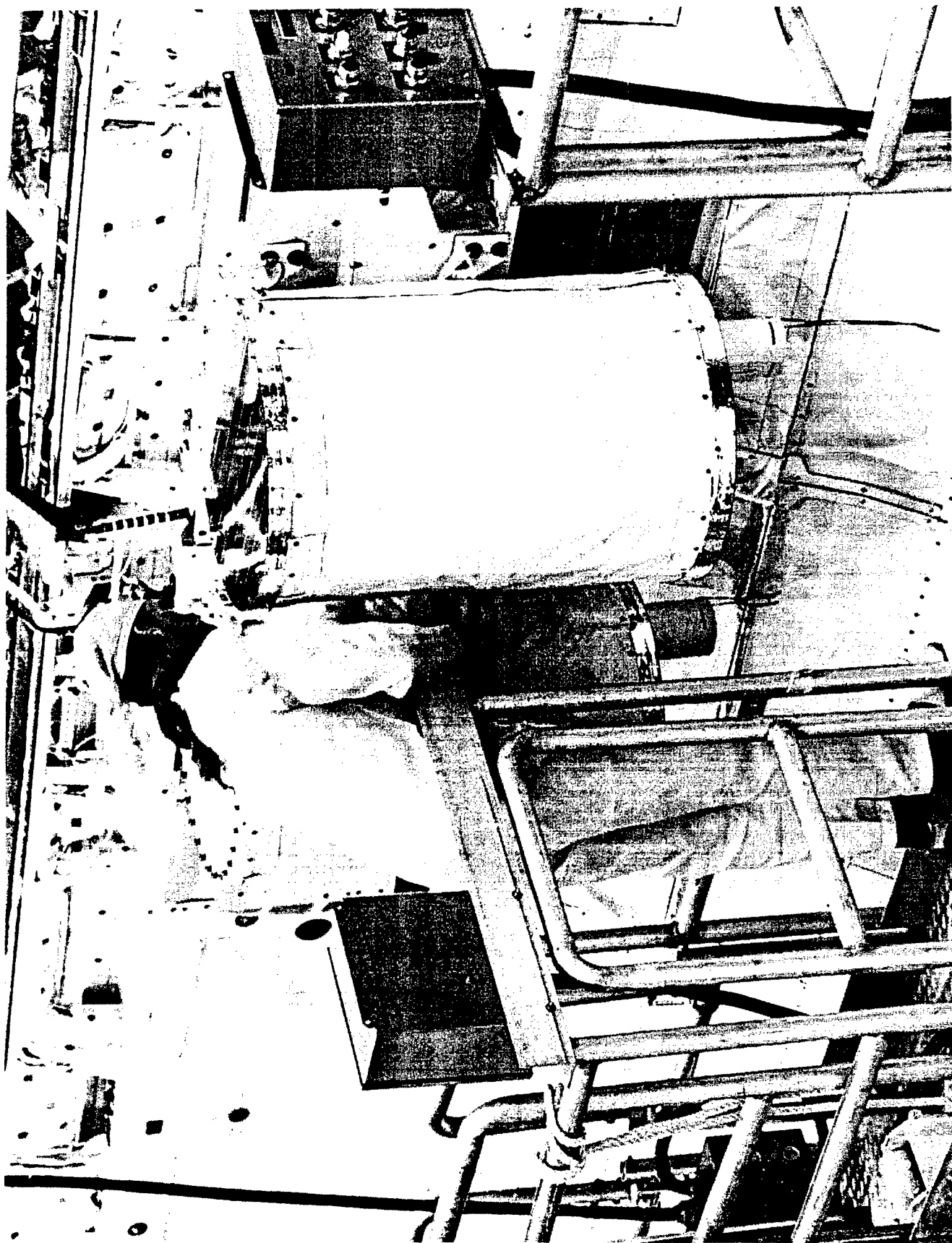
Payload Integration

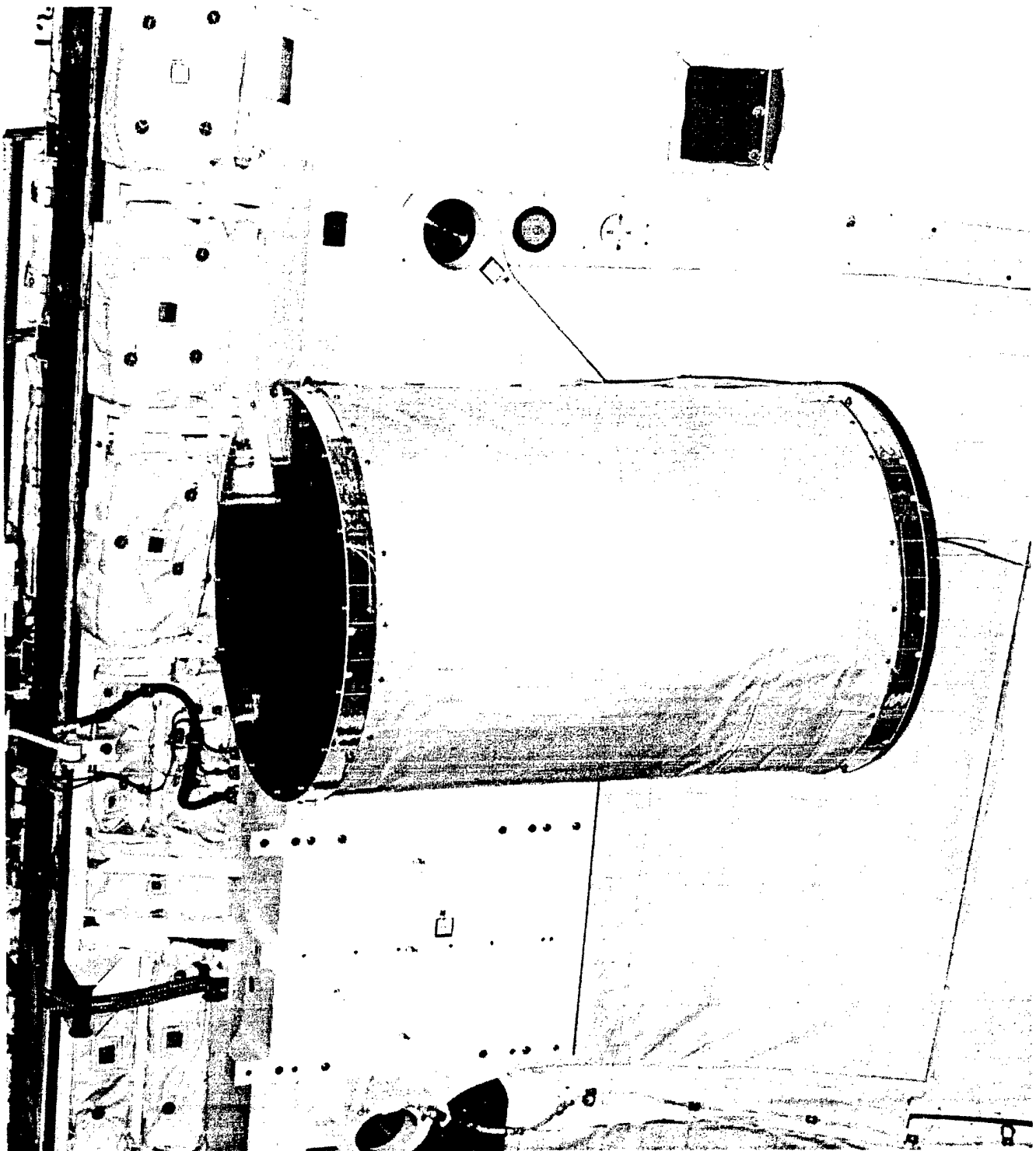
Orbiter

- Mid - Deck Payloads
KSC
- CAP Payloads
KSC
Adapter Beam, MPES
- Hitchhiker Payloads
KSC
Adapter Beam, MPES





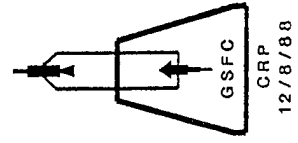


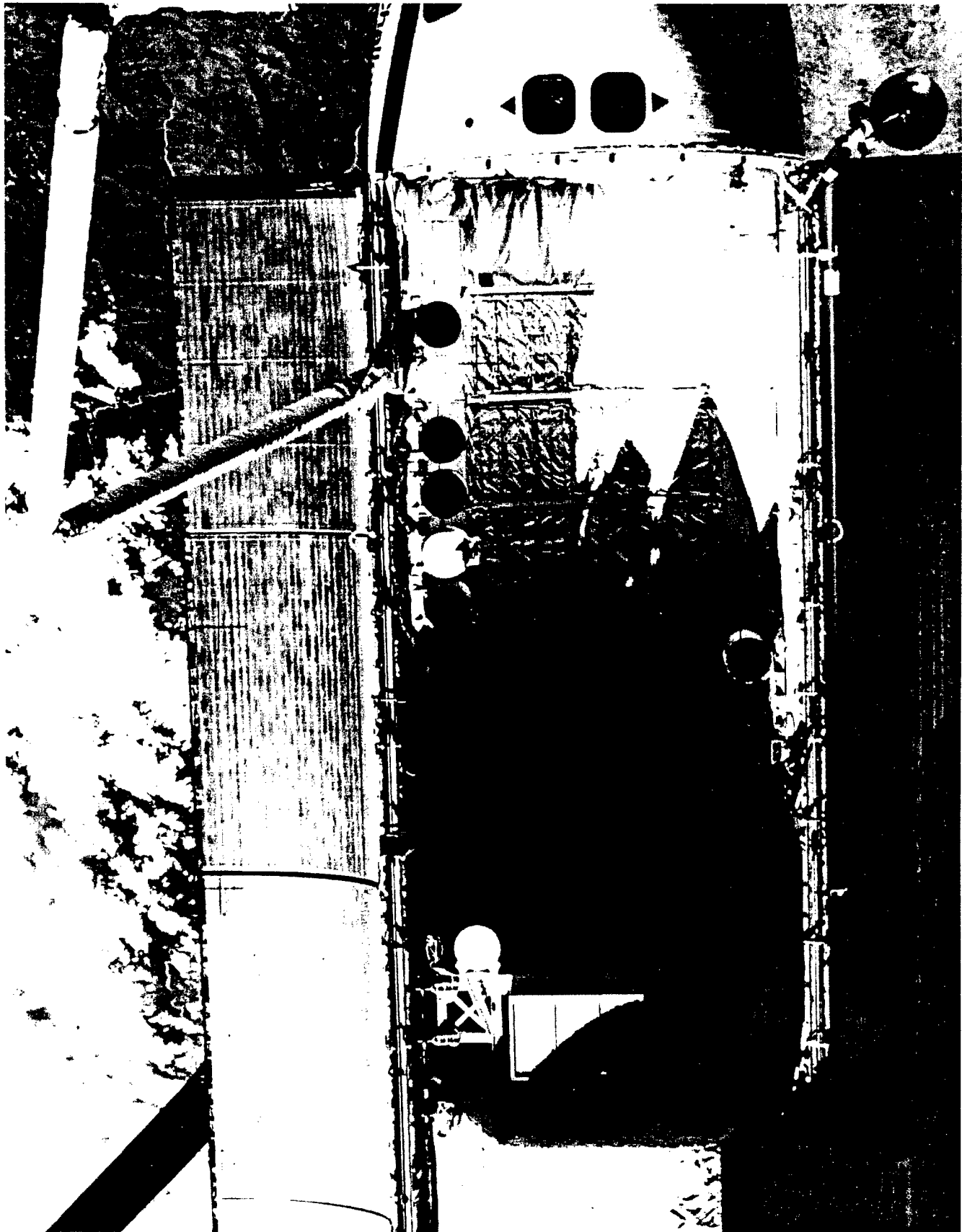




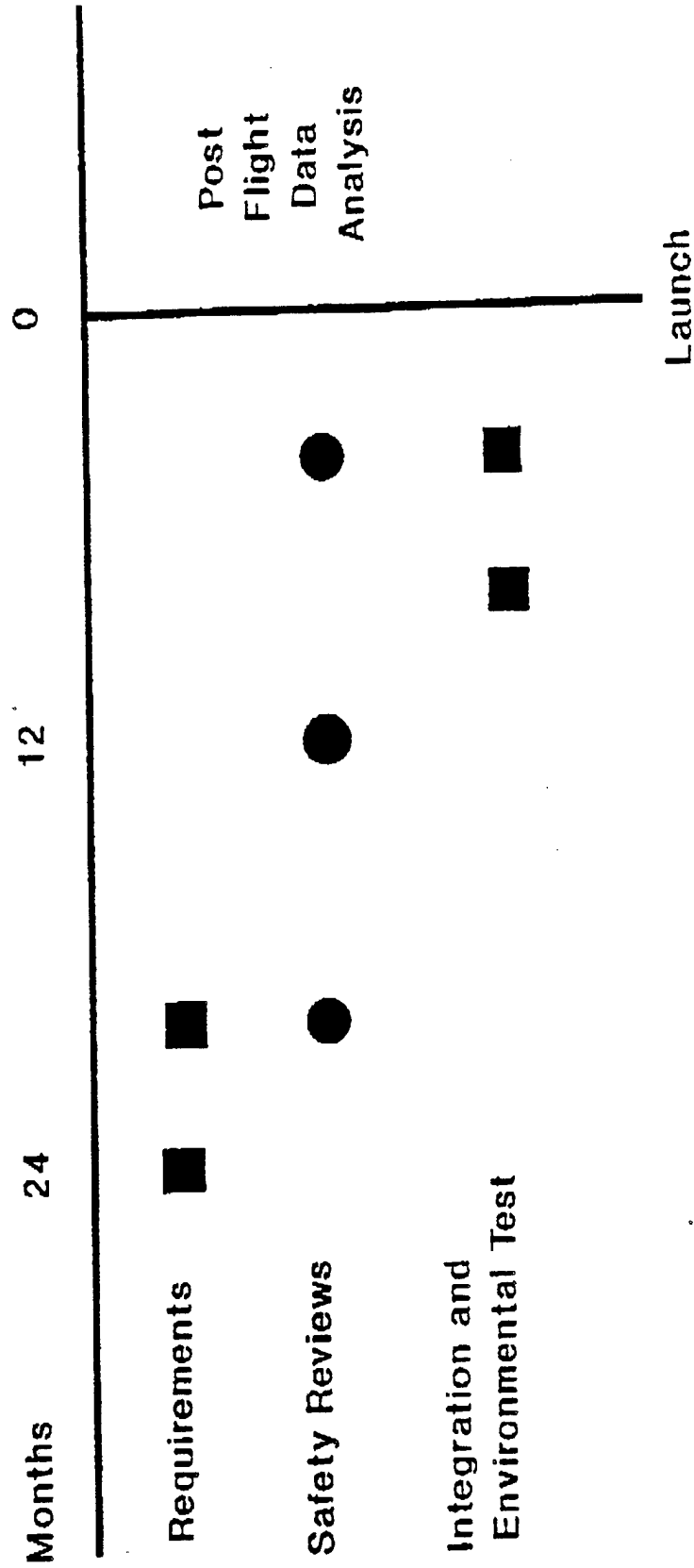
Mission

- Launch
- On Orbit Operations
- POCC
- Landing
- Post Landing





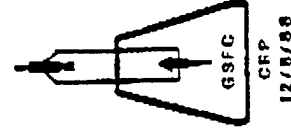
In-Step Payload Review and Integration Schedule



In-Step Payloads

The Future

- Current Flight Opportunities on Shuttle
- Will expand to Expendable Launch Vehicles
- Begin with available Shared Flights
- May Fund Dedicated OAST ELV
- Eventual Space Station Experiments



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SPACE SHUTTLE SYSTEM PAYLOAD INTEGRATION PROCESS

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**NSTS
INTEGRATION
AND
OPERATIONS**

**JOHN C. O'LAUGHLIN
SPACELAB & MIDDECK INTEGRATION OFFICE
JOHNSON SPACE CENTER**



NSTS INTEGRATION AND OPERATIONS

THE SPACE SHUTTLE SYSTEM PAYLOAD INTEGRATION PROCESS OVERVIEW

- NATIONAL SPACE TRANSPORTATION SYSTEM (NSTS) ORGANIZATION
- SPACE SHUTTLE SYSTEM DESCRIPTION
- PAYLOAD INTEGRATION PROCESS
- SCHEDULES/MANIFESTING



**NSTS
INTEGRATION
AND
OPERATIONS**

NSTS ORGANIZATION



NSTS INTEGRATION AND OPERATIONS

NSTS ORGANIZATION

- NASA HEADQUARTERS
- OVERALL MANAGEMENT OF THE NSTS
- MANAGES TRANSPORTATION SERVICES
 - FLIGHT SCHEDULING
 - REQUEST FOR FLIGHT ASSIGNMENT (NASA FORM 1628)
 - NEGOTIATION AND IMPLEMENTATION (POLICY, LEGAL, BUSINESS AND FINANCIAL ASPECTS)
- JSC
- MANAGES THE DEVELOPMENT AND OPERATIONS OF THE SPACE SHUTTLE
- MANAGES TECHNICAL INTEGRATION OF PAYLOAD INTO THE STS SHUTTLE
 - WORKING GROUPS FOR ENGINEERING AND OPERATIONS PLANNING
 - DEFINE INTERFACE AND OPERATIONAL REQUIREMENTS
 - IDENTIFY, DEFINE, AND INTEGRATE ENGINEERING TASKS



NSTS INTEGRATION AND OPERATIONS

- KSC
 - LAUNCH AND LANDING SUPPORT FOR THE SHUTTLE
 - IMPLEMENTS ACTIVITIES ASSOCIATED WITH PREPARING THE SPACE SHUTTLE AND ITS PAYLOADS
 - PAYLOAD PROCESSING
 - LAUNCH SUPPORT
 - LANDING
 - POST-FLIGHT SERVICES
- MSFC
 - RESPONSIBLE FOR MANAGING THE DEVELOPMENT OF :
 - SOLID ROCKET BOOSTERS
 - SPACE SHUTTLE MAIN ENGINES
 - EXTERNAL TANK
 - SPACELAB MODULES AND PALLETS



**NSTS
INTEGRATION
AND
OPERATIONS**

- GSFC
- RESPONSIBLE FOR MANAGING:
 - COMMUNICATIONS NETWORK
 - SPACE FLIGHT TRACKING DATA NETWORK
 - GET AWAY SPECIAL (GAS) PROGRAM
 - OTHER SMALL PAYLOAD CARRIER PROGRAMS

NSTS
INTEGRATION
AND
OPERATIONS



SPACE SHUTTLE SYSTEM DESCRIPTION



NSTS INTEGRATION AND OPERATIONS

SPACE SHUTTLE SYSTEM

- ORBITER
 - PAYLOAD BAY
 - MIDDECK
- SOLID ROCKET BOOSTERS
- EXTERNAL TANK
- FLIGHT CREW
 - COMMANDER
 - PILOT
- MISSION SPECIALIST (2 OR MORE)



NSTS INTEGRATION AND OPERATIONS

SPACE SHUTTLE SYSTEM

SPACE SHUTTLE SYSTEM

OVERALL LENGTH 184.2 FT (56.1 m)
HEIGHT 76.6 FT (23.3 m)

EXTERNAL TANK

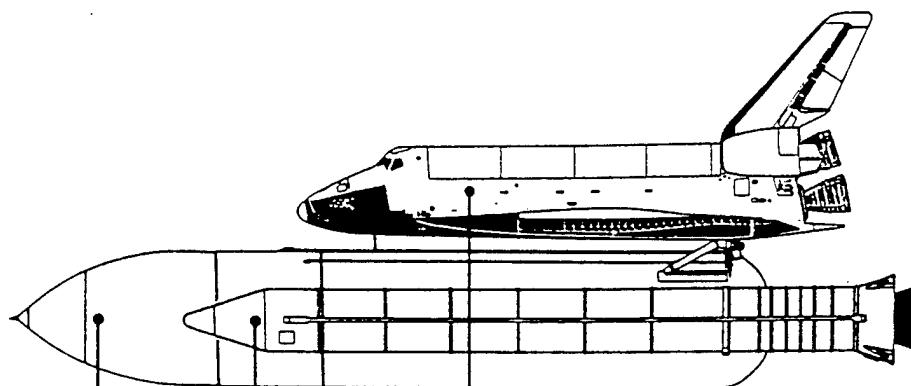
DIAMETER 27.8 FT (8.5 m)
LENGTH 154.4 FT (47.1 m)

SOLID ROCKET BOOSTER

DIAMETER 12.2 FT (3.7 m)
HEIGHT 149.1 FT (45.4 m)
THRUST (EACH) 2,700,000 LB (12,010,140 N)
— LAUNCH

ORBITER

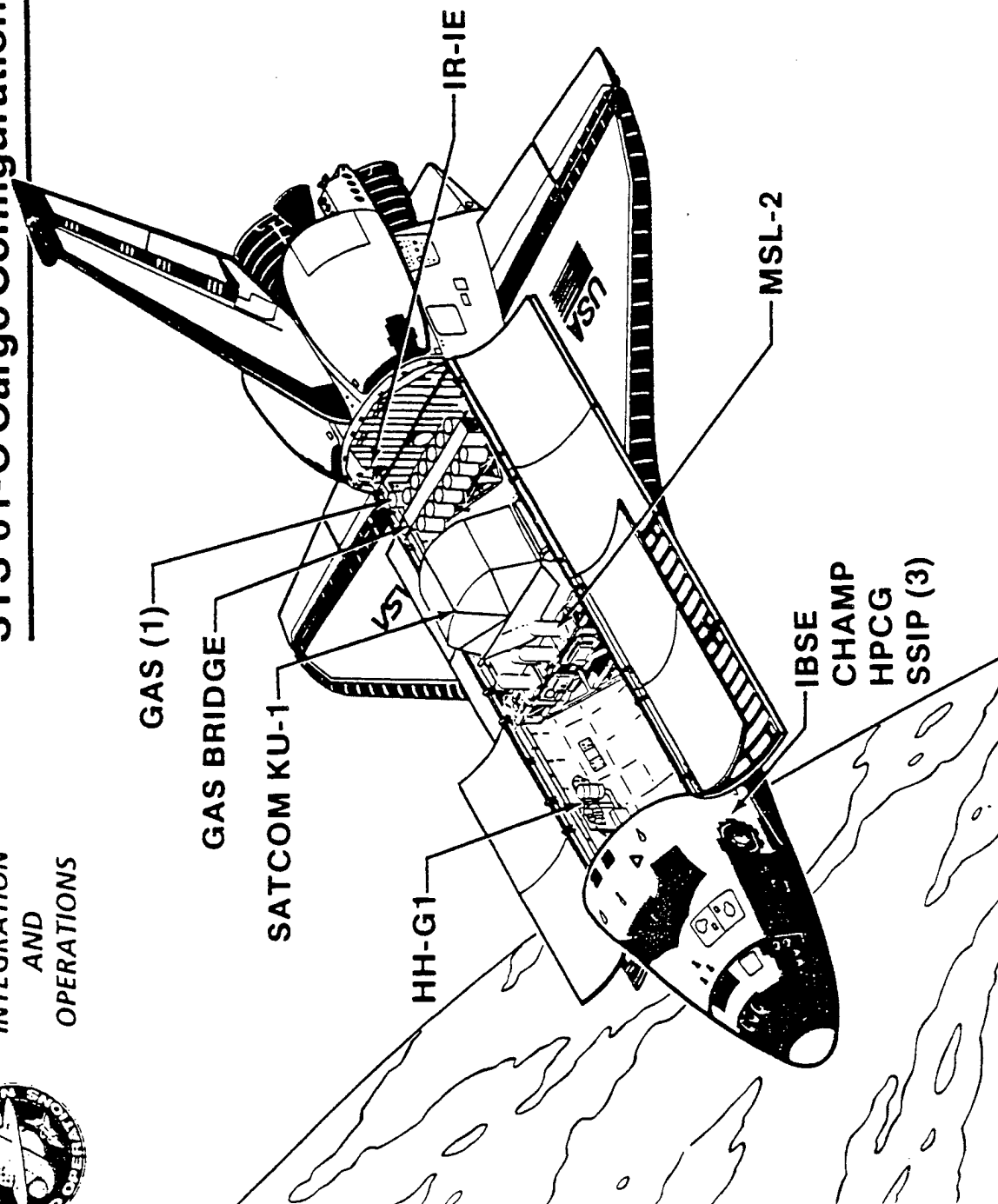
LENGTH 122.2 FT (37.2 m)
WINGSPAN 78.1 FT (23.8 m)
TAXI HEIGHT ~ 57 FT (~ 17 m)
PAYLOAD BAY 15 FT DIAM BY 60 FT LONG
(4.6 m BY 18.3 m)
MAIN ENGINES (3)
— VACUUM THRUST EACH 470,000 LB (2,090.7 kN)
OMS ENGINES (2)
— VACUUM THRUST EACH 6,000 LB (26.7 kN)
RCS
— 38 ENGINES
— VACUUM THRUST EACH 870 LB (3,869.9 N)
— 6 VERNIER ENGINES
— VACUUM THRUST EACH 25 LB (111.2 N)





NSTS
INTEGRATION
AND
OPERATIONS

STS 61-C Cargo Configuration





**NSTS
INTEGRATION
AND
OPERATIONS**

PAYLOAD INTEGRATION PROCESS



**NSTS
INTEGRATION
AND
OPERATIONS**

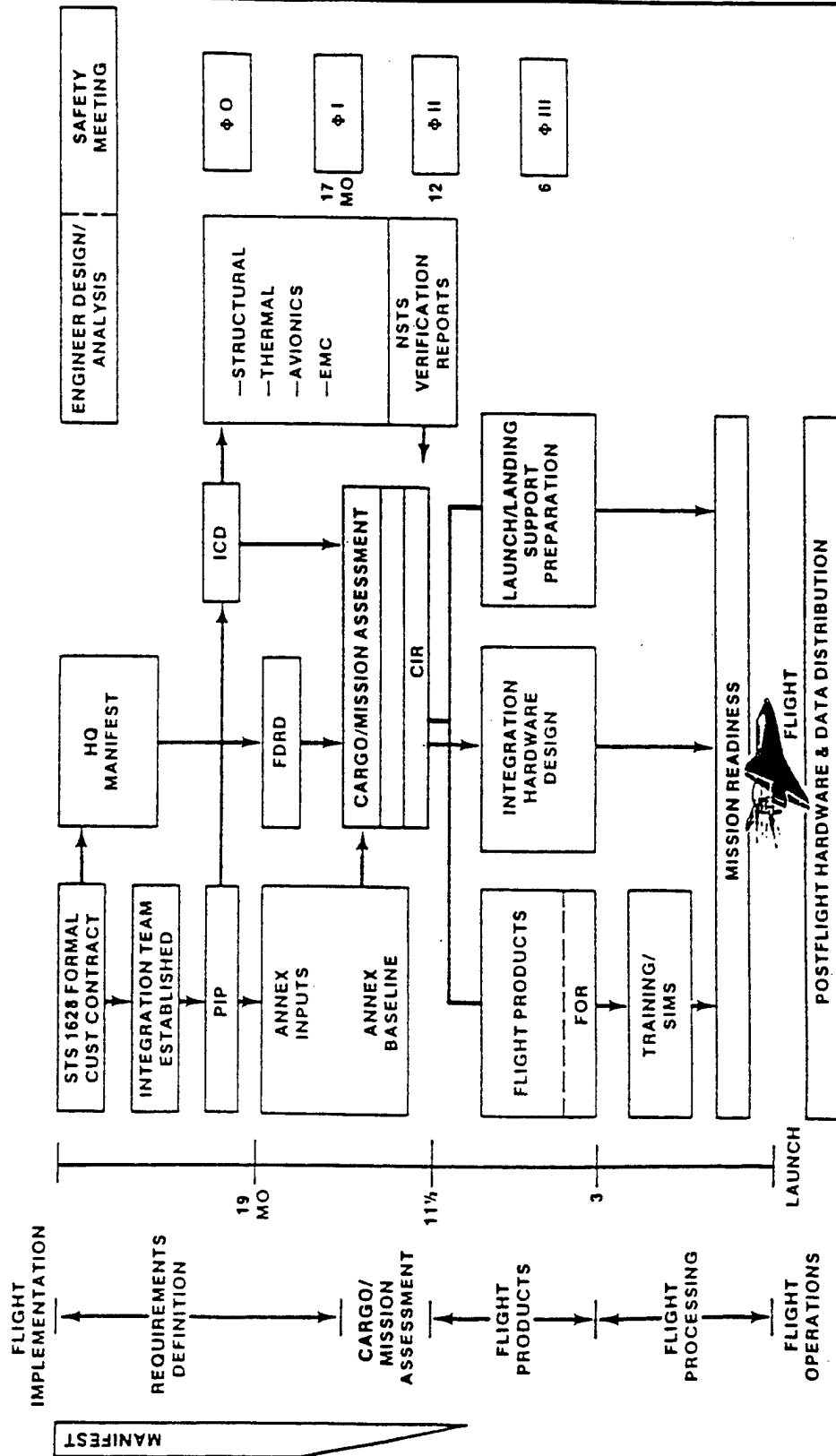
PAYLOAD INTEGRATION PROCESS OVERVIEW

- FORMAL REQUEST FOR FLIGHT ASSIGNMENT (FORM 1628)
- DEVELOPMENT OF FORMAL AGREEMENTS
- IMPLEMENTATION OF AGREEMENTS
- PHASED SAFETY REVIEWS - FLIGHT AND GROUND EQUIPMENT
- LAUNCH
- POSTFLIGHT ACTIVITIES



NSTS INTEGRATION AND OPERATIONS

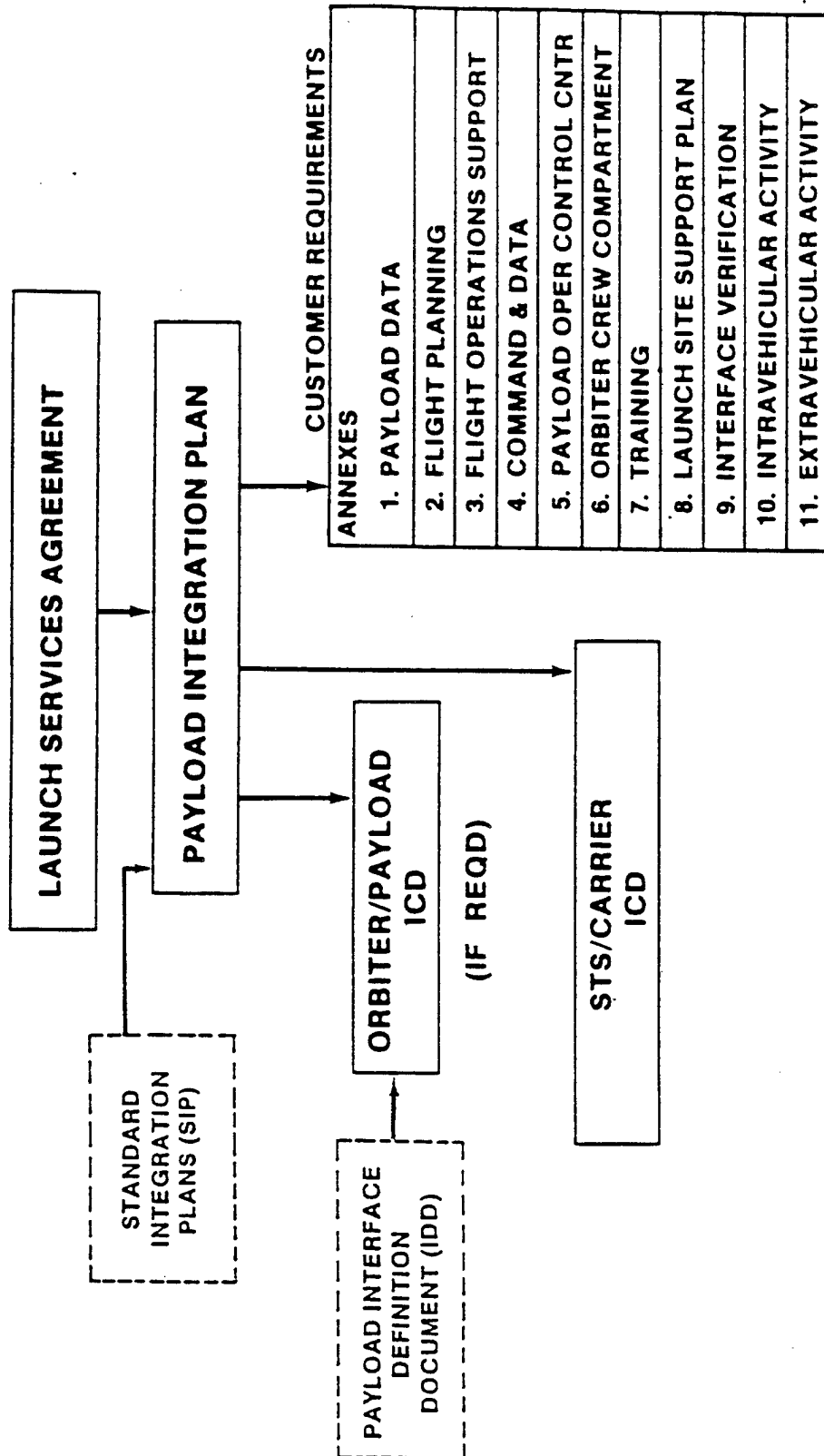
PAYLOAD INTEGRATION PROCESS OVERVIEW





NSTS
INTEGRATION
AND
OPERATIONS

JOINT AGREEMENTS





**NSTS
INTEGRATION
AND
OPERATIONS**

NASA PAYLOAD INTEGRATION TEAM

- HQ - CUSTOMER SERVICE MANAGER
 - FLIGHT SCHEDULE
 - POLICY
- JSC - PAYLOAD INTEGRATION MANAGER (PIM)
 - CUSTOMER PRIMARY POINT OF CONTACT
 - ENSURE PAYLOAD REQ. ACCURATELY DEFINED/DOCUMENTED
 - COORDINATES ENGINEERING TECHNICAL SUPPORT
- KSC - LAUNCH SITE SUPPORT MANAGER (LSSM)
 - CUSTOMER POINT OF CONTACT AT KSC
 - ENSURES PAYLOAD PROCESSING SUPPORT AT LAUNCH SITE



NSTS
INTEGRATION
AND
OPERATIONS

SCHEDULES/MANIFESTING



**NSTS
INTEGRATION
AND
OPERATIONS**

PAYLOAD INTEGRATION SCHEDULE

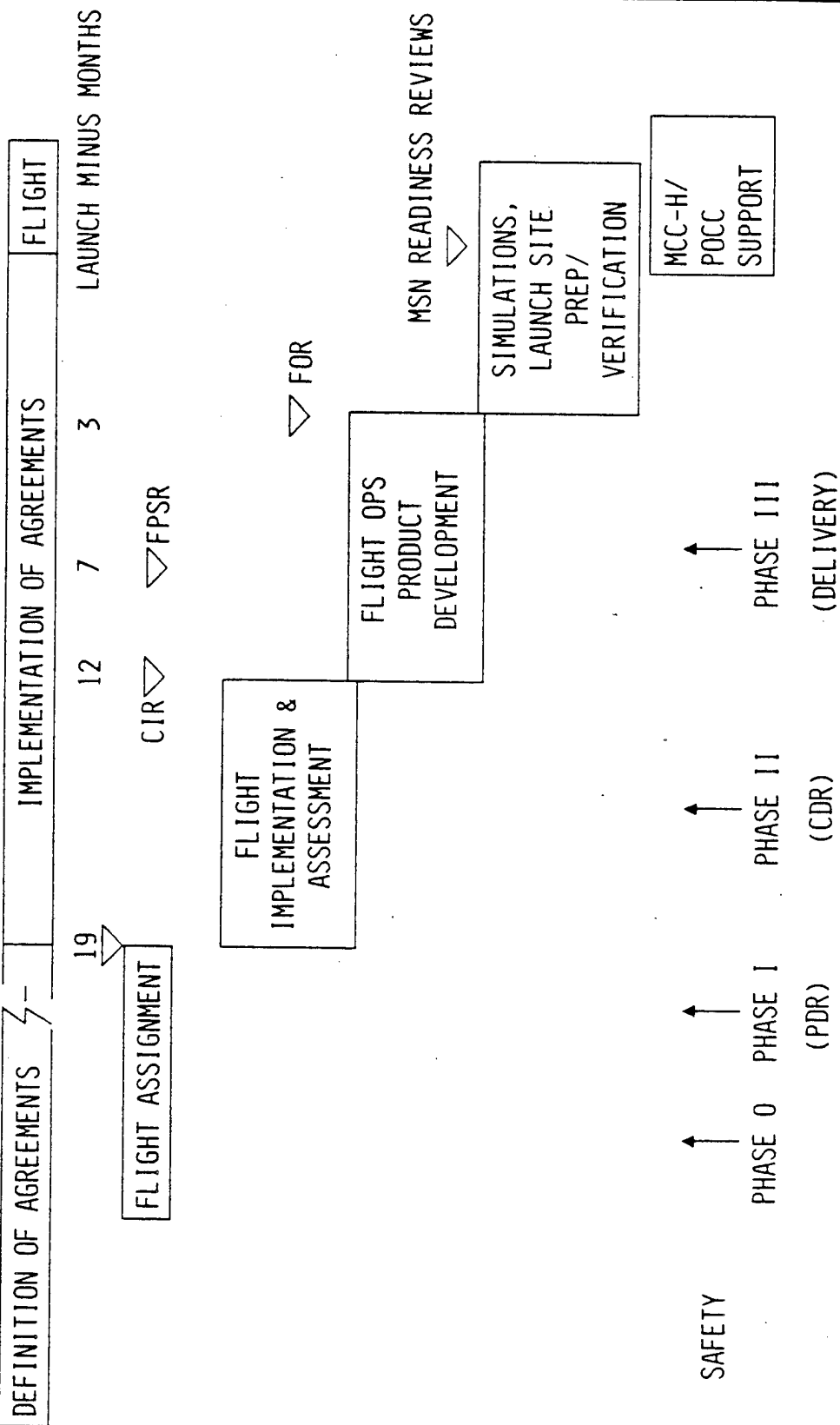
- **FINAL MANIFESTING IS DEPENDENT ON COMPLETION OF JOINT AGREEMENTS (PIP, ICD, ANNEXES)**
- **COMPLETION DATES OF JOINT AGREEMENTS ARE DEPENDENT UPON CATEGORY OF PAYLOAD**
- **PAYLOAD INTEGRATION PROCESS FOR ALL PAYLOADS SHOULD START AS SOON AS POSSIBLE AFTER AGREEMENT TO PROCEED (ACCEPTANCE OF FORM 1628 BY NASA HEADQUARTERS)**
- **QUARTER SECTION TYPICAL SCHEDULE**
 - **PAYLOAD INTEGRATION PLAN..... DRAFT COMPLETE 2-3 MONTHS AFTER FORM 1628**
 - **ICD..... COMPLETE 1 MONTH AFTER PIP**
 - **ANNEXES..... CONSISTENT WITH START OF CIR ASSESSMENT ACTIVITY**
 - **SAFETY REVIEWS..... PAYLOAD DEVELOPMENT**
- **MISSION CAN BE DEFINED IN THE FDRD WHEN JOINT AGREEMENTS ARE BASELINED PRIOR TO THE "NO LATER THAN" DATES SHOWN ON THE FOLLOWING MATRIX**



NSTS INTEGRATION AND OPERATIONS

1628

PROCESS FLOW





**NSTS
INTEGRATION
AND
OPERATIONS**

PAYLOAD CATEGORIES

- **PRIMARY PAYLOAD**
 - DRIVES THE OVERALL FLIGHT DESIGN
 - GENERALLY WEIGHS MORE THAN 8000 POUNDS
 - REQUIRES AT LEAST ONE-FOURTH OF PAYLOAD BAY SERVICES
- **COMPLEX SECONDARY PAYLOAD**
 - EXCEEDS NSTS ACCOMMODATIONS AS DEFINED IN APPLICABLE DOCUMENTATION
- **HAS ONE OR MORE OF THESE CHARACTERISTICS:**
 - UTILIZES QUARTER-BAY PAYLOAD SERVICES
 - HAS OPTIONAL PAYLOAD BAY INTERFACES
 - HAS REQUIREMENTS WHICH DRIVE THE FLIGHT DESIGN
 - HAS UNIQUE INSTALLATION REQUIREMENTS IN THE ORBITER MIDDECK



**NSTS
INTEGRATION
AND
OPERATIONS**

- **NONSTANDARD SECONDARY/SMALL PAYLOAD
ACCOMMODATION (SPA)**
 - **REQUIRES MINOR DEVIATIONS FROM GAS OR MIDDECK SIP
AND/OR IDD**
 - **SPA MEETS THE SIP AND IDD REQUIREMENTS, BUT ITS
COMPLEXITY REQUIRES THAT IT BE TREATED AS A
NONSTANDARD SECONDARY PAYLOAD FROM A SCHEDULE
PERSPECTIVE**
 - **DEVIATION FROM SPA STANDARDS REQUIRES THAT A
PAYLOAD BE TREATED AS A COMPLEX SECONDARY**
- **STANDARD SECONDARY**
 - **DOES NOT EXCEED NSTS ACCOMMODATIONS AS DEFINED IN THE
GAS OR MIDDECK SIP AND/OR IDD**



**NSTS
INTEGRATION
AND
OPERATIONS**

FLIGHT ASSIGNMENT

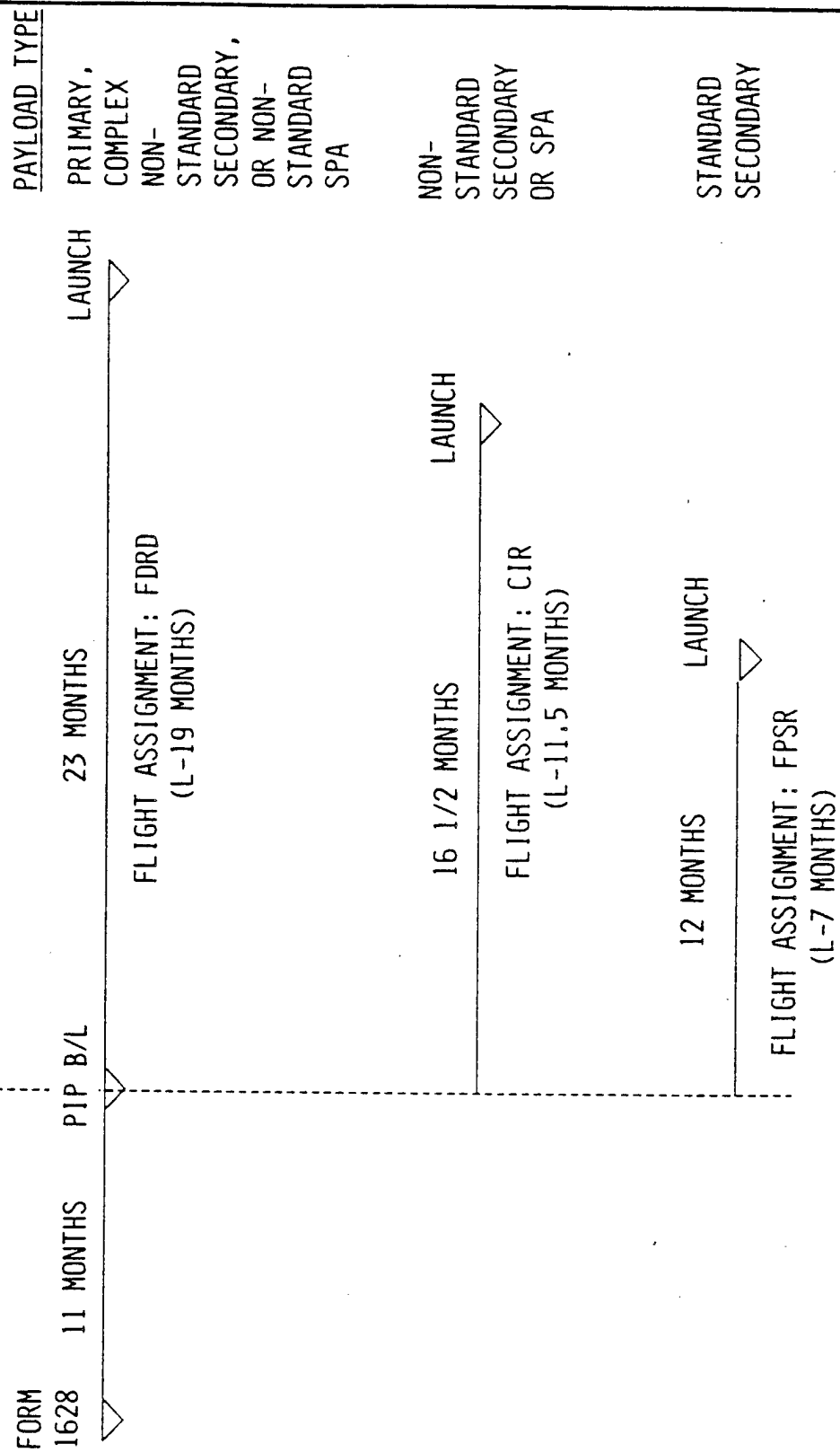
PAYLOAD CATEGORY	LATEST FLIGHT ASSIGNMENT	PREREQUISITES
PRIMARY	FDRD L-19 MONTHS	BASELINED* PIP AND ICD
COMPLEX SECONDARY	FDRD L-19 MONTHS	BASELINED PIP AND ICD
NONSTANDARD SECONDARY OR SPA	CARGO INTEGRATION REVIEW (CIR) L-11.5 MONTHS	BASELINED PIP AND ICD. ALL ANNEXES BASELINED EXCEPT 4 AND 9; HOWEVER, CUSTOMER SUBMITTAL OF ANNEXES 4 AND 9 IS REQUIRED.
STANDARD SECONDARY	FLIGHT PLANNING AND STOWAGE REVIEW (FPSR) L-7 MONTHS	BASELINED PIP, ICD, AND ALL ANNEXES. PHASE II SAFETY REVIEW IS REQUIRED.

*BASELINED = SIGNED BY BOTH NSTS AND THE CUSTOMER



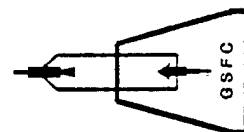
NSTS INTEGRATION AND OPERATIONS

TIMELINE REQUIRED FOR FLIGHT READINESS



COMPLEX AUTONOMOUS PAYLOAD CARRIERS

435



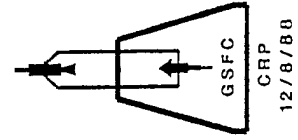
12/8/88

CLARKE R. PROUTY
SPECIAL PAYLOADS DIVISION
GODDARD SPACE FLIGHT CENTER

GAS / CAP

Similarities

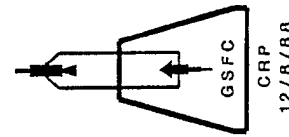
- Hardware
- Facilities
- Personnel



GAS / CAP

Differences

GAS	CAP
Existing Customers	Secondaries Policy
Subject to Queue	Manifested
Restrictive Interfaces	More Commands Possible Some Pointing Possible <u>P</u> ayload Integration <u>P</u> lan (PIP)
	Longer Processing

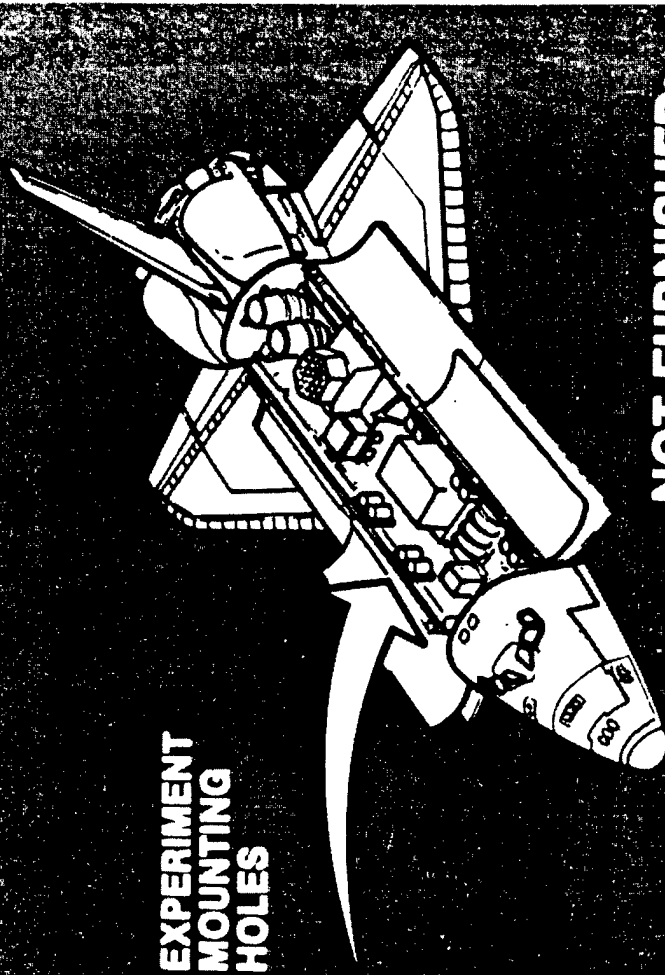


Get Away Special

Concept

- Encourage the use of Space by all Researchers:
Private Individuals and Organizations
- Foster Enthusiasm in Younger Generation
- Increase Knowledge of Space
- Be Alert to Possible growth of GAS
Investigation into a Prime Experiment
- Generate New Activities Unique to Space

GETAWAY SPECIAL ACCOMMODATIONS



EXPERIMENT
MOUNTING
HOLES

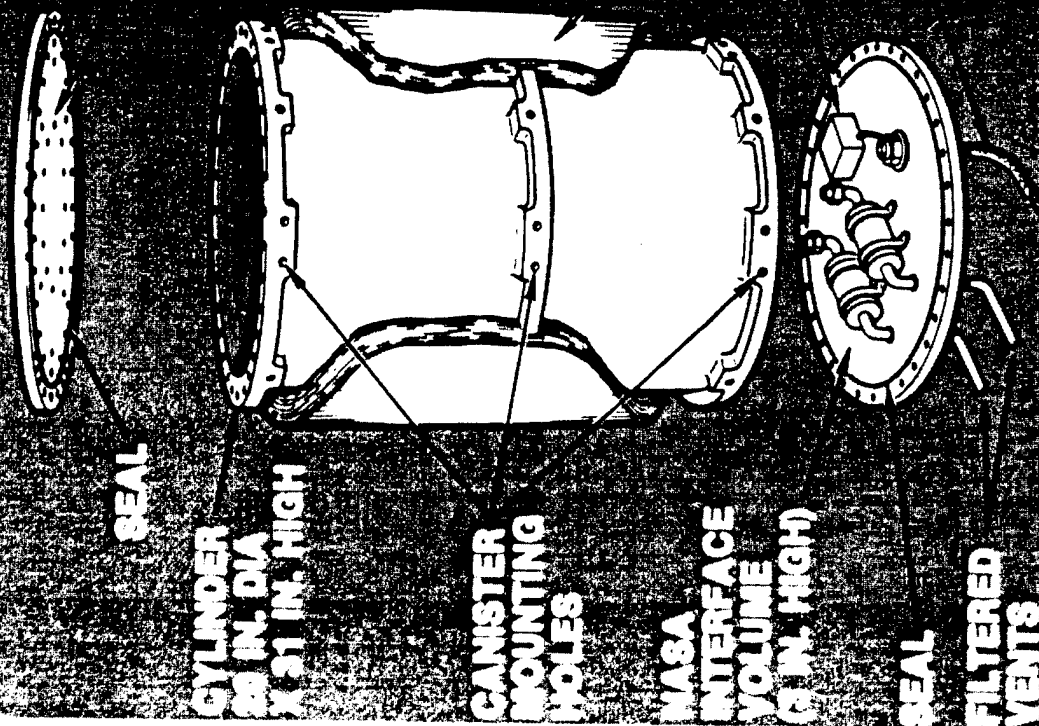
NOT FURNISHED:

- POWER
- DATA STORAGE
- EXPERIMENT CONTROL SYSTEM
- ENVIRONMENTAL CONTROL

THERMAL
INSULATION

CONTROL
DECODER

SHIELDED TWISTED
WIRE PAIR FOR
ON/OFF COMMANDS



SEAL

CYLINDER
24 IN. DIA
X 31 IN. HIGH

CANISTER
MOUNTING
HOLES

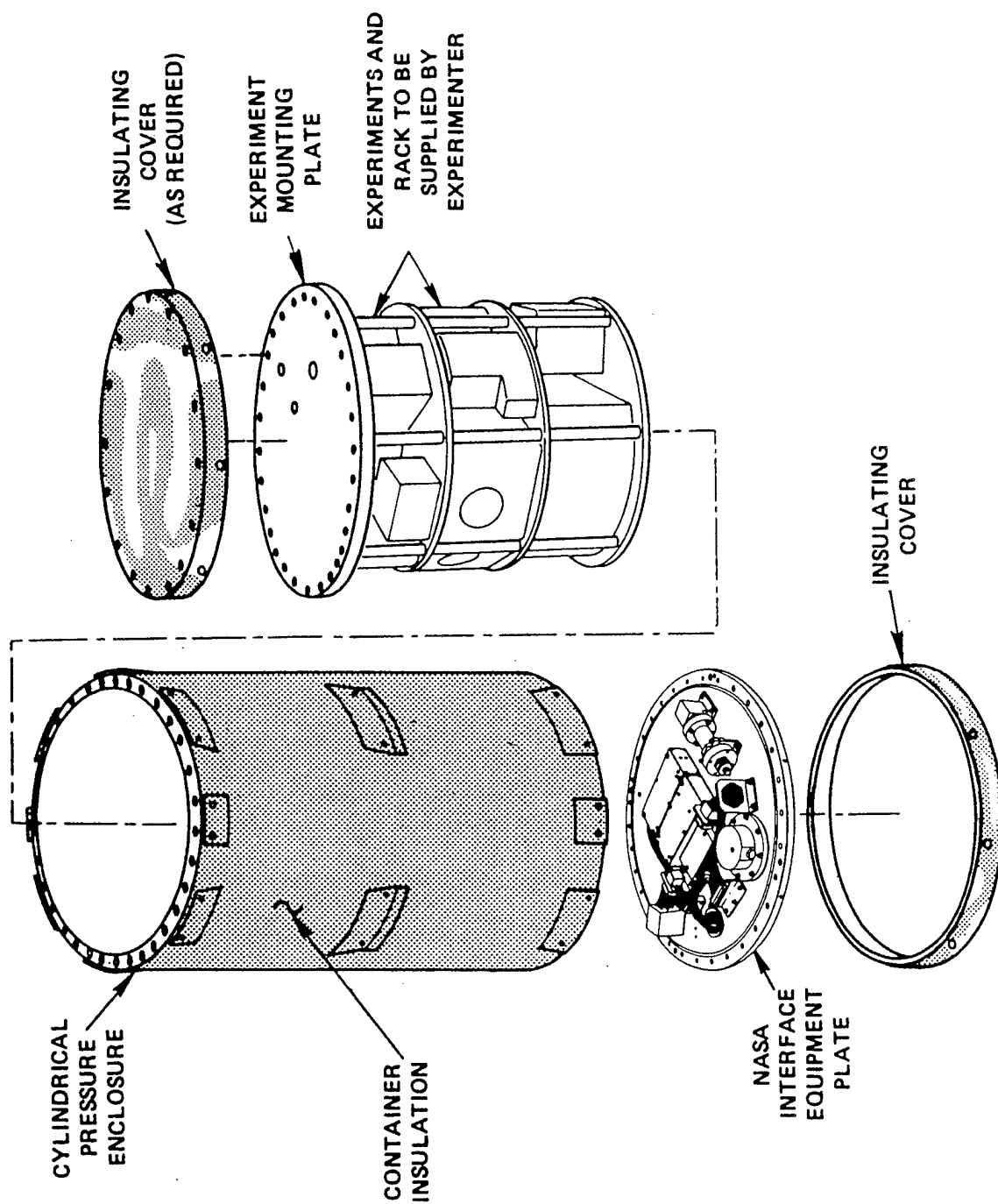
NASA
INTERFACE
VOLUME
(7 IN. HIGH)

SEAL

FILTERED
VENTS

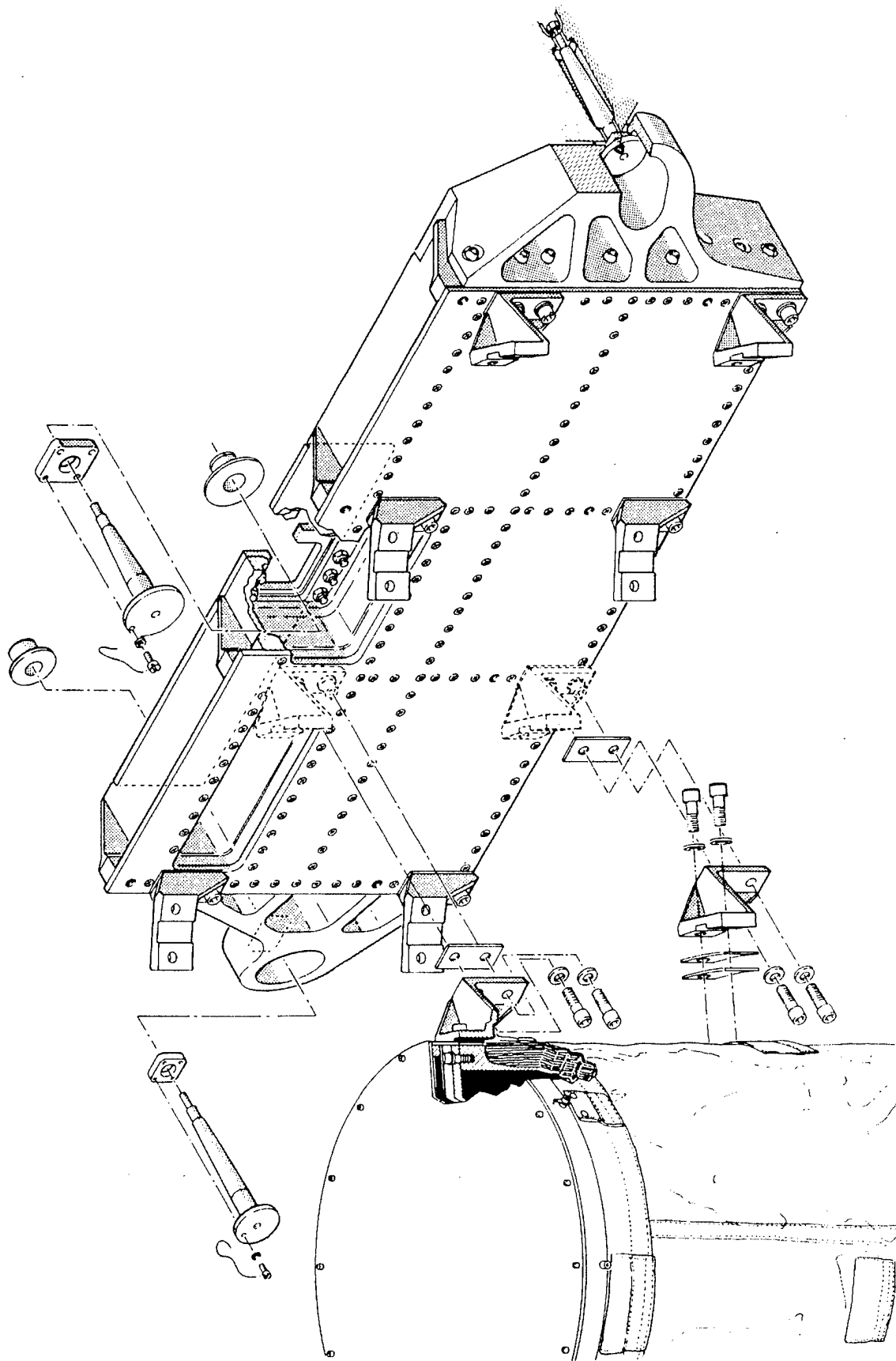
GET AWAY SPECIAL SMALL SELF-CONTAINED PAYLOADS

CONTAINER CONCEPT

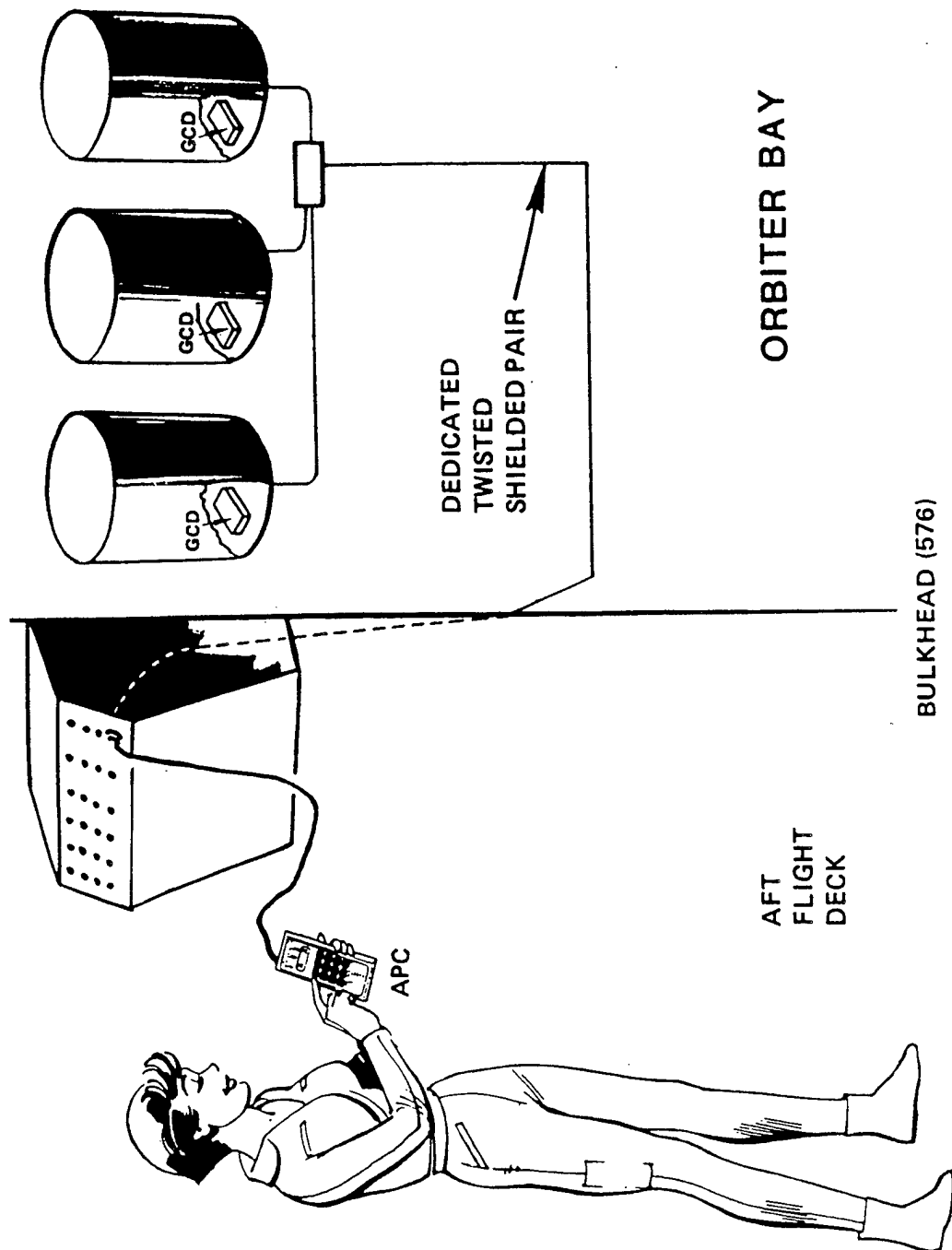


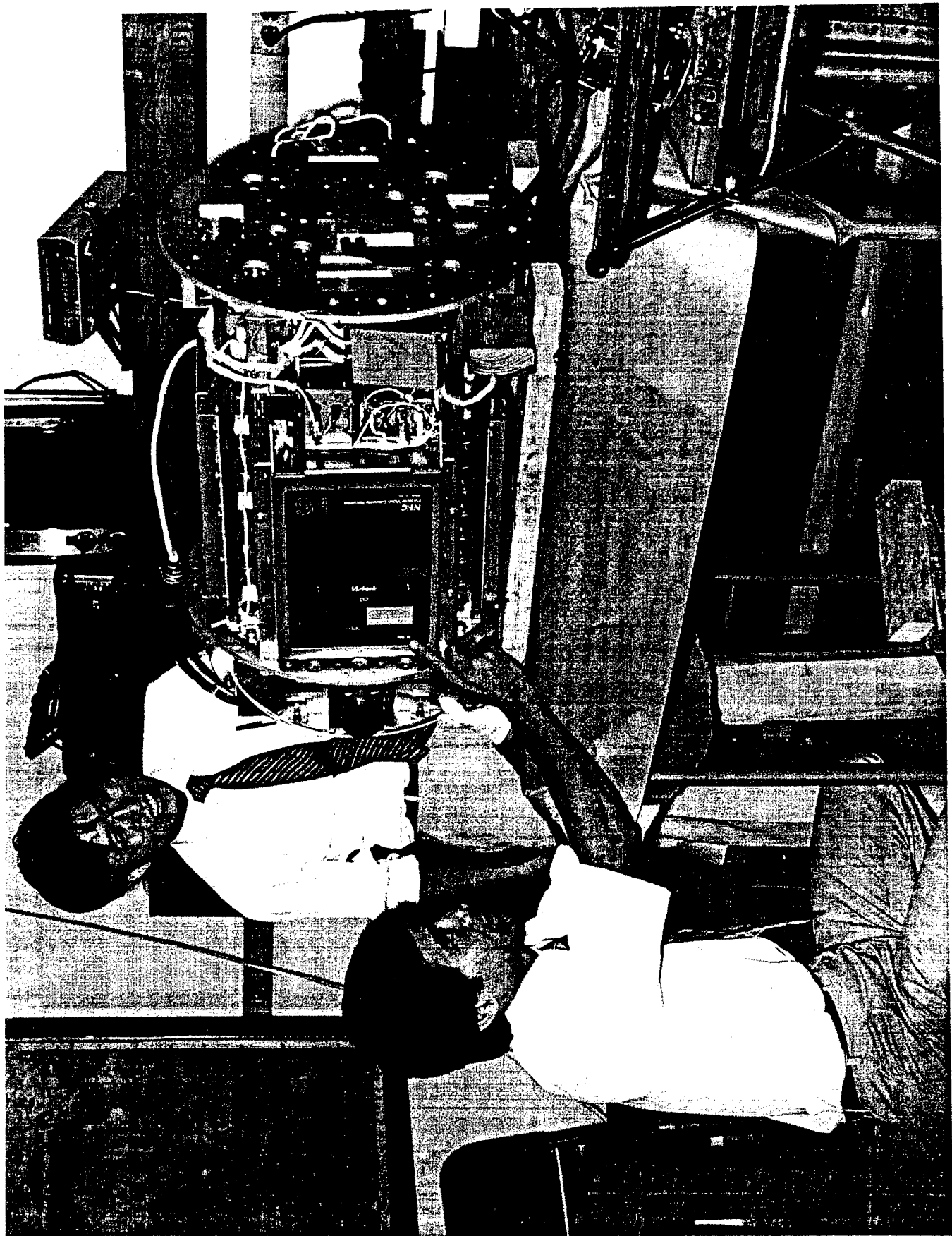
GAS

CONTAINER/ADAPTER BEAM ASSEMBLY



GET AWAY SPECIAL SMALL SELF-CONTAINED PAYLOADS CONTROL CONCEPT





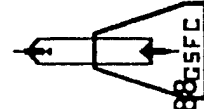
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HITCHHIKER PROJECT OVERVIEW

**T.C. GOLDSMITH
SHUTTLE SMALL PAYLOADS PROJECT
GODDARD SPACE FLIGHT CENTER**

SHUTTLE SMALL PAYLOADS PROJECT

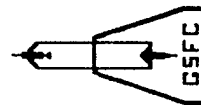
- THE SHUTTLE SMALL PAYLOADS PROJECT CONTAINS THE HITCHHIKER, GET-AWAY-SPECIAL (GAS), AND COMPLEX AUTONOMOUS PAYLOADS (CAP) PROJECTS.
- HITCHHIKER INCLUDES HH-G SIDE MOUNT CARRIERS AND HH-M CROSS-BAY CARRIERS WHICH CONNECT TO ORBITER ELECTRICAL SERVICES AND ARE FLOWN UNDER THE SECONDARY PAYLOAD MANIFEST.
- GAS PAYLOADS ARE MOUNTED IN CANISTERS, DO NOT CONNECT TO ORBITER ELECTRICAL SERVICES, AND DO NOT REQUIRE SIGNIFICANT STS SUPPORT. GAS PAYLOADS ARE IN AN EXISTING TERTIARY PAYLOAD QUEUE. NO NEW RESERVATIONS ARE BEING ACCEPTED BUT EXISTING LAUNCH SLOTS MAY BE SOLD BY EXISTING RESERVATION HOLDERS.
- COMPLEX AUTONOMOUS PAYLOADS USE GAS PROJECT CARRIER EQUIPMENT, DO NOT CONNECT TO ORBITER ELECTRICAL SERVICES, BUT MAY REQUIRE STS SERVICES SUCH AS POINTING, CREW ACTIVITY, LATE ACCESS, ETC. IN EXCESS OF THOSE ALLOWED FOR GAS. CAP PAYLOADS ARE MANIFESTED UNDER THE SECONDARY PAYLOAD SYSTEM.



TCG 11/28/88

HITCHHIKER PROGRAM DESCRIPTION

- o THE HITCHHIKER PROGRAM WAS INITIATED BY THE NASA OFFICE OF SPACE FLIGHT IN 1984 TO PROVIDE A QUICK REACTION SHUTTLE CARRIER SERVICE FOR SMALL PAYLOADS. GSFC DEVELOPED THE SHUTTLE PAYLOAD OF OPPORTUNITY CARRIER (SPOC) SYSTEM TO SUPPORT THE HITCHHIKER-G PROGRAM. SPOC WAS SPECIFICALLY DESIGNED TO HAVE SIMPLE, STANDARD CARRIER TO ORBITER INTERFACES AND STANDARD, USER-FRIENDLY, CARRIER TO CUSTOMER INTERFACES TO REDUCE PAYLOAD UNIQUE INTEGRATION EFFORT REQUIRED AND THEREBY REDUCE LEAD TIME AND RECURRING COST. HITCHHIKER-G IS A FAMILY OF COMPONENTS DESIGNED TO MOUNT SMALL PAYLOADS TO THE SIDE OF THE ORBITER WITH MINIMUM TOTAL PAYLOAD WEIGHT.
- o HITCHHIKER-M IS A SECOND CARRIER SYSTEM DEVELOPED BY MSFC AND CONSISTING OF A CROSS-BAY (BRIDGE) TYPE CARRIER INTENDED FOR SOMEWHAT HEAVIER PAYLOADS. IN 1987 THE HITCHHIKER-M CARRIER SYSTEM WAS COMBINED WITH THE HITCHHIKER-G PROJECT AT GSFC AND WILL FLY WITH THE SAME ELECTRICAL CUSTOMER AND ORBITER INTERFACES AS THE HITCHHIKER-G.
- o HITCHHIKER IS BASICALLY AN EXTENSION OF THE STS AND IS PROVIDED AND OPERATED BY THE OFFICE OF SPACE FLIGHT AT NO COST TO A NASA USER PROVIDED ONLY STANDARD SERVICES ARE REQUIRED. EXCESS SERVICES ARE FUNDED BY THE CUSTOMER.
- o HITCHHIKERS ARE FLOWN AS SECONDARY PAYLOADS UNDER THE 7/87 NASA SECONDARY PAYLOAD POLICY AND CAN FLY AS EITHER "SMALL" PAYLOADS OR STANDARD ATTACHED MIXED CARGO PAYLOADS.



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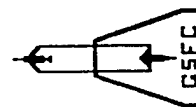
HITCHHIKER MANIFESTING SITUATION

- o A NEW POLICY FOR SECONDARY PAYLOADS ON NASA SHUTTLE FLIGHTS WAS ANNOUNCED 7/29/87 AS FOLLOWS:

- o ALLOCATIONS OF SECONDARY PAYLOAD SPACE BY WEIGHT (PERCENTAGE OF AVAILABLE SPACE) HAVE BEEN ESTABLISHED FOR THE VARIOUS DISCIPLINES AS FOLLOWS: THE CORRESPONDING TOTAL PAYLOAD WEIGHT FOR EACH DISCIPLINE IS SHOWN FOR THE 4/30/88 MANIFEST.

CODE E 38	39602	SCIENCE AND APPLICATIONS
CODE C 31	33500	COMMERCIALIZATION
CODE S 10	16575	SPACE STATION TECHNOLOGY
CODE R 9	10215	SPACE TECHNOLOGY
CODE M 5	4470	STS TECHNOLOGY
CODE A 3	3666	AGENCY LEVEL
CODE X 3	3835	FOREIGN REIMBURSABLE
CODE C 1	0	DOMESTIC REIMBURSABLE
DOD 0	0	DOD (UNDER NEGOTIATION)
TOTAL 100	111863	

- o GET-AWAY-SPECIAL (GAS) PAYLOADS WILL FLY IN SPACE AVAILABLE AFTER ACCOMMODATING PRIMARY AND SECONDARY PAYLOADS AND WILL CONTINUE TO USE THE EXISTING QUEUE AND POLICY. NO NEW GAS PAYLOADS ARE BEING ACCEPTED.
- o EMPHASIS TO BE PLACED ON MICROGRAVITY PAYLOADS OR SPACE STATION SUPPORT.

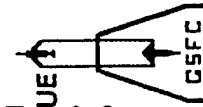


TCG 4/29/88

MANIFESTED IN-BAY SECONDARY PAYLOADS AS OF 10/1/88

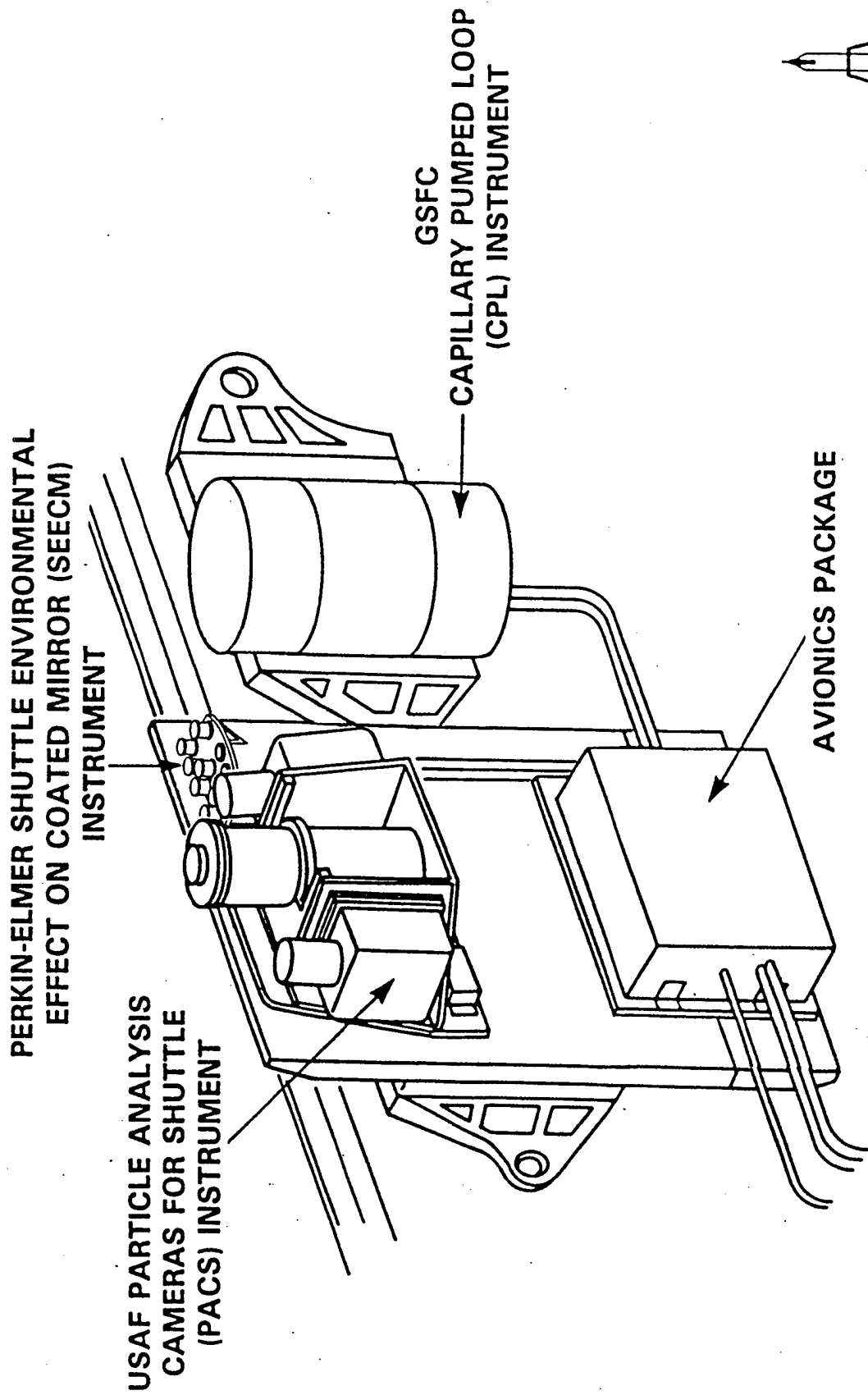
FLIGHT	PAYLOAD	ORG	WEIGHT	CARRIER
89- 2/18	SHARE	CDS	830	UNIQUE
89- 2/18	SSBUD-1	CDE	1219	CSCP
90-11/08	SSBUD-2	CDE	1219	CSCP
90-TBD	TPC	CDR	495	CSCP
91- 1/31	PMG-1	CDM	730	HH-G
91- 1/31	ASP	CDX	540	HH-G
91- 8/15	FTS-DTF-1	CDS	1500	TBD
91-12/23	CXH-1	CDC	4000	HH-M
92- 2/27	DEE	CDM	300	UNIQUE
92- 2/27	SDS-1	CDE	930	HH-G
92- 6/11	EOIM/TEMP2A2	CDS	2345	UNIQUE
92- 6/11	SSBUD-3	CDE	1219	CSCP
92- 7/30	CTM	CDX	830	HH-G
92- 7/30	HPE	CDX	930	HH-G
92-10/29	SPARTAN-2	CDE	5700	SPARTAN
92-11/19	SEDS	CDM	350	UNIQUE
92-TBD	CGAS-1	CDC	500	CSCP
93- 1/14	MAST-1 CSI	CDR	7000	UNIQUE
93- 2/11	LTE-1	CDR	4900	UNIQUE
93- 2/11	CXH-2	CDC	3000	HH-M
93- 3/18	SDS-2	CDE	740	HH-G
93- 4/08	SFH	CDM	3200	HH-M
93- 4/15	MSL-3	CDE	5700	MSL
93- 6/10	SSBUD-4	CDE	980	CSCP
93- 6/17	FTS-DTF-2	CDS	5500	TBD
93- 6/17	CXM-1	CDC	6000	MSL
93- 8/05	CXH-3	CDC	3000	HH-M
93- 9/09	SRAD	CDS	5700	UNIQUE
93-TBD	CGAS-2	CDC	500	CSCP
93-TBD	CGAS-3	CDC	500	CSCP

* HITCHHIKER / CSCP PAYLOADS

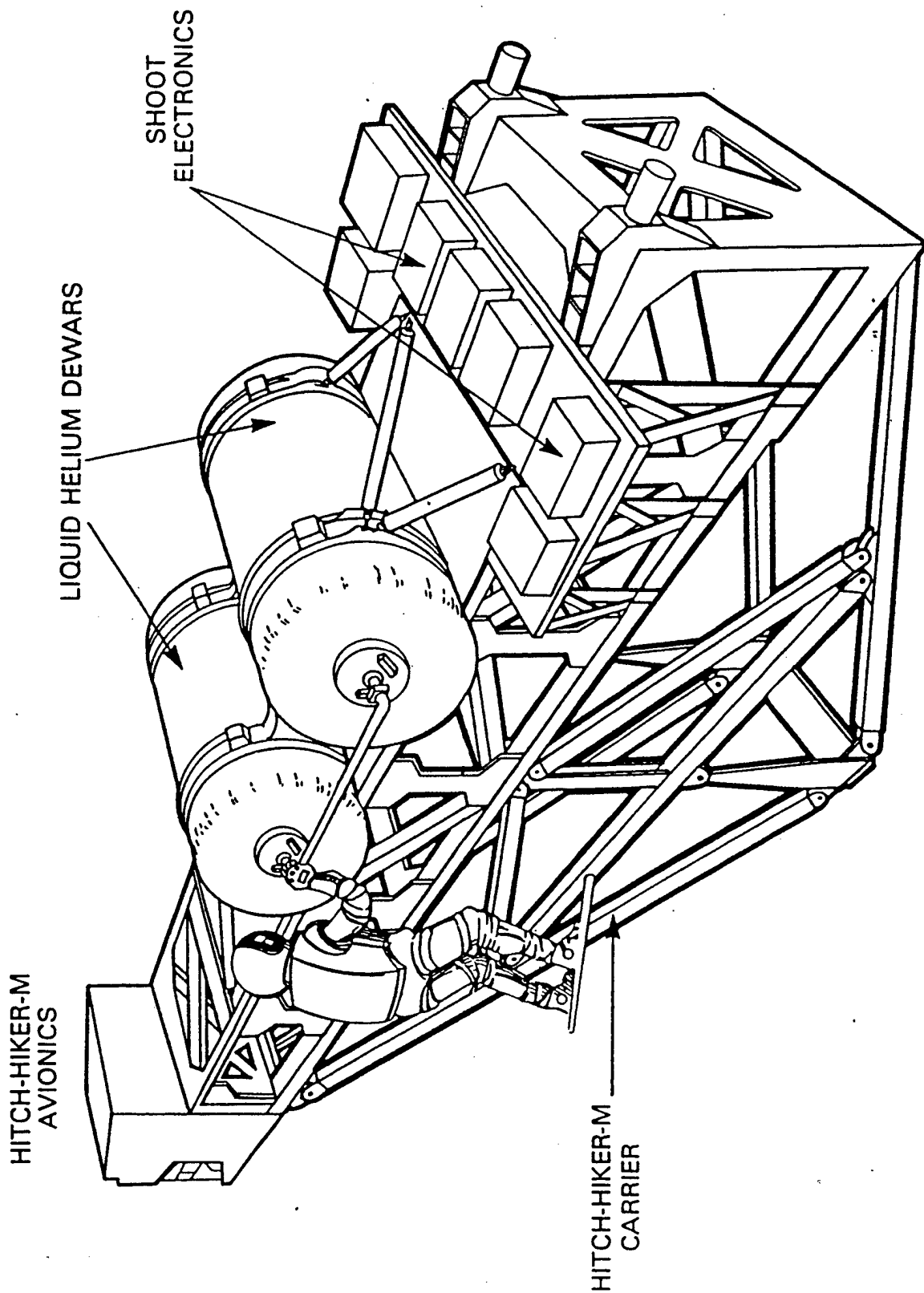


TCG 10/3/88

HITCHHIKER-G MISSION ONE

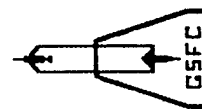


SUPERFLUID HELIUM ON ORBIT TRANSFER FLIGHT DEMONSTRATION



SPOC FEATURES FOR REDUCTION OF CUSTOMER COSTS

- STANDARD PRE-DEFINED INTERFACES REDUCE ENGINEERING EFFORT, DESIGN ITERATION, AND LEAD TIME.
- TRANSPARENT DATA SYSTEM ALLOWS USE OF CUSTOMER'S OWN GROUND SUPPORT EQUIPMENT, SOFTWARE, AND PERSONNEL DURING PAYLOAD INTEGRATION AND FLIGHT OPERATIONS MINIMIZING RETRAINING AND RETESTING EFFORTS AND ALLOWING THE CUSTOMER MAXIMUM AUTONOMY.
- SIMPLE MOUNTING SCHEME.
- CANISTER OPTION PROVIDES CONTAINMENT AND REDUCES SAFETY ANALYSIS.
- SHORT HANDS-ON INTEGRATION PERIOD - INSTRUMENTS DELIVERED AS LATE AS L-5 MONTHS.
- REDUCED REQUIREMENTS FOR CONFERENCES, TRAVEL, ETC.

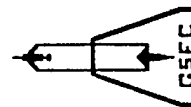


TCG 3-17-86

TYPICAL HITCHHIKER SCHEDULE MILESTONES (MONTHS)

CUSTOMER SUBMITS CUSTOMER PAYLOAD REQUIREMENTS DOCUMENT	-24
CUSTOMER PAYLOAD ACCOMMODATION CONFERENCE AT GSFC	-23
PRELIMINARY SAFETY DATA	-18
CUSTOMER PAYLOAD DELIVERED TO GSFC	-6
INTEGRATED PAYLOAD DELIVERED TO LAUNCH SITE	-3
LAUNCH	0
CUSTOMER PAYLOAD RETURNED TO CUSTOMER	1
ALL DATA DELIVERED TO CUSTOMER	1

P R E L I M I N A R Y



TCG 11/10/87

HITCHHIKER MECHANICAL ACCOMMODATIONS

o PLATE

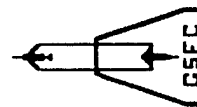
- THE LARGE PLATE IS 50 X 60 INCHES AND CAN ACCOMMODATE UP TO 250 LBS OF CUSTOMER HARDWARE IN ADDITION TO THE SPOC AVIONICS.
- THE SMALL PLATE IS 25 X 39 INCHES AND CAN ACCOMMODATE 100 LBS.
- PLATES HAVE A GRID OF 3/8 BOLT HOLES ON 70 MM CENTERS.

o CANISTER

- THE CANISTERS CAN ACCOMMODATE A PAYLOAD 19.25 INCHES (DIA) X 28 INCHES (HEIGHT).
- CANISTERS WITH OPENING DOORS CAN ACCOMMODATE 170 LB PAYLOADS.
- SEALED CANISTERS (1 ATM AIR OR NITROGEN) CAN ACCOMMODATE 200 LB.

o BRIDGE (HH-M)

- THE BRIDGE HAS THREE ATTACHMENT LOCATIONS EACH ON THE TOP, FRONT, AND REAR OF THE TRUSS. THE TOP LOCATIONS CAN ACCOMMODATE UP TO 380 LBS EACH AND THE SIDE LOCATIONS CAN ACCOMMODATE UP TO AT LEAST 170 LBS. THE SIDE MOUNTING AREAS ARE 27 X 28 INCHES AND THE TOP MOUNTS ARE 28 X 36 INCHES. STANDARD MOUNTING HOLES ARE PROVIDED.



TCG 11/10/87

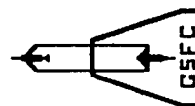
HITCHHIKER CUSTOMER ACCOMMODATIONS (CONT'D)

o THERMAL

- THERMAL CONTROL SURFACES, HEATERS, THERMOSTATS, ETC. ON PLATE MOUNTED CUSTOMER EQUIPMENT ARE PROVIDED BY THE CUSTOMER.
- GSFC PROVIDES EXTERNAL THERMAL BLANKET OR WHITE PAINT SURFACE FOR CANISTERS.
- NO FLUID LOOP COOLING IS PROVIDED BUT SEVERAL HUNDRED WATTS (CONTINUOUS) OR SEVERAL KW (SHORT PERIODS) OF HEAT DISSIPATION CAN USUALLY BE ACCOMMODATED BY RADIATION AND TEMPORARY STORAGE OF HEAT IN THE THERMAL MASS OF THE EQUIPMENT.

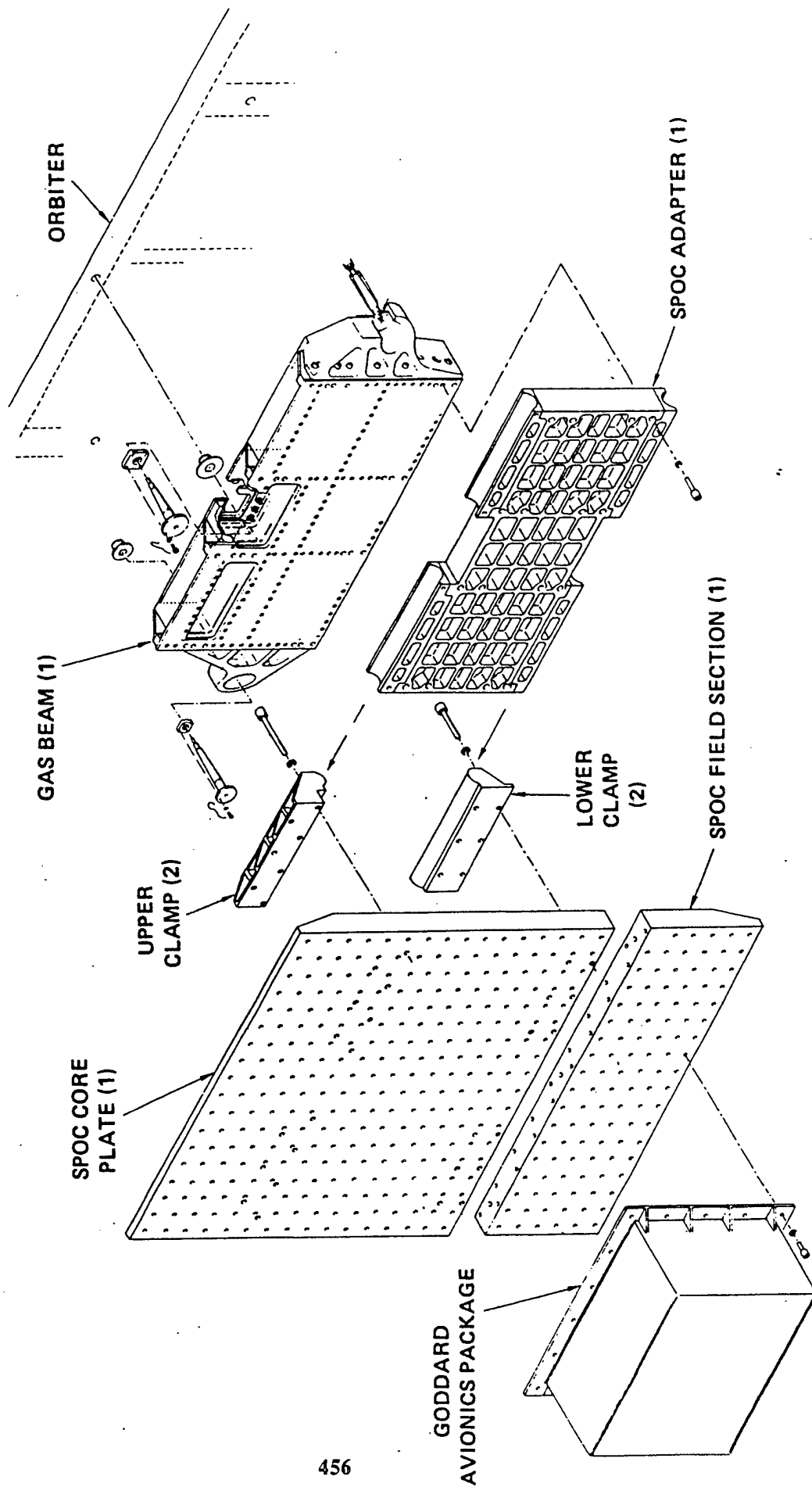
o ATTITUDE CONTROL

- ORBITER CAN POINT AT A TARGET WITHIN 9 ARC MINUTES (5 ARC MIN FOR SHORT PERIODS).
- USER SUPPLIED POINTING SYSTEM CAN BE USED TO IMPROVE POINTING ACCURACY.
- NOMINAL SHUTTLE ATTITUDE IS BAY DOWN.



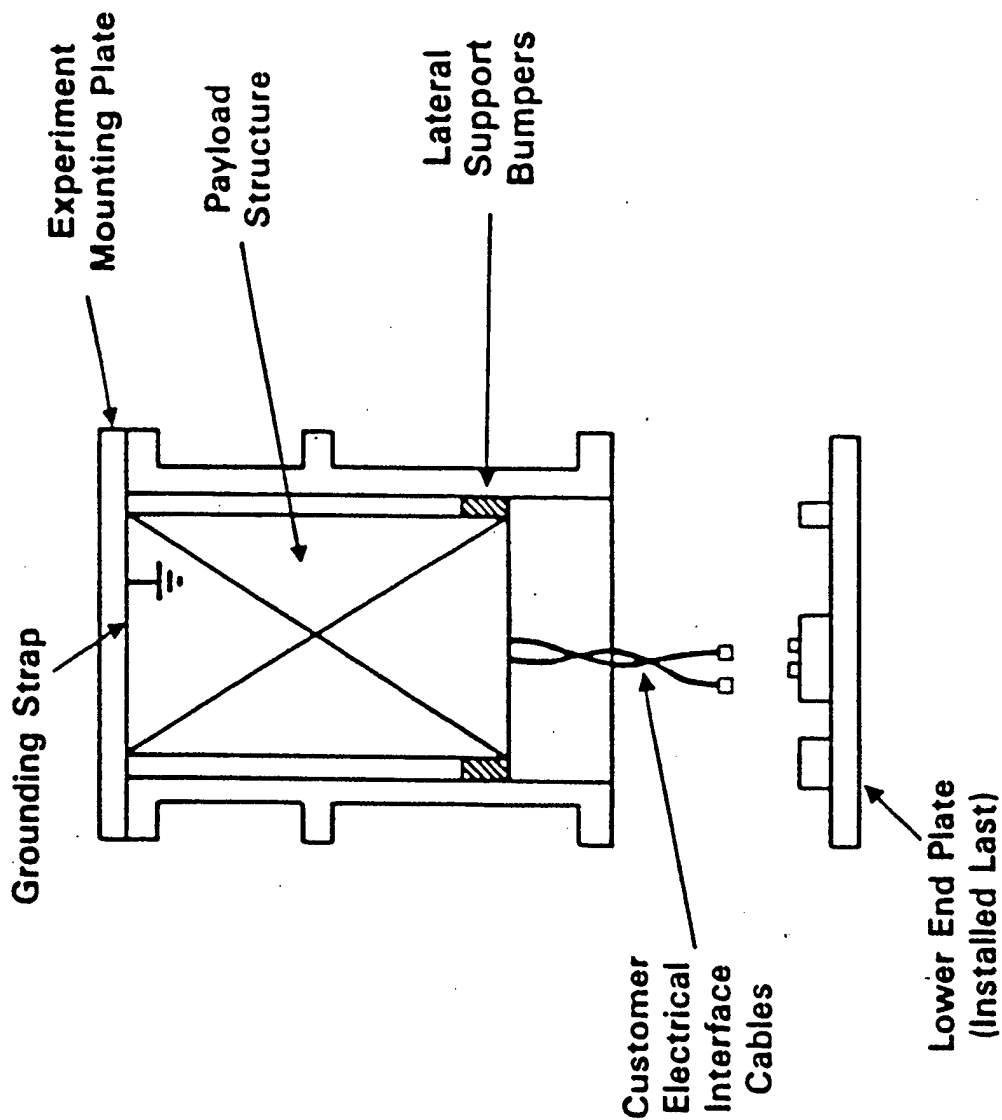
TCG 11/10/87

SPOC STRUCTURAL ASSEMBLY (EXPLODED VIEW)



Hitchhiker-G Canister

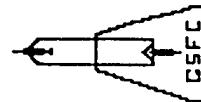
Mechanical and Electrical Interfaces



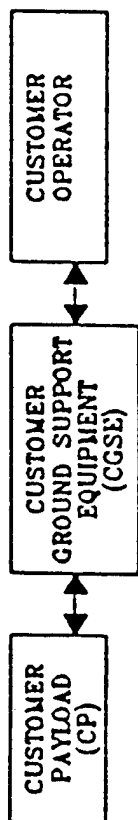
CUSTOMER ELECTRICAL INTERFACES

The standard electrical interface or "port", consists of a signal cable and a separate power cable which provide the following:

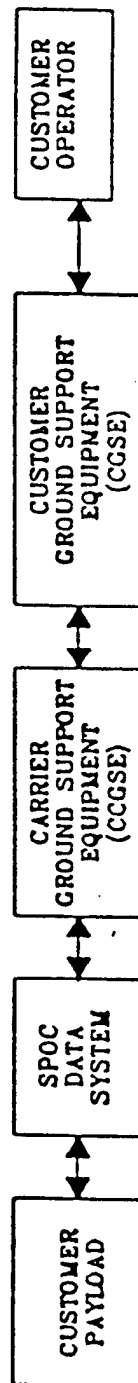
- o Two 28 V (+/- 4 V) 10 Amp. power lines which can be turned on (together) by ground command. Customer power and energy are monitored by the carrier system. The maximum simultaneous total customer power for a Hitchhiker is 1300 W and the nominal maximum total customer energy is 6 KWH/ day with additional energy negotiable. Non-Hitchhiker payloads may use up to 1650 W (2300 W for 15 minutes) and 10 KWH/day.
- o Four 28V bi-level or pulse commands (10 ma max) which can be used with relay drivers and relays to control additional power switching within a payload. (For canister payloads one command is reserved for control of the door.)
- o An asynchronous 1200 baud uplink command channel.
- o An asynchronous 1200 baud low-rate, downlink data channel. This data is available over Ku-band service or S-band service and can also be recorded on the orbiter's tape recorder.
- o A medium-rate downlink channel 1-1400 KB/s for use with the real-time-only Ku-band TDRS service. The total simultaneous customer data rate for the carrier cannot exceed 1400 KB/s.
- o IRIG-B serial time code and a one pulse per minute square wave signal which can be complemented by a time command via the above asynchronous uplink channel.
- o Three channels for temperature sensors to allow measurement of payload temperatures even when the payload power is off (for canister payloads these channels are reserved for door position, canister pressure, and temperature).
- o An analog channel, 0-5V, 8 bit quantizing, 10 hertz sample rate. An index pulse is also supplied which can be used to advance a user supplied analog multiplexer to allow measuring a large number of parameters.



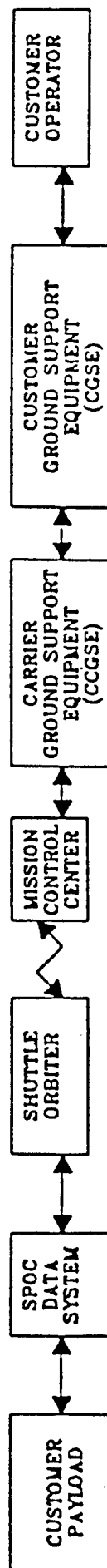
TCG 9/8/86



AT CUSTOMER'S FACILITY

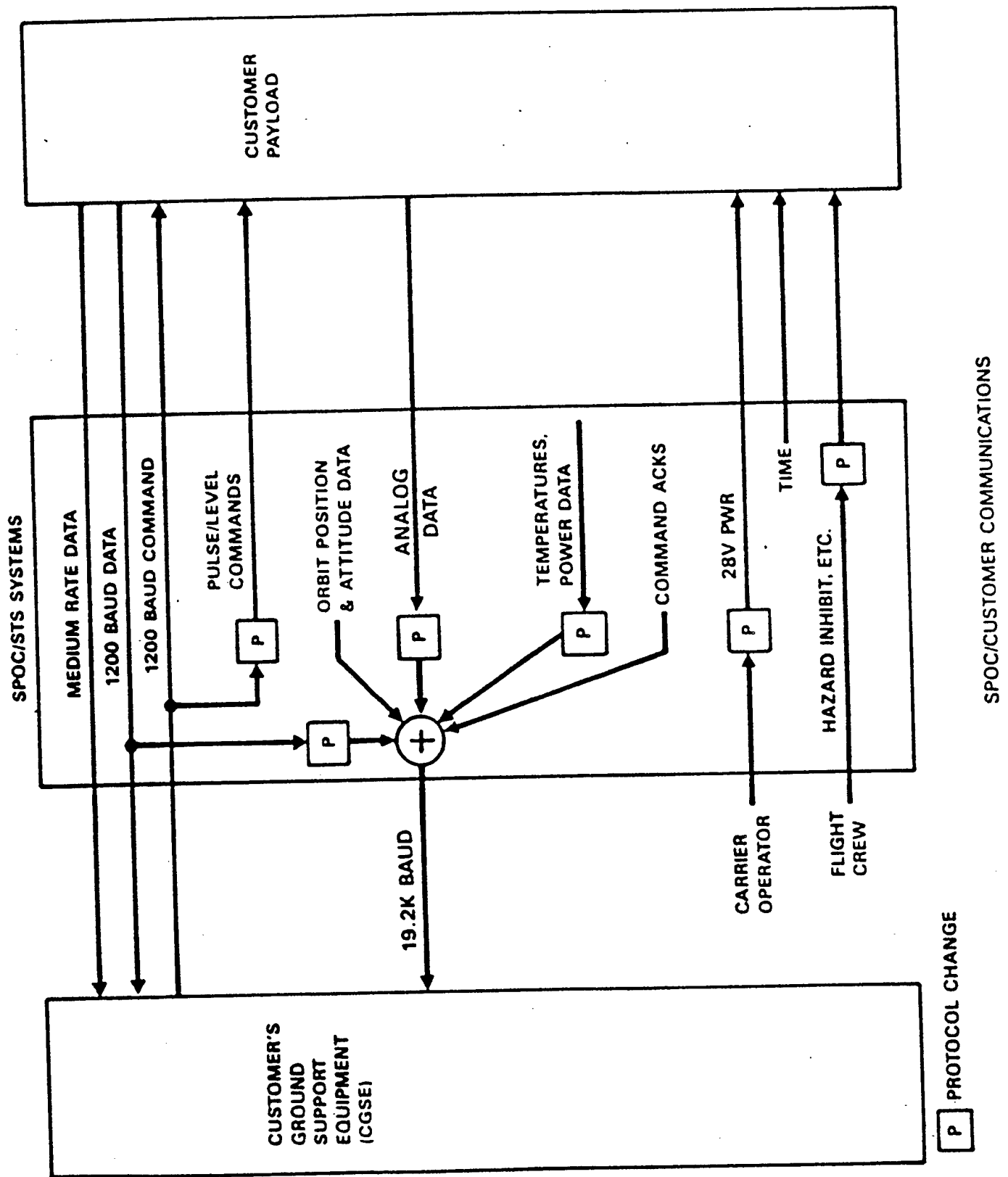


AT CUSTOMER/CARRIER INTEGRATION



AT FLIGHT OPERATIONS

SPOC TRANSPARENT DATA SYSTEM COMMUNICATIONS



MIDDECK PAYLOAD INTEGRATION

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**NSTS
INTEGRATION
AND
OPERATIONS**

**JOHN C. O'LAUGHLIN
SPACELAB & MIDDECK INTEGRATION OFFICE
JOHNSON SPACE CENTER**



NSTS INTEGRATION AND OPERATIONS

MIDDECK PAYLOAD INTEGRATION

- ORBITER CREW MODULE DESCRIPTION
- MIDDECK PAYLOAD ACCOMMODATIONS
- PAYLOAD DESIGN GUIDELINES/CONSIDERATIONS
- SCHEDULES/MANIFESTING

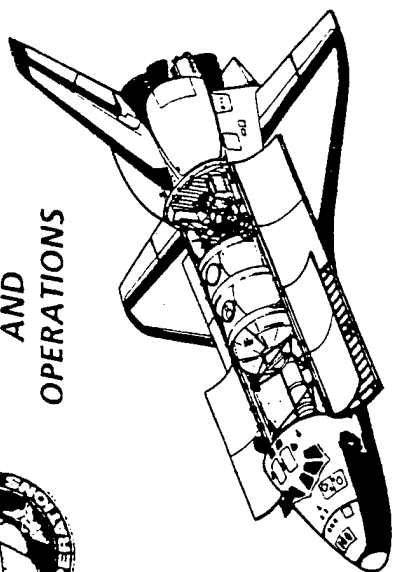
NSTS
INTEGRATION
AND
OPERATIONS



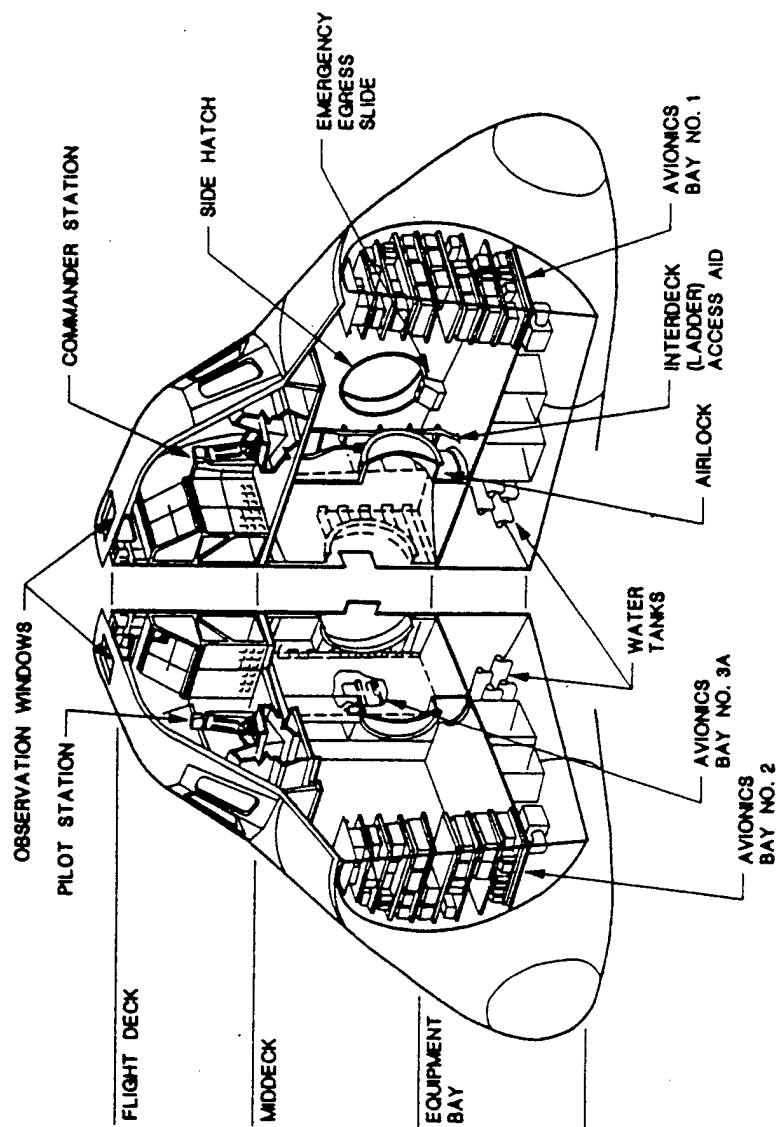
ORBITER CREW MODULE DESCRIPTION



NSTS INTEGRATION AND OPERATIONS

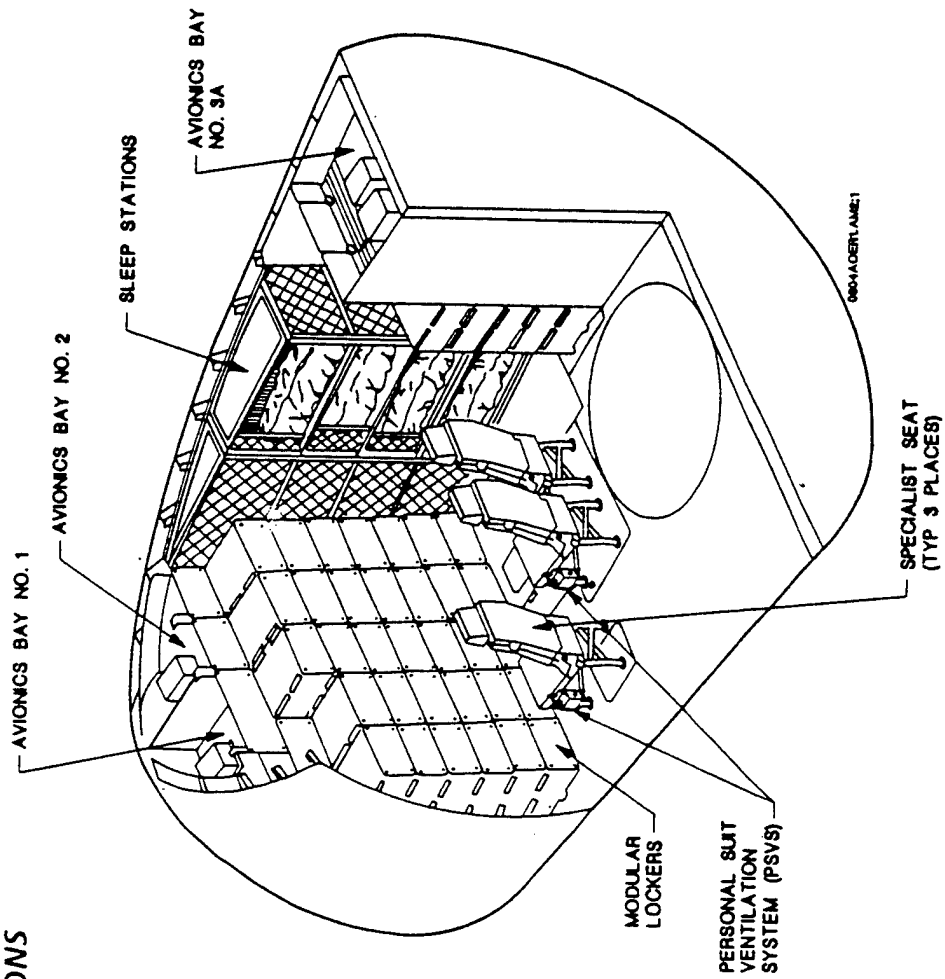


ORBITER CREW MODULE





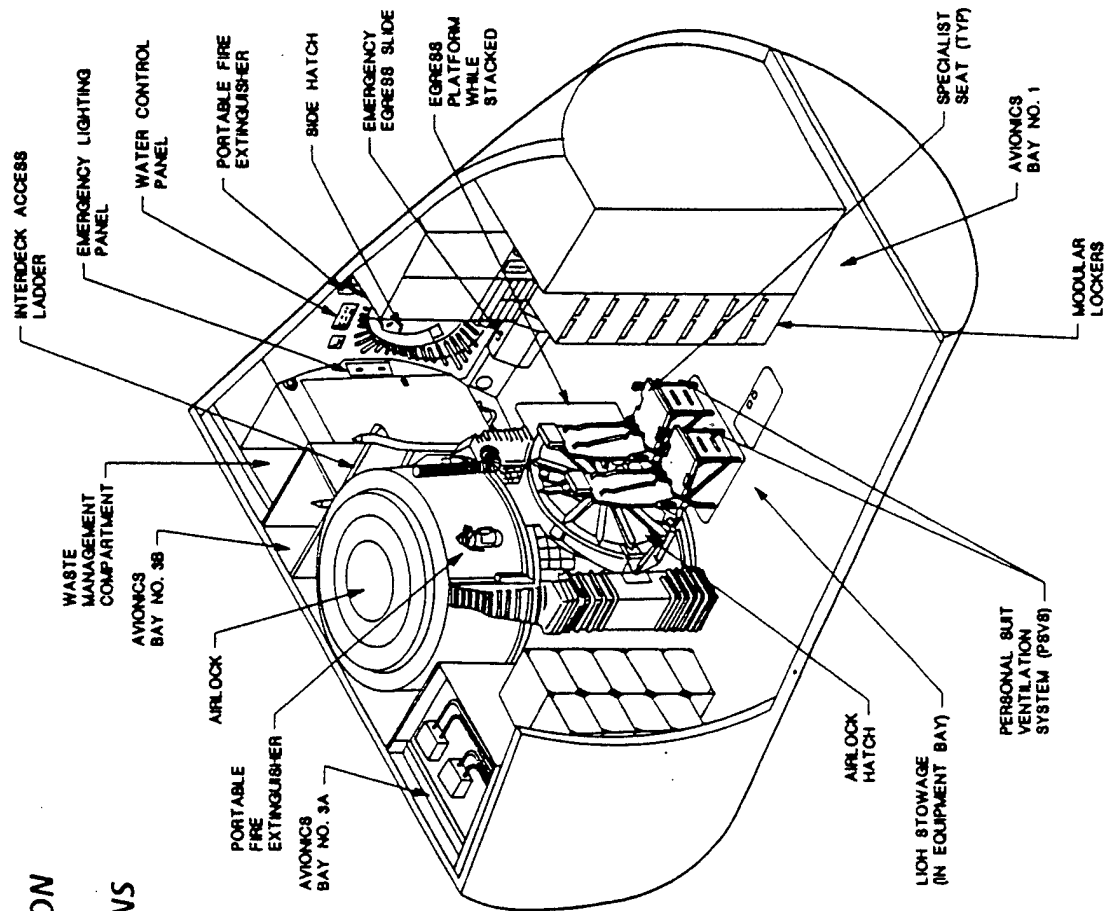
**NSTS
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AND
OPERATIONS**



MIDDECK - RIGHT SIDE VIEW LOOKING FORWARD AND OUTBOARD



NSTS INTEGRATION AND OPERATIONS



MIDDECK - LEFT SIDE VIEW LOOKING AFT AND OUTBOARD

**NSTS
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AND
OPERATIONS**



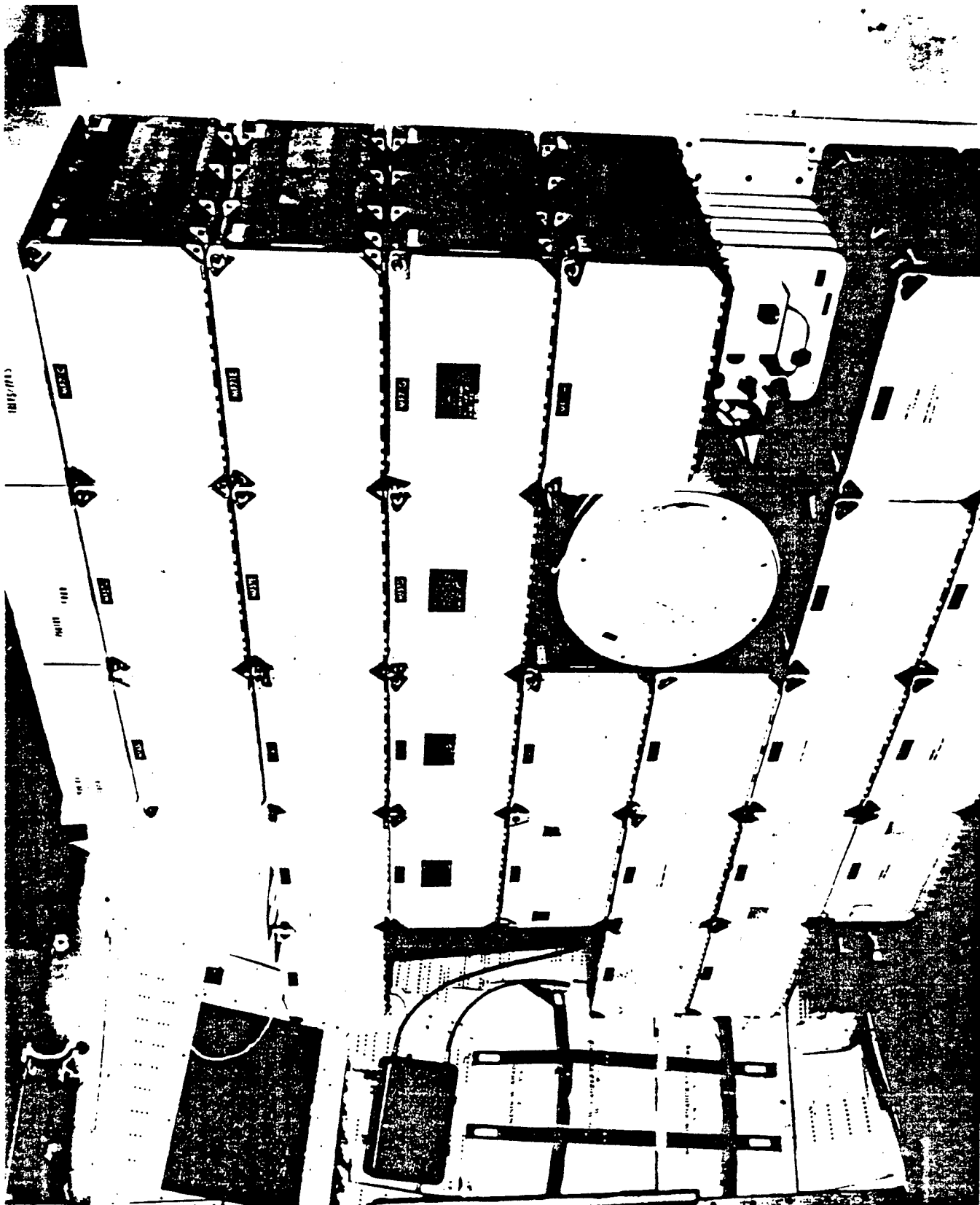
MIDDECK PAYLOAD ACCOMMODATIONS



**NSTS
INTEGRATION
AND
OPERATIONS**

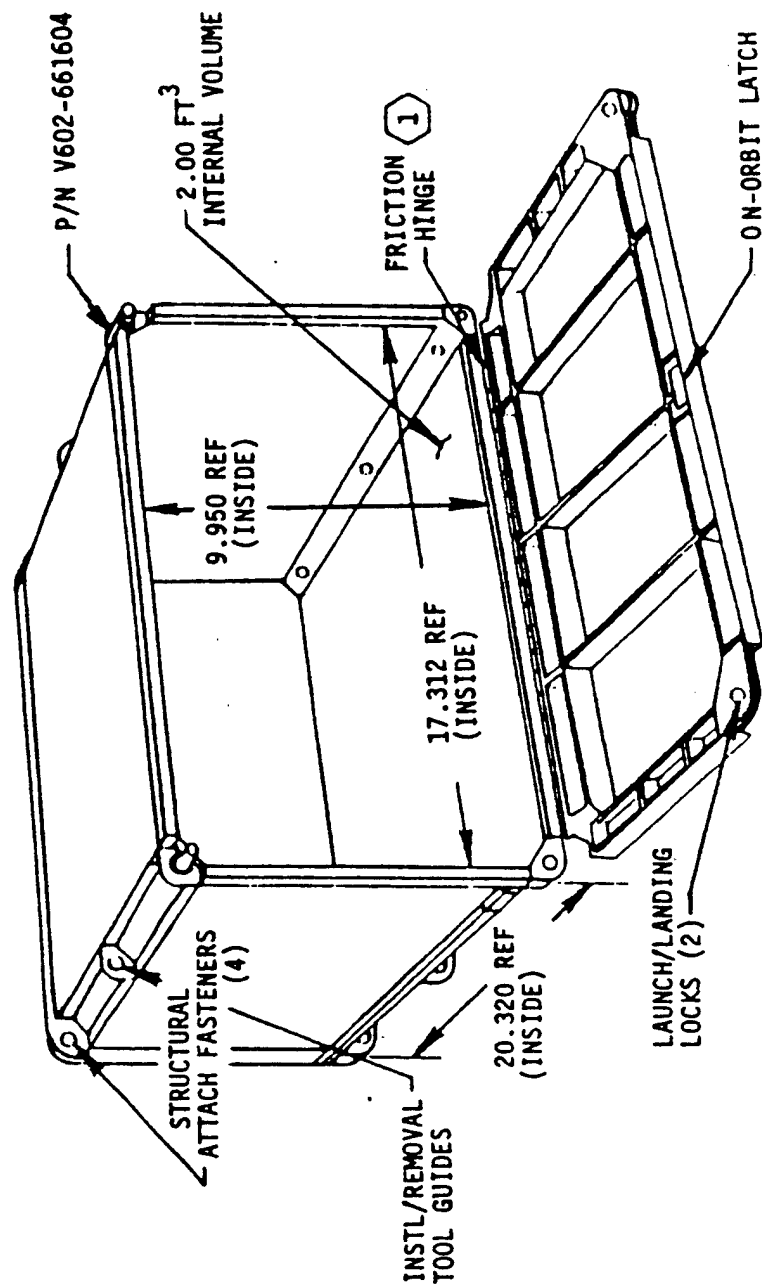
PHYSICAL ACCOMMODATIONS

- LOCKER STOWED PAYLOAD
 - 54 POUND MAX PAYLOAD WEIGHT
 - CENTER-OF-GRAVITY (CG) OF LOCKER CAN BE NO MORE THAN 14 INCHES FROM FACE OF ORBITER WIRE TRAY
 - LOCKER PROVIDES 2 CUBIC FEET OF STOWAGE VOLUME
- NONLOCKER PAYLOAD
 - 69 POUND MAX PAYLOAD WEIGHT - ONE LOCKER REPLACEMENT
 - 120 POUND MAX PAYLOAD WEIGHT - TWO LOCKER REPLACEMENT
 - CG OF PAYLOAD CAN BE NO MORE THAN 14 INCHES FROM FACE OF ORBITER WIRE TRAY.
 - MAX PAYLOAD WEIGHT CG DEPENDENT
 - PAYLOAD SHALL NOT PROTRUDE BEYOND FACE OF LOCKERS





NSTS INTEGRATION AND OPERATIONS

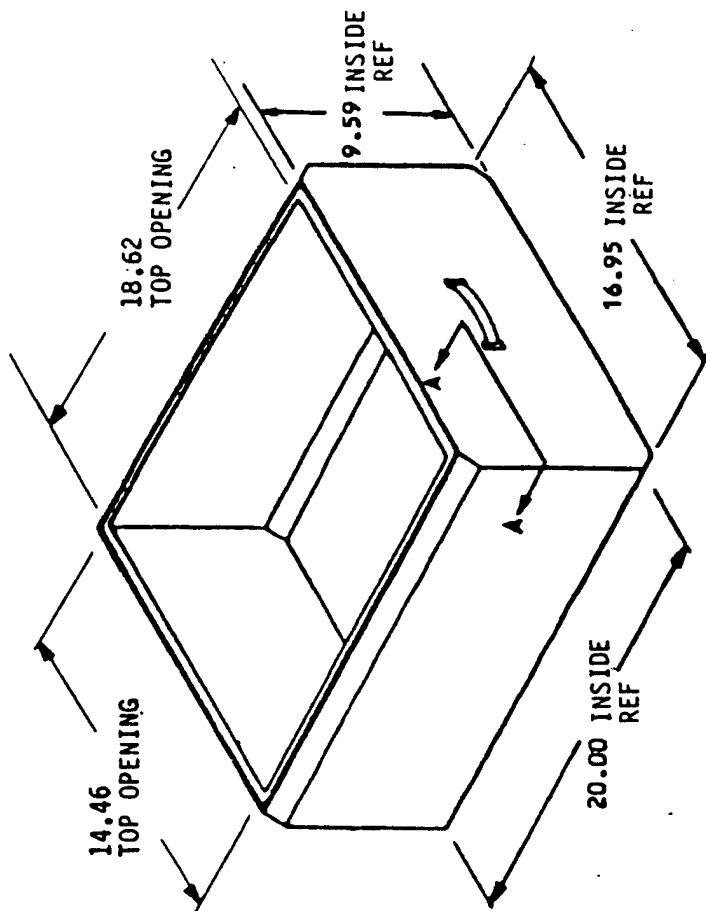


STANDARD MIDDECK MODULAR LOCKER

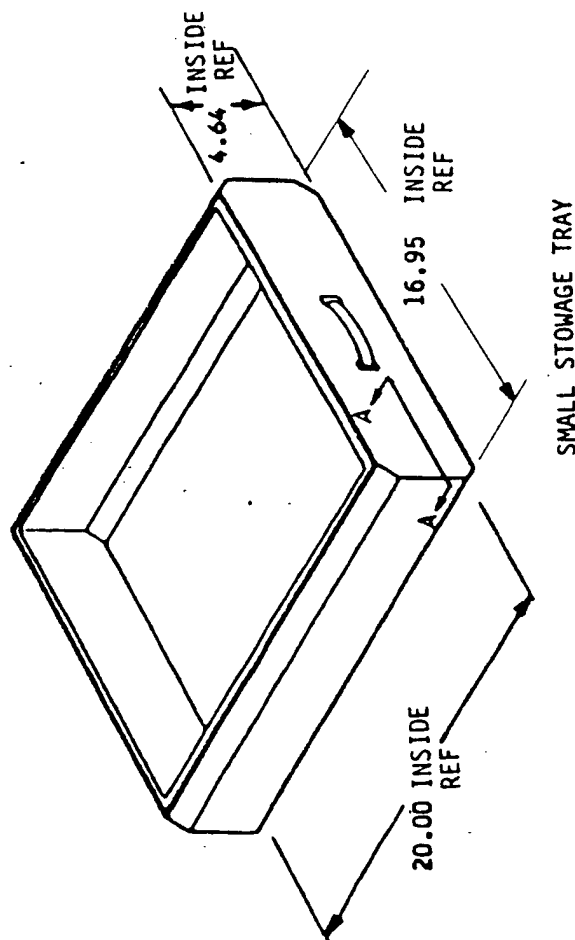
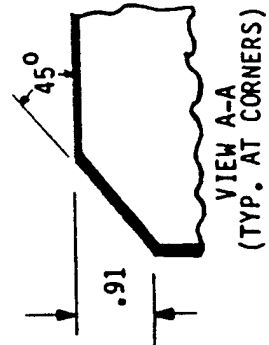


NSTS INTEGRATION AND OPERATIONS

MIDDECK LOCKER STANDARD STORAGE TRAYS



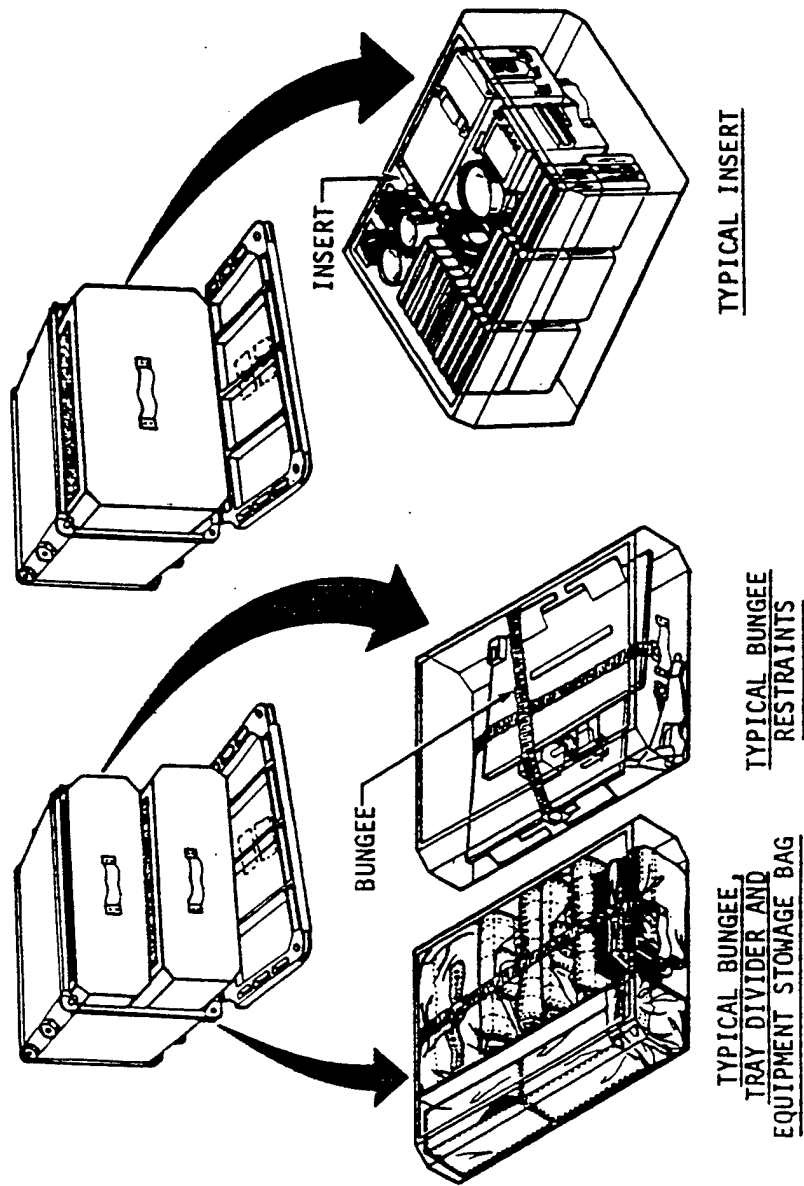
LARGE STORAGE TRAY



SMALL STORAGE TRAY



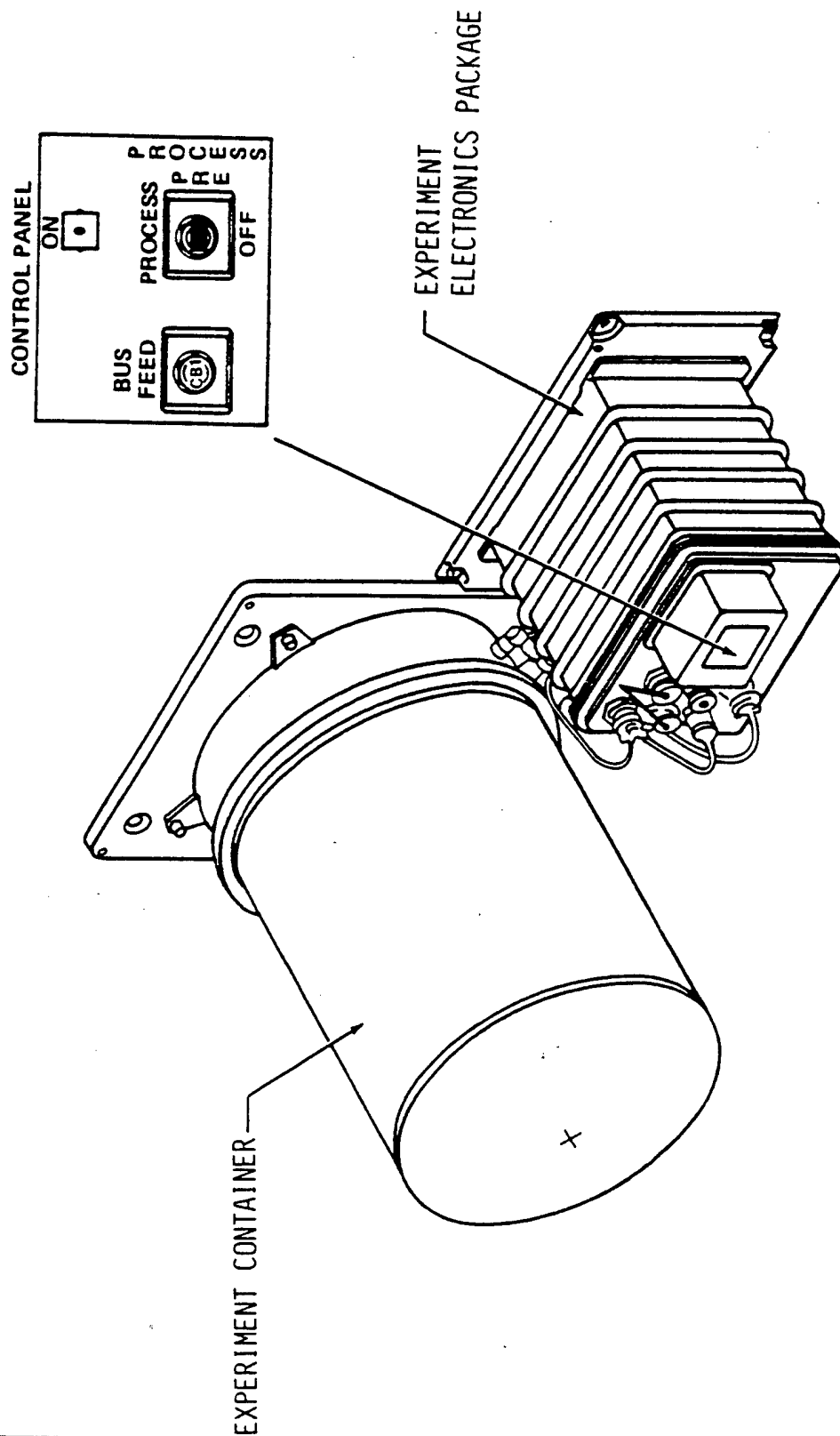
NSTS INTEGRATION AND OPERATIONS



MIDDECK MODULAR STOWAGE LOCKER CONFIGURATIONS



NSTS INTEGRATION AND OPERATIONS



EXAMPLE NONLOCKER MIDDECK PAYLOAD



NSTS
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ELECTRICAL POWER

- NOMINAL 28 VOLT DC, LIMITED TO 115 WATTS MAX CONTINUOUS
- POWER GENERALLY NOT AVAILABLE DURING ASCENT/DESCENT
- STANDARD POWER CABLES PROVIDED BY NSTS



NSTS INTEGRATION AND OPERATIONS

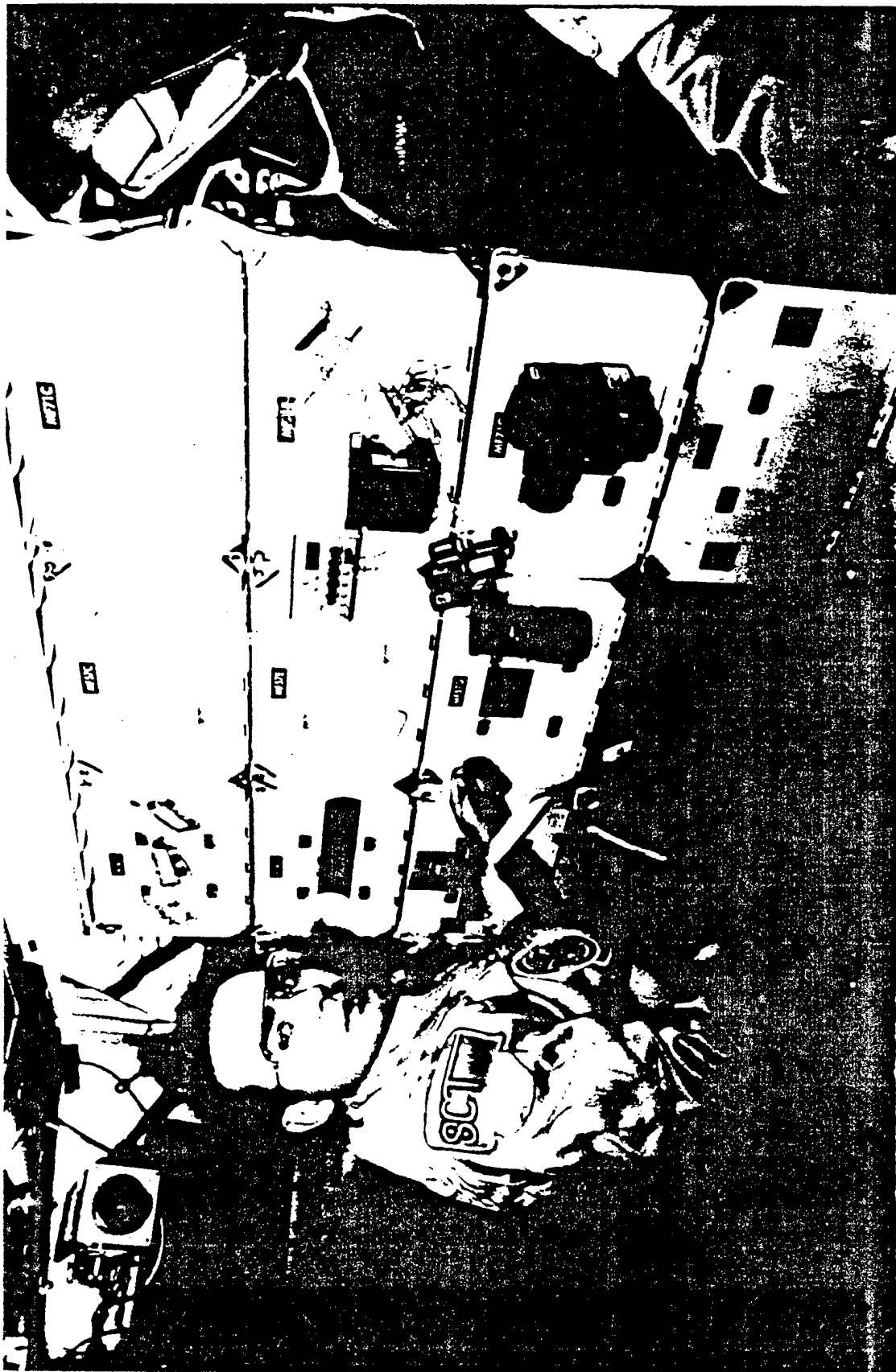
THERMAL

- COOLING
 - HEAT DISSIPATED INTO CREW COMPARTMENT BY PASSIVE OR FORCED AIR COOLING
 - PASSIVE AIR COOLING - HEAT LOAD LIMITED TO 60 WATTS MAX CONTINUOUS FOR LOCKER STOWED PAYLOAD
 - FORCED AIR COOLING - HEAT LOAD LIMITED TO 115 WATTS MAX CONTINUOUS
 - PAYLOAD PROVIDES AIR CIRCULATION FAN
 - AIR OUTLET TEMPERATURE LIMITED TO 120°F MAX
- EXTERNAL SURFACE TEMPERATURES
 - PAYLOAD SURFACES ACCESSIBLE TO CREW LIMITED TO 113°F MAX
 - PAYLOAD SURFACES INACCESSIBLE TO CREW LIMITED TO 120°F MAX



**NSTS
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AND
OPERATIONS**

PAYLOAD DESIGN GUIDELINES/CONSIDERATIONS





NSTS INTEGRATION AND OPERATIONS

- PAYLOAD OPERATIONS LIMITED TO MIDDECK EXCEPT FOR "OUT-THE-WINDOW" PHOTOGRAPHIC ACTIVITIES
- NO PAYLOAD OPERATIONS ON LAUNCH AND LANDING DAYS EXCEPT FOR SIMPLE ACTIVATION/DEACTIVATION ACTIVITIES
- PAYLOAD OPERATIONS REQUIRING CREW INVOLVEMENT ALLOWED ONLY DURING CREW AWAKE PERIODS
- NORMAL SHUTTLE FLIGHT HAS ONE-SHIFT ON-ORBIT WORKDAY OF 10 HOURS WITH 8 HOURS AVAILABLE FOR PAYLOAD OPERATIONS. AN ADDITIONAL 1 HOUR MAY BE AVAILABLE JUST BEFORE AND JUST AFTER THE NORMAL WORKDAY FOR SIMPLE PAYLOAD OPERATIONS
- TYPICAL SHUTTLE FLIGHT HAS A CREW OF 5 AND A DURATION OF 4-5 DAYS
- NO GROUND COMMANDING OR DATA DOWNLINK AVAILABLE FOR MIDDECK PAYLOADS



NSTS INTEGRATION AND OPERATIONS

- DOCUMENTATION FOR PAYLOADS
 - PAYLOAD PROVIDED SYSTEMS FOR DATA STORAGE
 - CREW COMMENTS - AUDIO/LOG BOOKS
 - VIDEO
 - PHOTOGRAPHY
- PAYLOAD INSTALLATION/REMOVAL
 - MIDDECK PAYLOADS NORMALLY INSTALLED IN SHUTTLE ORBITER 3-8 DAYS PRIOR TO LAUNCH AND REMOVED ONE DAY AFTER LANDING
 - IF ABSOLUTELY REQUIRED (SUBJECT TO NSTS APPROVAL) INSTALLATION OF MIDDECK PAYLOADS MAY BE PROVIDED AS LATE AS 18 HOURS PRIOR TO LAUNCH AND REMOVAL AS EARLY AS 2 HOURS AFTER LANDING
- PAYLOAD INSTALLED ORIENTATION SHOULD BE CONSIDERED DURING DESIGN - WILL BE DIFFERENT DURING LAUNCH AND LANDING PHASES



NSTS INTEGRATION AND OPERATIONS

- SHUTTLE DOES NOT PROVIDE ABSOLUTE ZERO-GRAVITY ENVIRONMENT - CREW MOVEMENTS, CREW TREADMILL EXERCISE, THRUSTER FIRINGS, AND OTHER PAYLOAD OPERATIONS WILL INDUCE DISTURBANCES
- MATERIALS SELECTION VERY IMPORTANT FOR MIDDECK PAYLOADS TO PROTECT THE CREW AND ORBITER
 - TOXICITY
 - FLAMMABILITY
 - NUCLEAR RADIATION
- WORKING IN LOW GRAVITY GENERALLY REQUIRES MORE TIME THAN SAME TASK ON GROUND
- IF PAYLOAD ASSEMBLY IS REQUIRED ON-ORBIT, AVOID USE OF SMALL PARTS THAT CAN GET LOOSE IN CABIN
- VELCRO (NSTS APPROVED TYPE) CAN BE USED TO RESTRAIN PAYLOAD COMPONENTS DURING ON-ORBIT ACTIVITIES



NSTS INTEGRATION AND OPERATIONS

- REDUNDANT/SPARE PARTS SHOULD BE CONSIDERED FOR CRITICAL PAYLOAD COMPONENTS
- SIMPLE IN-FLIGHT MAINTENANCE CAN BE DESIGNED INTO PAYLOAD, BUT MUST NOT VIOLATE SAFETY REQUIREMENTS AND MUST BE APPROVED BY NSTS



**NSTS
INTEGRATION
AND
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SCHEDULES/MANIFESTING



**NSTS
INTEGRATION
AND
OPERATIONS**

FLIGHT ASSIGNMENT

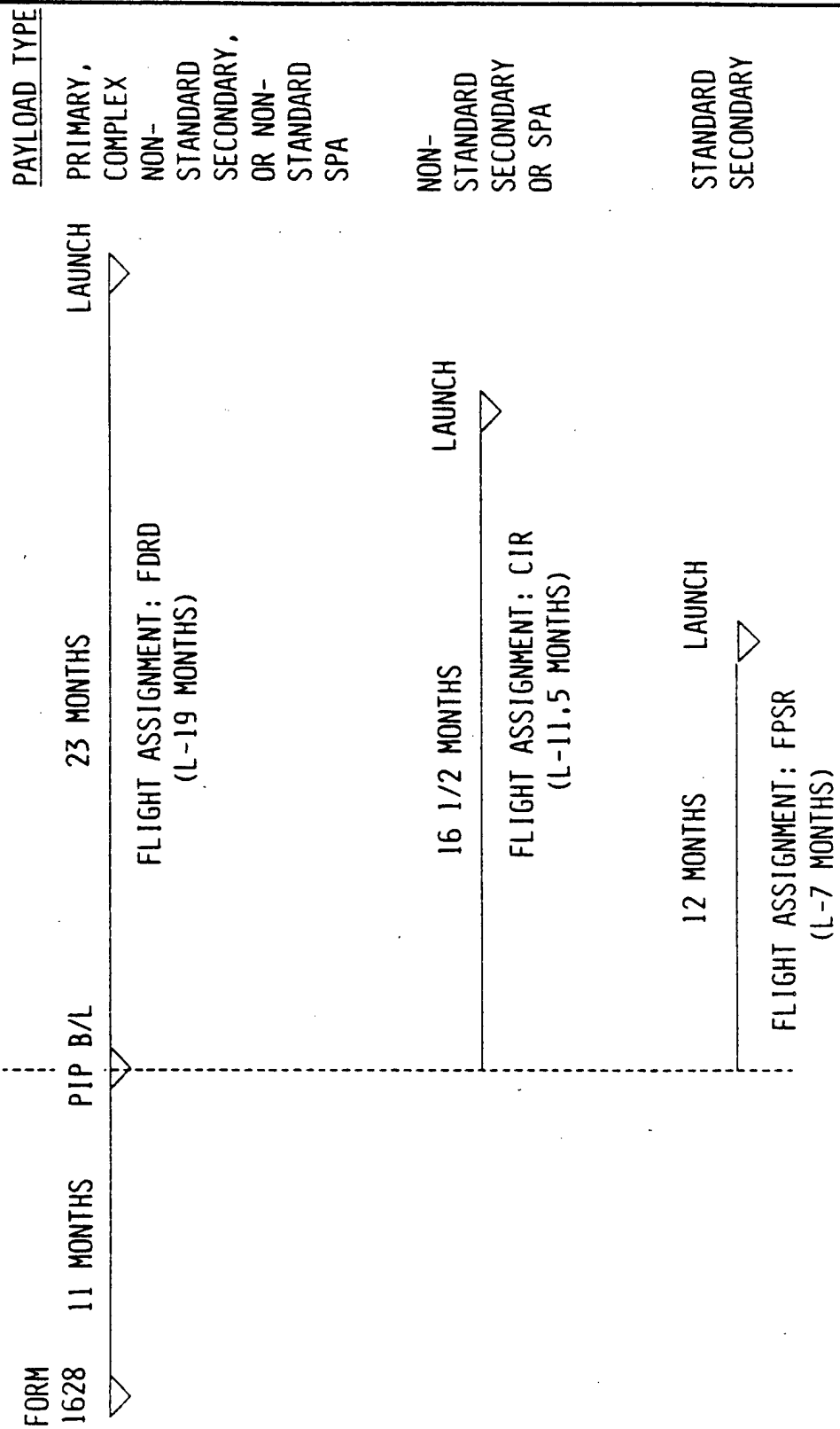
PAYLOAD CATEGORY	LATEST FLIGHT ASSIGNMENT	PREREQUISITES
PRIMARY	FDRD L-19 MONTHS	BASELINED* PIP AND ICD
COMPLEX SECONDARY	FDRD L-19 MONTHS	BASELINED PIP AND ICD
NONSTANDARD SECONDARY OR SPA	CARGO INTEGRATION REVIEW (CIR) L-11.5 MONTHS	BASELINED PIP AND ICD. ALL ANNEXES BASELINED EXCEPT 4 AND 9; HOWEVER, CUSTOMER SUBMITTAL OF ANNEXES 4 AND 9 IS REQUIRED.
STANDARD SECONDARY	FLIGHT PLANNING AND STOWAGE REVIEW (FPSR) L-7 MONTHS	BASELINED PIP, ICD, AND ALL ANNEXES. PHASE II SAFETY REVIEW IS REQUIRED.

*BASELINED = SIGNED BY BOTH NSTS AND THE CUSTOMER



NSTS **INTEGRATION** **AND** **OPERATIONS**

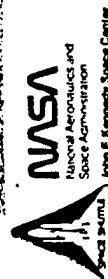
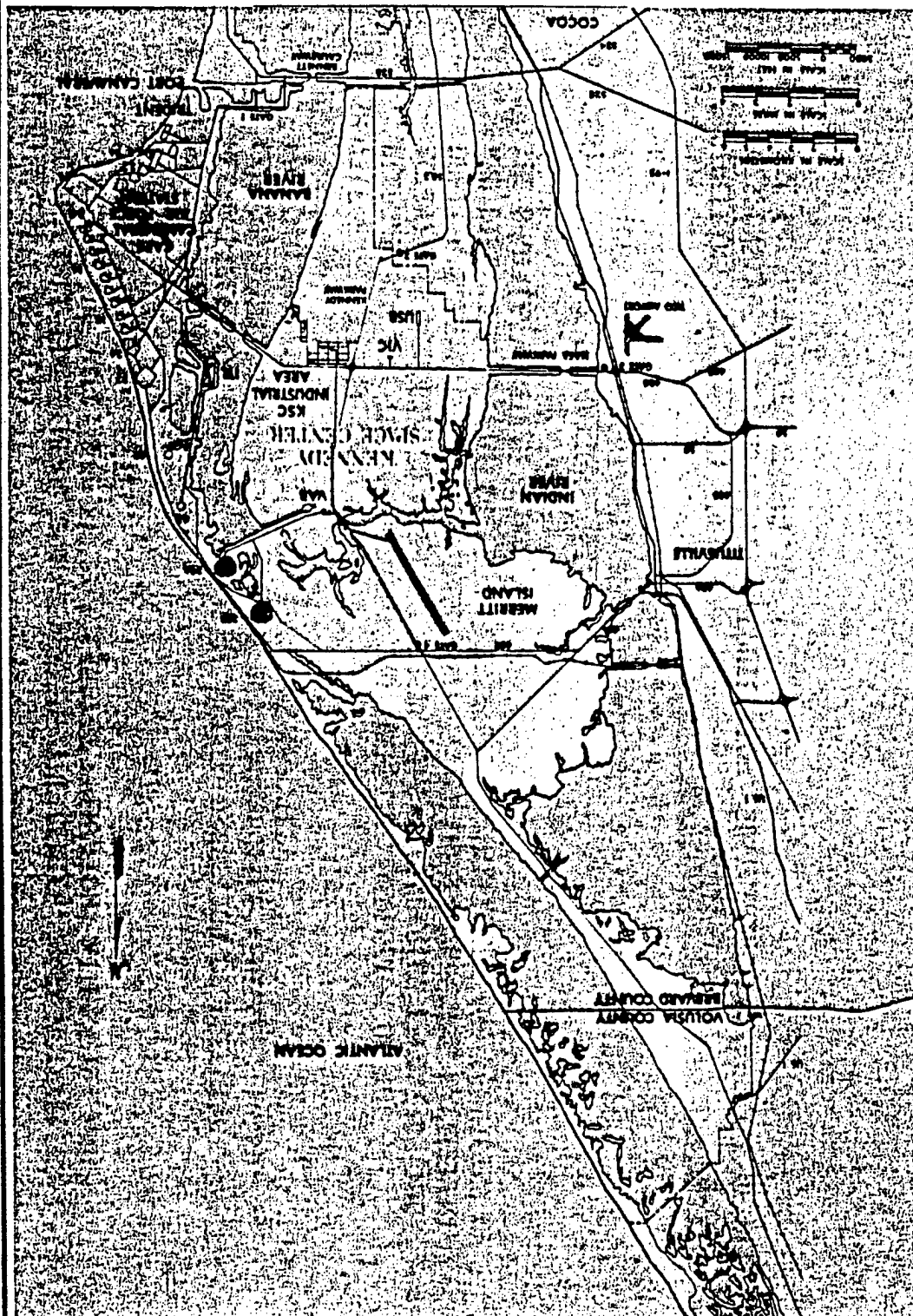
TIMELINE REQUIRED FOR FLIGHT READINESS



KSC PAYLOAD INTEGRATION PROCESS

**DEAN C. ZIMMERMAN
PAYLOAD SUPPORT OFFICE
KENNEDY SPACE CENTER**

KSC AND CCAFS



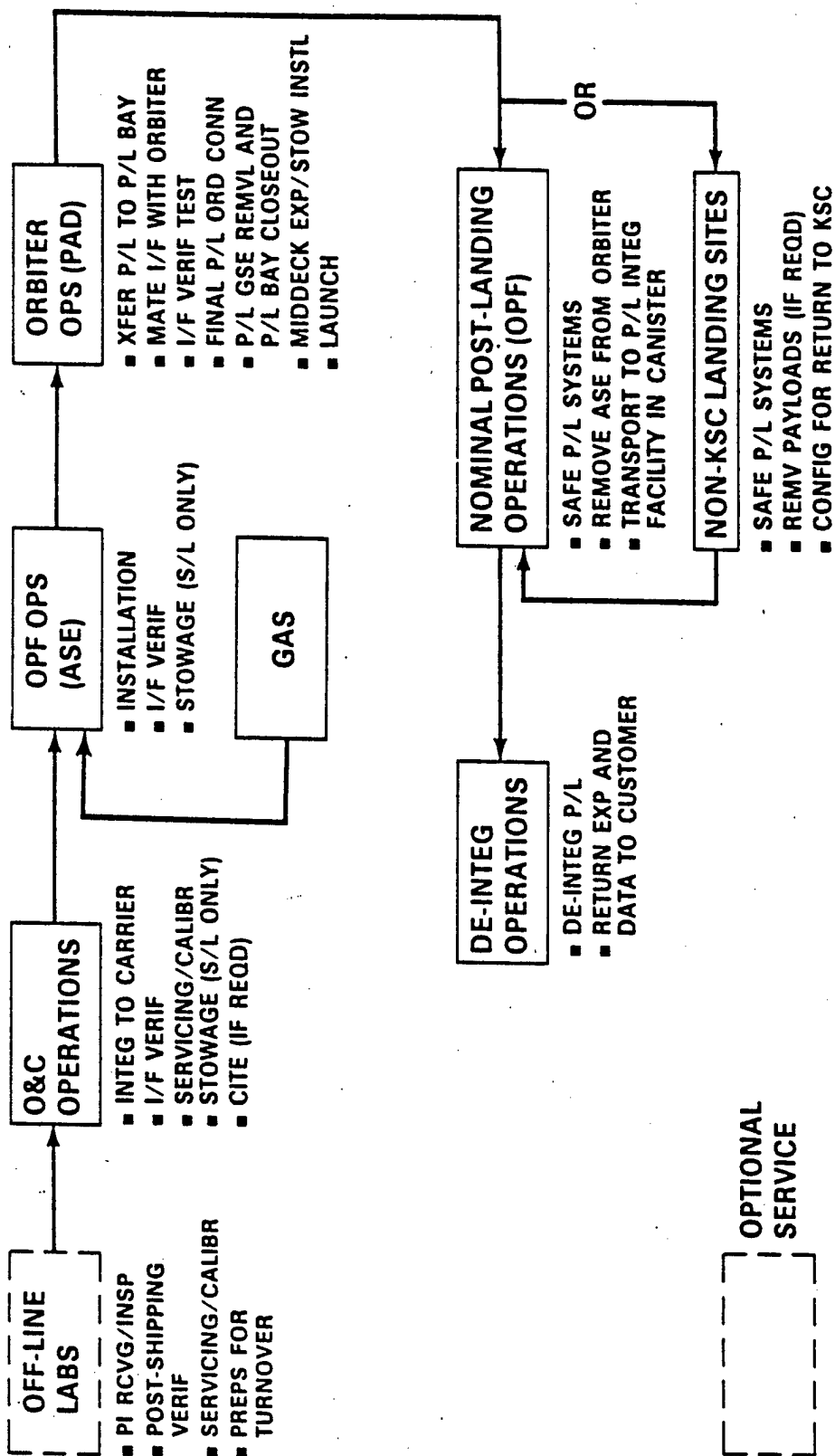
KSC FORM 4-607 (REV. 1/88)

PAYLOAD MANAGEMENT RESPONSIBILITIES

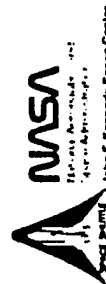
- KENNEDY SPACE CENTER (KSC) IS THE PRIMARY NASA LAUNCH SITE
 - RESPONSIBLE FOR THE MANAGEMENT AND DIRECTION OF:
 - ASSEMBLY AND VERIFICATION OF THE SHUTTLE
 - ASSEMBLY AND PROCESSING OF SPACELAB AND SIMILAR TYPE PAYLOADS
 - SUPPORT OF PAYLOAD PROCESSING AND FINAL PREPARATION FOR LAUNCH
 - FINAL TEST AND INTEGRATION OF PAYLOADS IN THE ORBITER BAY BEFORE LAUNCH
 - FINAL TEST AND INTEGRATION OF PAYLOADS WITH EXPENDABLE VEHICLES
 - COUNTDOWN AND LAUNCH
 - FACILITIES, COMMUNICATIONS, AND DATA SUPPORT TO EARLY PHASE OF ORBITAL ACTIVITY WHEN REQUIRED
 - PRIMARY AND CONTINGENCY LANDING SITE OPERATIONS
 - DEINTEGRATION OF PAYLOADS FROM THE STS UPON THEIR RETURN FROM SPACE
 - PERFORMING THE HOST ROLE AS THE CUSTOMER'S AGENT

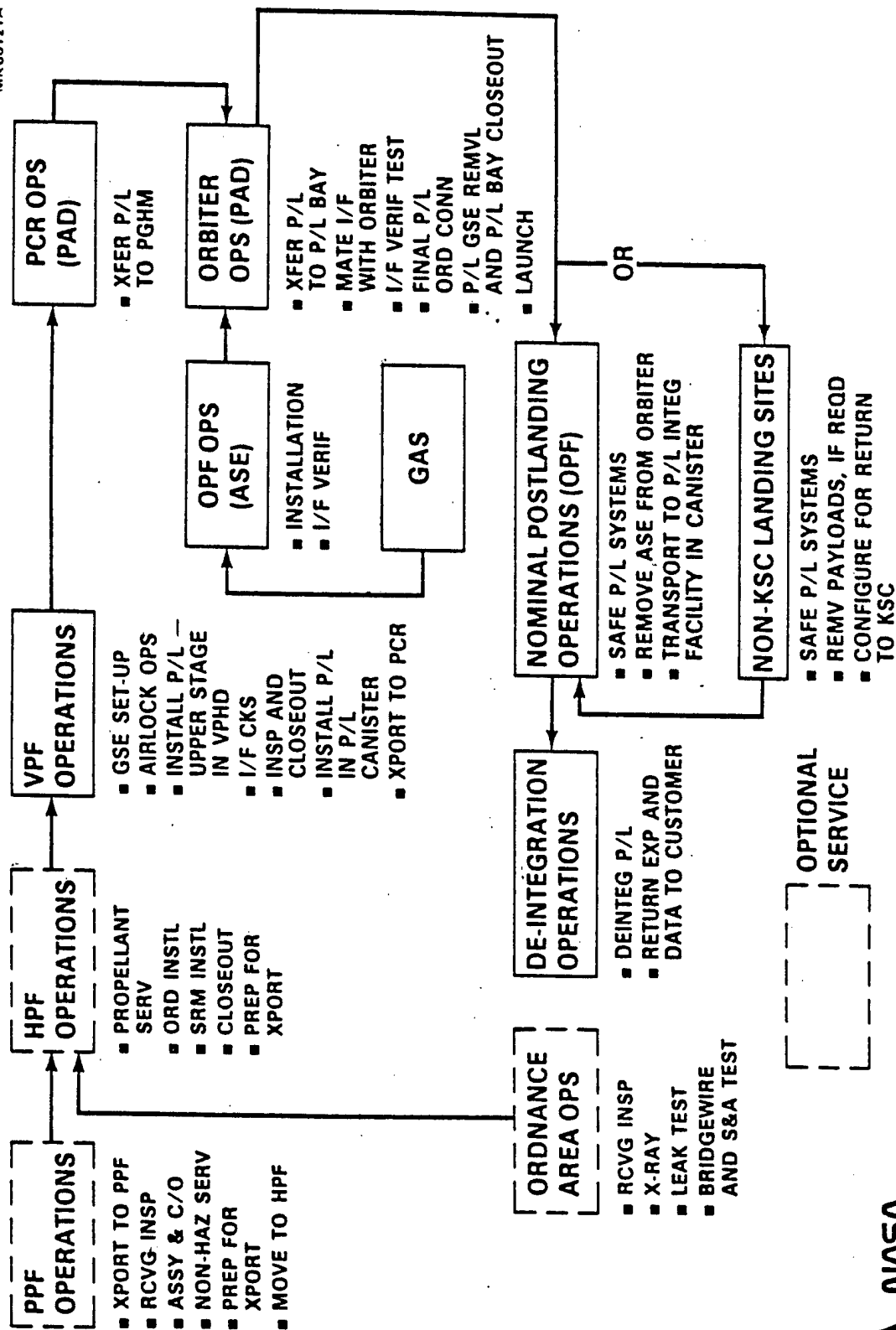


KSC FORM 1-60/1REV 1/83



EXAMPLE OF PAYLOAD FLOW FOR O&C INTEGRATION





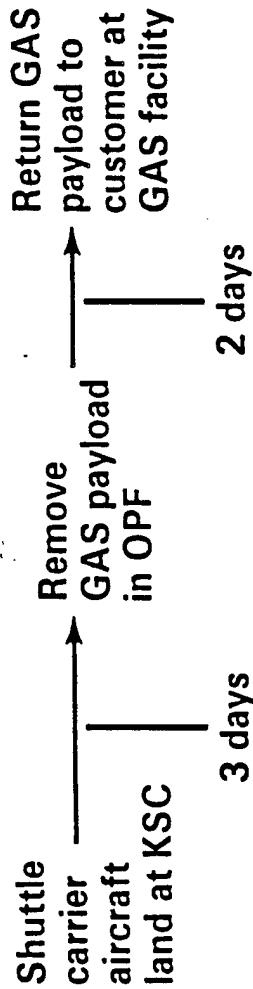
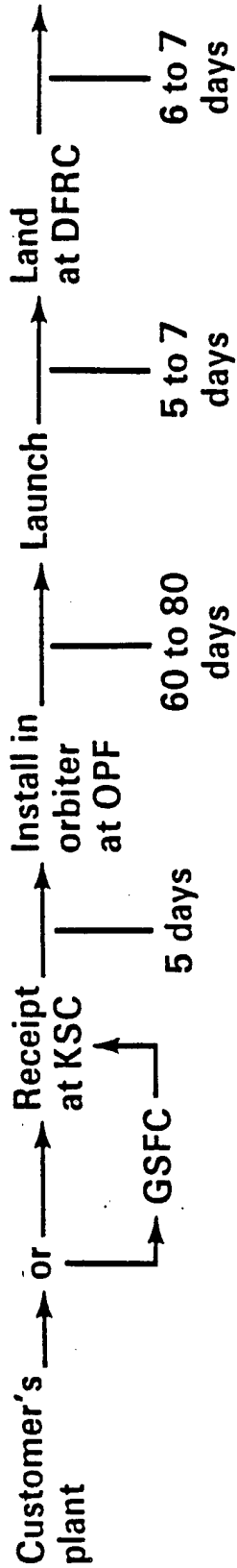
EXAMPLE OF PAYLOAD FLOW FOR VPF INTEGRATION



John F. Kennedy Space Center

KSC GET-AWAY SPECIAL PAYLOAD PROCESSING

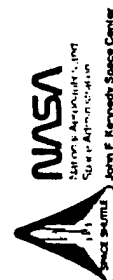
CP-PSO



KSC FORM 4-607 (REV. 1/88)



CINEMA 360° INSTALLATION



KSC FORM 4-607 (REV. 1/88)

GENERIC EXPERIMENT PHYSICAL AND FUNCTIONAL FAMILIARIZATION

- PERSONNEL ASSIGNED AFTER THE PAYLOAD EXPERIMENT COMPLEMENT IS DEFINED
 - ASSIGNMENT CONTINUES THROUGH EXPERIMENT DEINTEGRATION
- PERSONNEL PARTICIPATE IN
 - EXPERIMENT AND PAYLOAD DESIGN REVIEWS AT DESIGN FACILITY
 - TECHNICAL EXCHANGE MEETINGS
 - PAYLOAD GROUND OPERATIONS WORKING GROUP MEETINGS AT KSC
 - INTEGRATION AND TESTING ACTIVITIES AT THE EXPERIMENT DEVELOPER'S FACILITY
- PERSONNEL UTILIZE KNOWLEDGE ABOUT EXPERIMENTS TO
 - DEVELOP INPUTS FOR KSC PROCESSING SCHEDULES
 - DEVELOP PROCEDURES FOR EXPERIMENT ACTIVITIES AT KSC
 - EVALUATE REQUIREMENT VALIDITY AND IMPACT



- EVALUATE PRE-TURNOVER ACTIVITIES AND PROVIDE TASK DIRECTION FOR HAZARDOUS

OPERATIONS

- PARTICIPATE IN POST DELIVERY TESTS CONDUCTED BY EXPERIMENT DEVELOPER
 - KSC ENGINEERS GAIN ADDITIONAL EXPERIENCE WITH EXPERIMENT
 - KSC ENGINEERS KEEP ABREAST OF EXPERIMENT STATUS
- PROVIDE GENERIC TEST EQUIPMENT AND FACILITIES
- PROVIDE SERVICING SUPPORT AS REQUIRED



EXPERIMENT INTEGRATION

INTRODUCTION

- o KSC PERFORMS EXPERIMENT INTEGRATION AS DEFINED BY THE PAYLOAD MISSION MANAGER REQUIREMENTS
- o THE EXPERIMENTER IS AN INTEGRAL PART OF THE EXPERIMENT INTEGRATION TEAM
 - SETS UP AND VERIFIES EXPERIMENT GROUND SUPPORT EQUIPMENT
 - MONITORS AND OPERATES GSE DURING TESTING
 - PROVIDES DETAILS ON HOW EXPERIMENTS ARE OPERATED
 - PROVIDES EXPERIMENT EXPERTISE FOR PROBLEM RESOLUTION/UNIQUE EXPERIMENT OPERATIONS
 - INPUTS TO REVIEWS/SIGN-OFF PROCEDURES
- o INTERFACE VERIFICATION POLICY
 - INTERFACES ARE VERIFIED AT EARLIEST OPPORTUNITY BY FUNCTIONAL TEST(S)
 - EXPERIMENT COMPATIBILITY IS VERIFIED USING MSI/MAJOR INTEGRATED TESTING
 - NO "FAILURE" MODE/UNIQUE SOFTWARE VALIDATION (EXCEPT SAFETY RELATED)



EXPERIMENT INTEGRATION

REQUIREMENTS

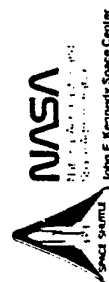
- o PAYLOAD MISSION MANAGER PROVIDES REQUIREMENTS DOCUMENT WITH ALL KSC PROCESSING REQUIREMENTS TO LSSM INCLUDING:
 - OFF-LINE FACILITY SUPPORT
 - EXPERIMENT INSTALLATION
 - INTERFACE VERIFICATION
 - SERVICING, ALIGNMENT, AND CALIBRATION
 - LAUNCH DELAY CONTINGENCIES
 - DEINTEGRATION
 - EXPERIMENTER POST FLIGHT SUPPORT
 - CONTINGENCY LANDING SITE PROCESSING
- o KSC RESPONDS TO REQUIREMENTS WITH THE KSC LAUNCH SITE SUPPORT PLAN (LSSP), ANNEX 8 OF THE PAYLOAD INTEGRATION PLAN (PIP)
- o LSSP COMMITS KSC RESOURCES:
 - IDENTIFIES INTEGRATION PHASE OF REQUIREMENT
 - IDENTIFIES THOSE REQUIREMENTS WHICH ARE NON-STANDARD (OPTIONAL SERVICES)
 - IDENTIFIES REQUIREMENTS WHICH CANNOT BE MET OR NEED FURTHER RESOLUTION (PRELIMINARY ONLY)



EXPERIMENT INTEGRATION

PMM/PI/ED PARTICIPATION

- 0 WORKS WITH KSC TO SATISFACTORILY IMPLEMENT REQUIREMENTS
- 0 PROVIDES PROCEDURE INPUTS RELATIVE TO PROPER EXPERIMENT OPERATION TO ENSURE ACCURATE TESTING AND HEALTH, REVIEW/SIGN RESULTANT PROCEDURES
- 0 PERFORM EXPERIMENT UNIQUE FUNCTIONS WHICH REQUIRE SPECIAL EXPERTISE OR TRAINING
- 0 CHECKOUT GSE IN USER ROOM
- 0 OPERATE GSE DURING KSC OPERATIONS (PASSIVE ACTIVITY)
- 0 PROVIDE EXPERIMENT EXPERTISE WHEN PROBLEMS OCCUR
- 0 EVALUATE EXPERIMENT GSE DATA
- 0 EVALUATE TEST RESULTS TO ENSURE OBJECTIVES ARE MET



EXPERIMENT INTEGRATION

OFF-LINE PREPARATIONS

- o "OFF-LINE" REFERS TO THOSE FUNCTIONS WHICH OCCUR OUTSIDE THE NORMAL SERIAL FLOW OF PAYLOAD HARDWARE INTEGRATION
 - NORMALLY PERFORMED BY EXPERIMENTER PERSONNEL
 - NORMALLY PERFORMED IN OFF-LINE AREAS (LAB, ETC.)
 - KSC PERSONNEL ONLY INVOLVED TO PROVIDE SUPPORT OR CONTROL HAZARDOUS OPERATIONS
- o "ON-LINE" REFERS TO THOSE FUNCTIONS WHICH OCCUR AS A PART OF THE INTEGRATION FLOW AFTER EXPERIMENT TURNOVER
 - NORMALLY PERFORMED BY KSC
 - NORMALLY OCCURRING IN THE INTEGRATION STAND/ORBITER



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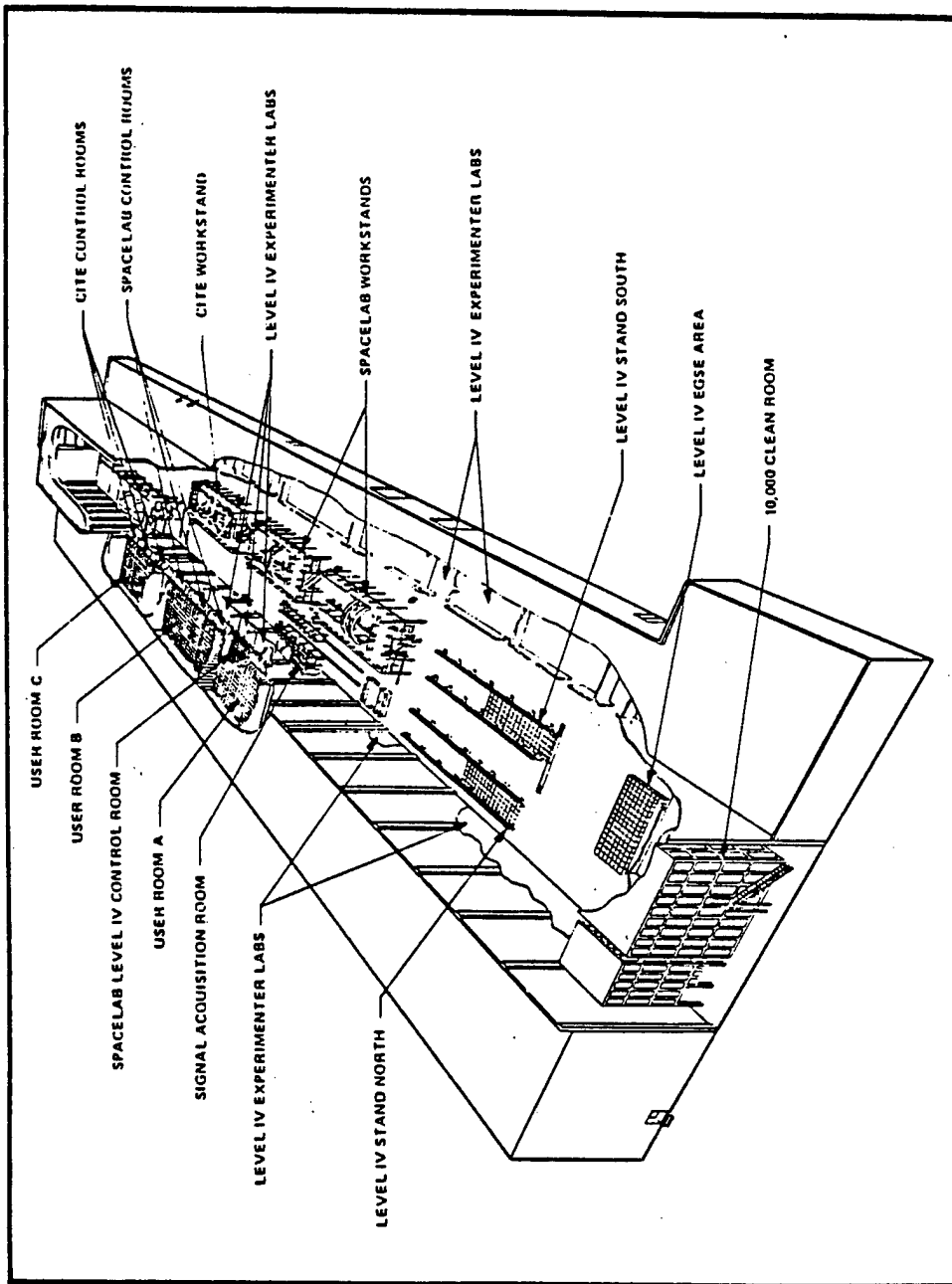
EXPERIMENT INTEGRATION

OFF-LINE ACTIVITIES (CONTINUED)

- 0 EXPERIMENT TURNOVER
 - THE PMM WILL PROVIDE KSC WITH A DATA PACKAGE DEFINING:
 - (1) EXPERIMENT CONFIGURATION
 - (2) OPEN WORK ITEMS (SCHEDULED)
 - (3) NON-FLIGHT ITEMS (RED TAG)
 - (4) OPEN PROBLEMS/VERIFICATIONS/WAIVERS
 - (5) FLIGHT SPARES
 - (6) BONDED STORAGE NEEDS
 - (7) HAZARDS (LASERS, CRYOGENS, ETC.)
 - THE PMM/PI/ED WILL CERTIFY THAT ALL GROUND SAFETY REVIEWS ARE COMPLETED (IDENTIFY ANY OPEN ITEMS) AND EXPERIMENT IS QUALIFIED FOR STS FLIGHT



KSC FORM 4-607 (REV. 1/78)



O&C BUILDING ASSEMBLY AND TEST AREA

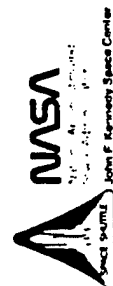


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KSC FORM 4607 (REV 1/88)

GENERIC EXPERIMENT INTEGRATION WITH CARRIER

- MECHANICAL INTEGRATION ACTIVITIES, SUCH AS
 - MISSION PECULIAR EQUIPMENT (MPE) INSTALLATION (E.G., FLUID LINES, CABLES, SUPPORT STRUCTURES)
 - EXPERIMENT INSTALLATION
 - MPE AND EXPERIMENT HARDWARE MODIFICATIONS
- MECHANICAL MISSION DEPENDENT ACTIVITIES, SUCH AS
 - EXPERIMENT ALIGNMENT
 - EXPERIMENT SERVICING
 - MPE FLUID SYSTEM LEAK CHECKS AND SERVICING
 - EXPERIMENT HARDWARE STOWAGE (MODULE MISSIONS)
- ELECTRICAL PRE-TEST ACTIVITIES, SUCH AS
 - CONTINUITY AND MEGGER CHECKS
 - VOLTAGE AND POLARITY CHECKS
 - ISOLATION CHECKS

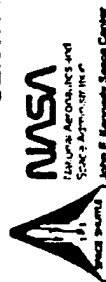


KSC FORM 4 607 (REV. 1/88)

GENERIC EXPERIMENT TESTING

- LEVEL IV EXPERIMENT FUNCTIONAL TESTS
 - VERIFY EXPERIMENT TO SUBSYSTEM AND TO ORBITER INTERFACES
 - VERIFY EXPERIMENT FUNCTIONAL OPERATIONS TO EXTENT PRACTICAL
- INTEGRATED TESTS
 - MOST SYSTEMS/EXPERIMENTS ARE ACTIVE
 - SYSTEMS/CREW ARE UTILIZED IN MAXIMUM RESOURCE MODE
 - COMPATIBILITY BETWEEN EXPERIMENTS/SUBSYSTEMS IS VERIFIED
- CREW EQUIPMENT INTERFACE TESTS
 - VERIFY CREW/CREW EQUIPMENT COMPATIBILITY
 - VERIFY EXPERIMENT/CREW EQUIPMENT INTERFACES AND COMPATIBILITY
- CITE TESTS (MISSION DEPENDENT)
 - UTILIZED FOR FIRST TIME CONFIGURATIONS
 - PROVIDE HIGH FIDELITY SIMULATION OF ORBITER
- ORBITER INTERFACE TESTS
 - PERFORMED AT EITHER THE OPF OR THE PAD
 - VERIFY PAYLOAD TO ORBITER INTERFACES

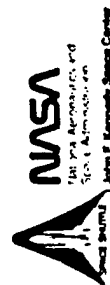
NOTE: EXTENSIVE INVOLVEMENT BY FLIGHT CREW MEMBERS DURING EXPERIMENT TESTING FOR CERTAIN PAYLOADS, SUCH AS SPACELABS.

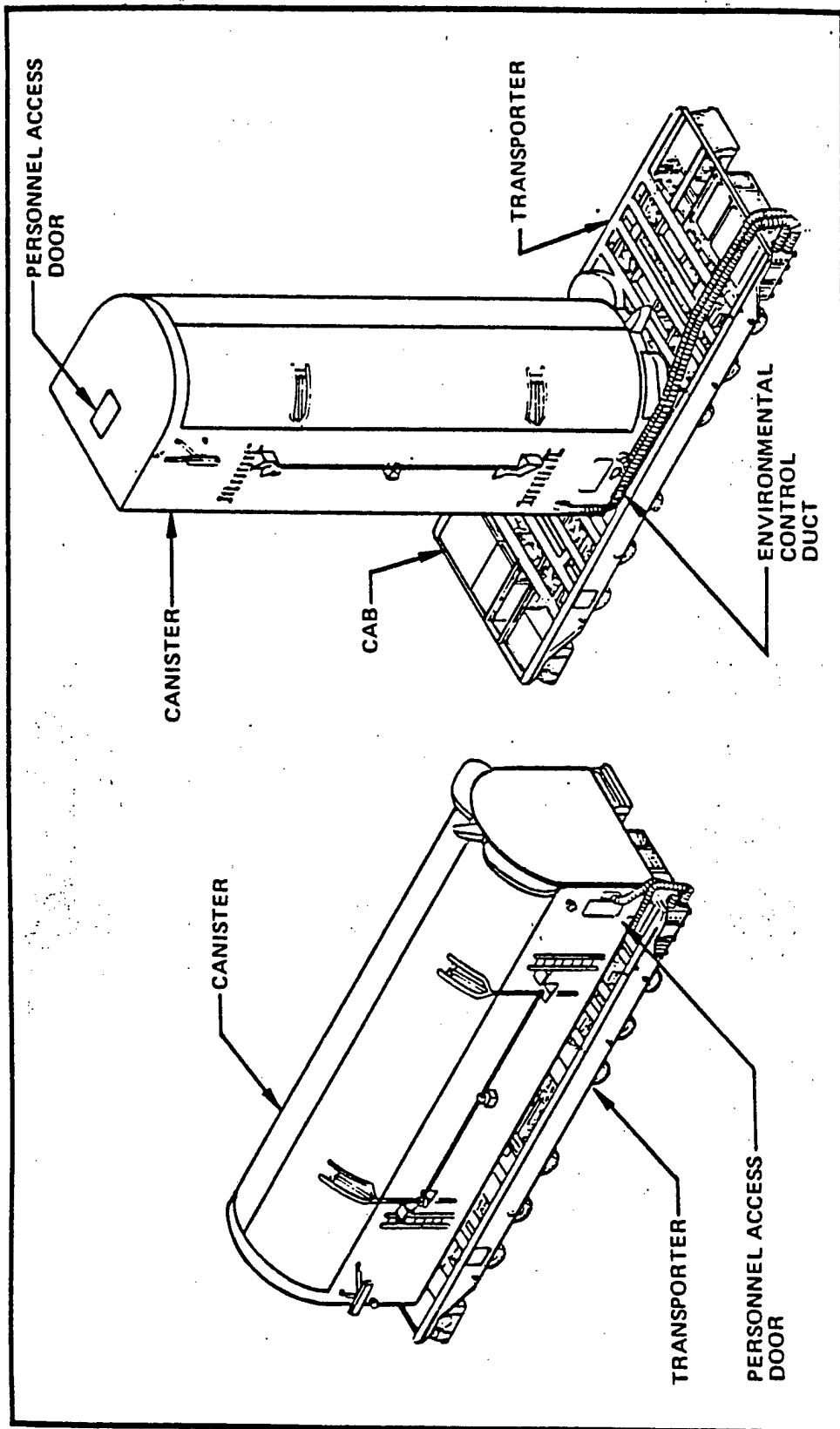


KSC FORM 4-607 (REV. 1/88)

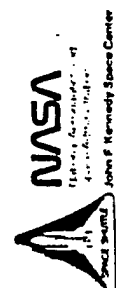
GENERIC EXPERIMENT SERVICING AND CLOSEOUT

- SERVICING AND CLOSEOUT OPERATIONS ARE MISSION DEPENDENT AND MAY BE PERFORMED IN THE O&C TEST STANDS, IN THE OPF, AND/OR AT THE PAD.
- SERVICING AND PERIODIC MAINTENANCE, SUCH AS
 - EXPERIMENT PURGES
 - FLUIDS FILL/TOPOFF
 - EXPERIMENT CALIBRATION
 - BATTERY INSTALLATION/CHARGE
- CLOSEOUT ACTIVITIES, SUCH AS
 - PAYLOAD ENVELOPE CLEARANCE CHECKS
 - PAYLOAD WEIGHT AND CG MEASUREMENTS
 - PYROTECHNICS INSTALLATION AND VERIFICATION
 - EXPERIMENT UNIQUE OPERATIONS (E.G., REMOVE BEFORE FLIGHT ITEMS)
 - OPF TIME CONSTRAINED STOWAGE AND CREW WALKDOWN (MODULE MISSIONS)
 - PAD LATE ACCESS FINAL STOWAGE (E.G., BIOLOGICAL SAMPLES, SL-3 PRIMATES AND RODENTS)

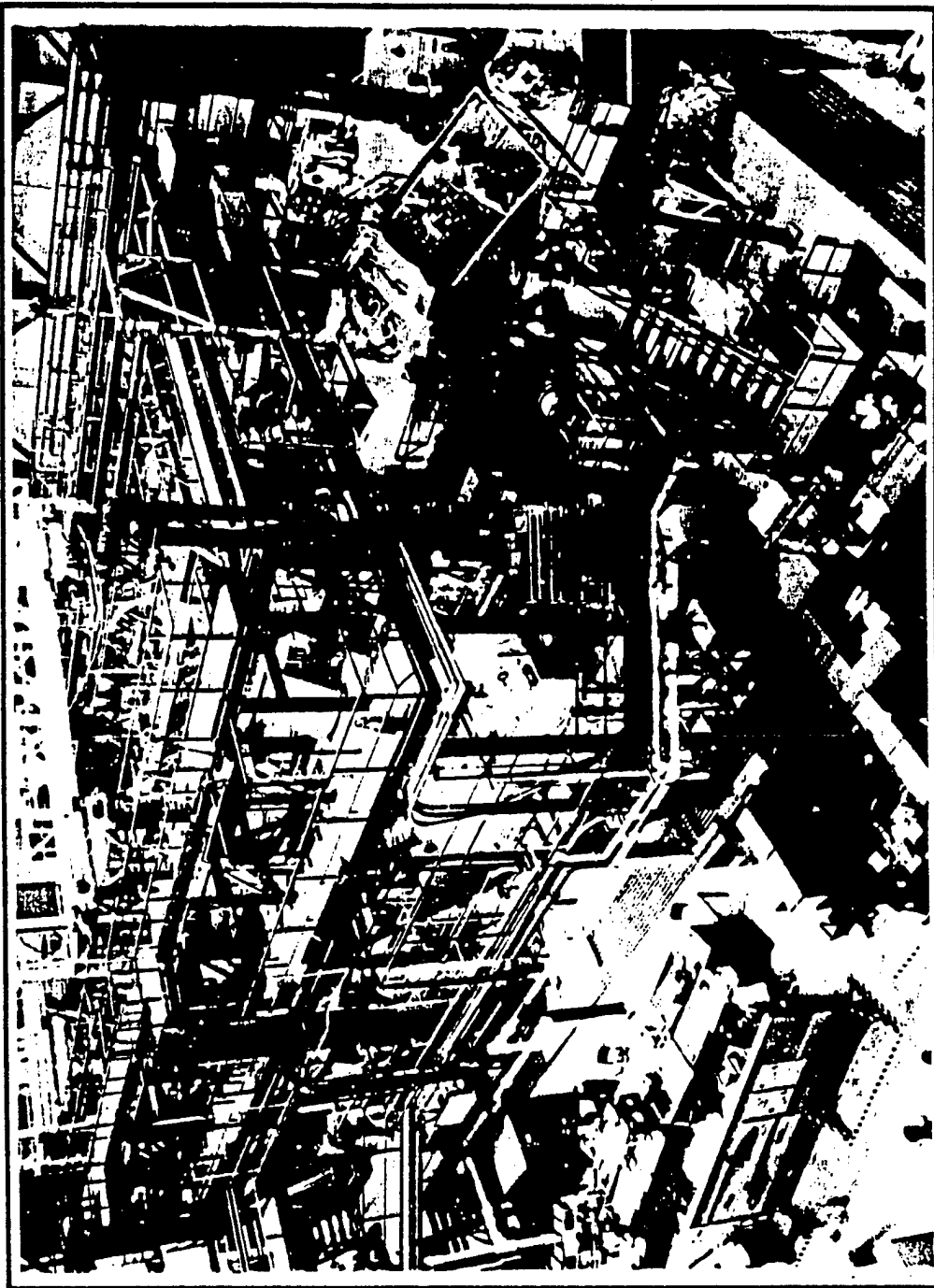




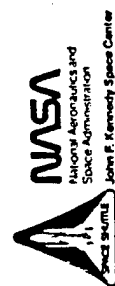
CANISTER/TRANSPORTER CONFIGURATIONS



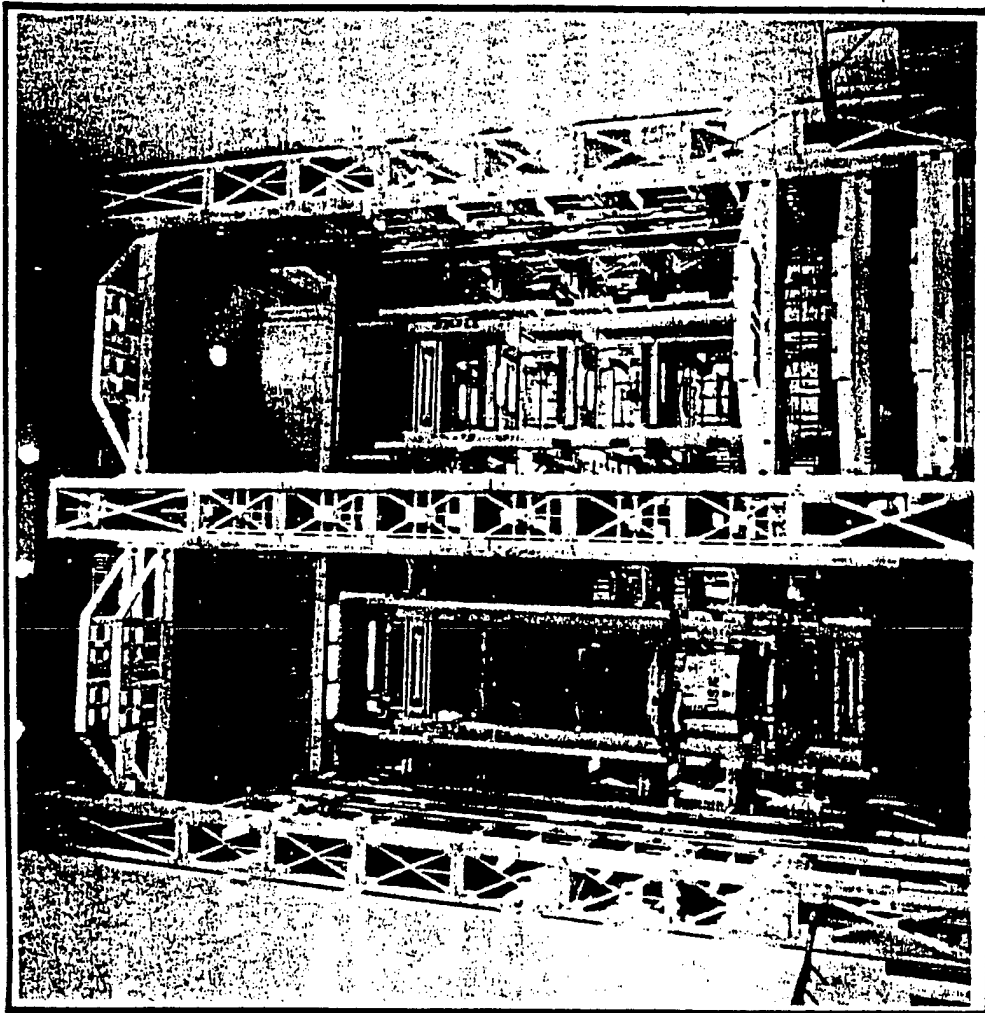
KSC FORM 4-607 (REV. 1/88)



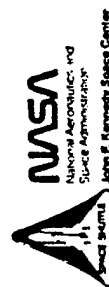
OPF WORKSTANDS



KSC FORM 4-607 (REV. 1/88)



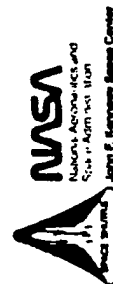
PAYLOAD AND UPPER STAGE INSTALLED IN A VPF WORK STAND



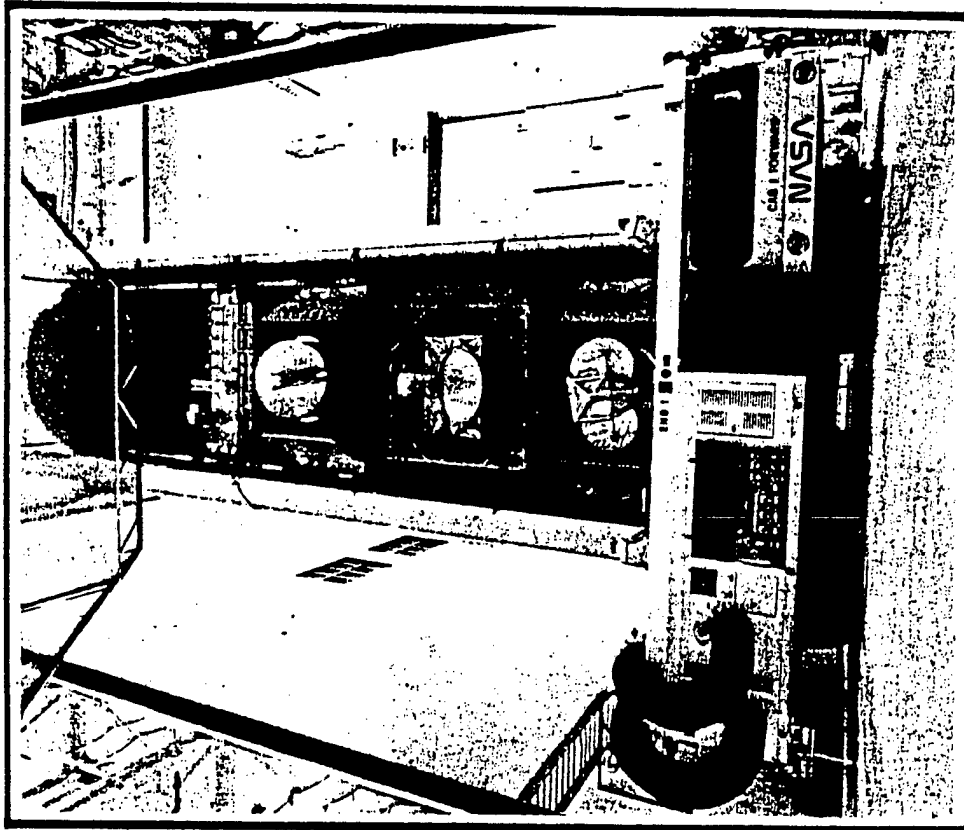
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VERTICAL PROCESSING FACILITY ACTIVITIES

- PAYLOAD INTEGRATION WITH ORBITER SYSTEMS AND OTHER PAYLOADS ALSO TAKES PLACE IN THE VERTICAL PROCESSING FACILITY (VPF)
- DELIVERY CONFIGURATION VARIES DEPENDING ON THE UPPER STAGE:
 - PAM ALREADY MATED WITH PAYLOAD
 - IUS/TDRS AND PAYLOAD ARRIVE SEPARATELY
 - SYCOM CLASS AND ITS PKM ARRIVE SEPARATELY
- PAYLOAD ELEMENTS STACKING AND TESTS INVOLVE:
 - MATING WITH UPPER STAGE AS NECESSARY AND INSTALLATION INTO WORKSTAND IN PAYLOAD BAY SEQUENCE
 - STANDALONE HEALTH AND STATUS TESTS
 - INTEGRATION TESTS
- ORBITER-TO-PAYLOAD INTERFACE VERIFICATION WITH PAYLOAD INTEGRATION TEST EQUIPMENT (CITE)
 - MISSION SEQUENCE TEST
 - END-TO-END TEST
 - ORDNANCE SYSTEMS TEST



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CANISTER/TRANSPORTER BEING READIED TO LEAVE VP



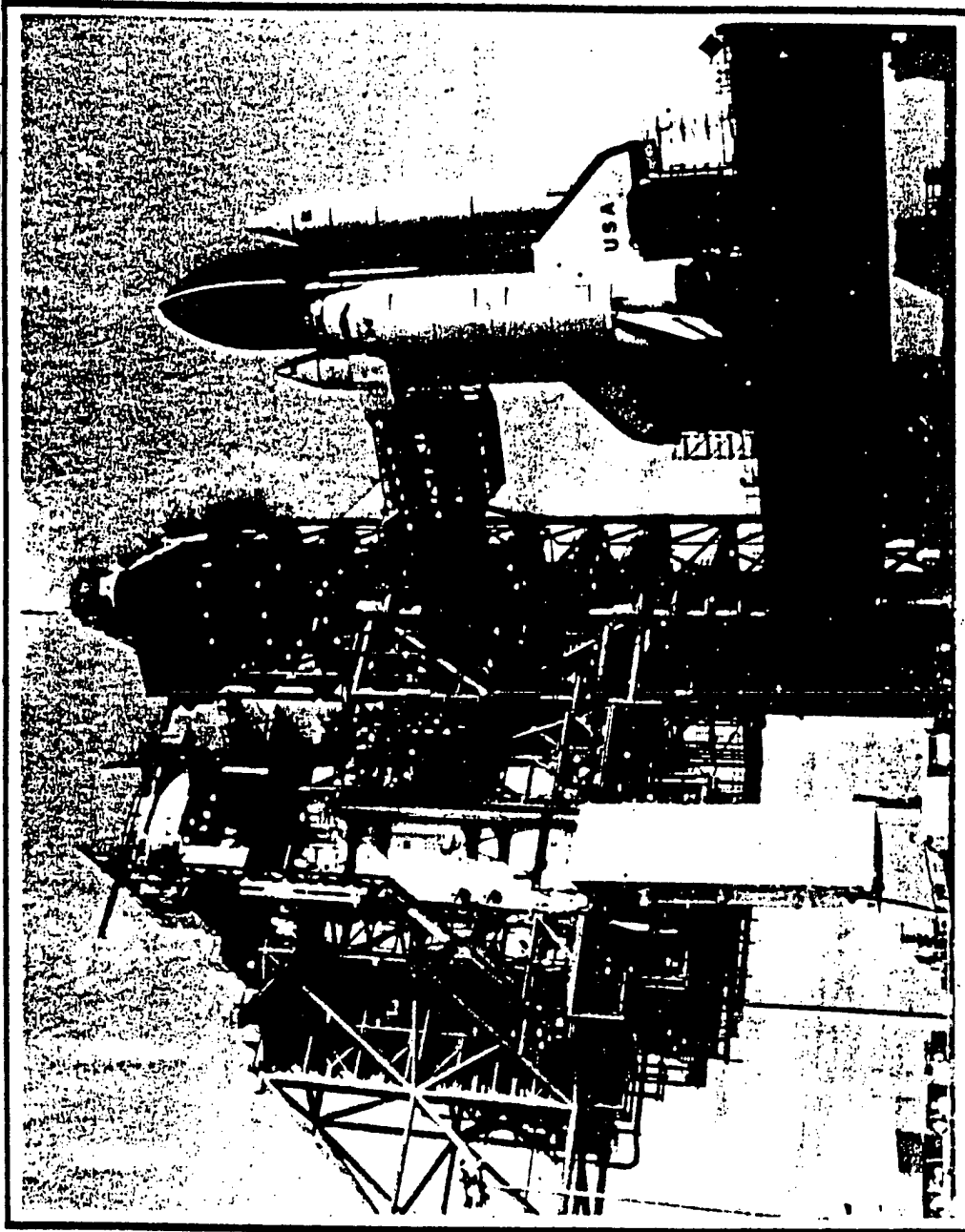
KSC FORM 4-607 (REV. 1/88)



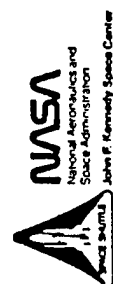
CANISTER/TRANSPORTER ON PAD



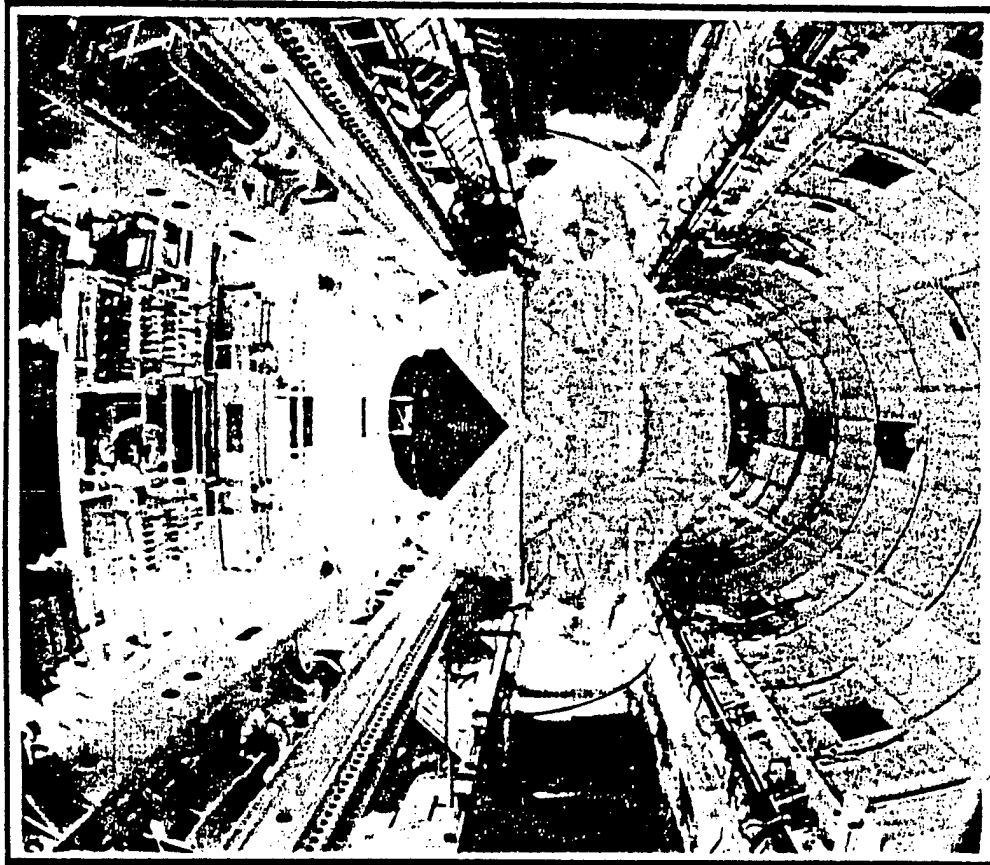
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CANISTER BEING RAISED TO PCR



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PAYLOAD ELEMENTS BEING TRANSFERRED FROM THE PCR
INTO THE SHUTTLE PAYLOAD BAY



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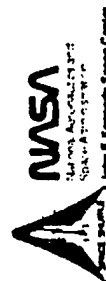
ORBITER INTEGRATION

- AFTER PAYLOAD INSTALLATION IN ORBITER PAYLOAD BAY IN THE OPF OR THE PCR:
 - OPF
 - PAYLOAD CABLES TO ORBITER ARE CONNECTED AND THE INTERFACE IS VERIFIED FROM FIRING ROOM AT LAUNCH CONTROL CENTER (LCC)
 - END-TO-END AND MISSION SEQUENCE TESTS WILL BE PERFORMED (IF REQUIRED)
 - PCR
 - FINAL ORDNANCE CONNECTIONS ARE MADE AND SAFING IS COMPLETED
 - ALL CLOSEOUT PREPARATIONS FOR FLIGHT ARE PERFORMED AND VERIFIED
 - PAYLOAD BAY DOORS ARE CLOSED AT L-10 DAYS
 - LATE SERVICING OR COMMANDS WILL BE ACCOMPLISHED THROUGH THE ORBITER UMBILICALS AS PART OF THE SHUTTLE COUNTDOWN PRIOR TO T-9 MINUTES
 - ACCESS IS EXTREMELY LIMITED AFTER INSTALLATION OF THE PAYLOAD AT THE VPF AND PCR



PAYLOAD LAUNCH OPERATIONS CONTROL LOCATIONS

- LAUNCH CONTROL CENTER (LCC)
 - SHUTTLE COUNTDOWN AND LAUNCH CONTROL
 - KSC PAYLOAD MANAGEMENT AND TEST CONTROL
 - CUSTOMER ENGINEERING SUPPORT AREA (LPS DATA MONITORING)
- MISSION DIRECTOR'S CENTER (VERTICAL PAYLOADS)
 - CUSTOMER MANAGEMENT LAUNCH DIRECTION
 - COMMUNICATIONS TO ALL LOCATIONS
- O&C CONTROL ROOM (HORIZONTAL PAYLOADS)
 - CUSTOMER MANAGEMENT LAUNCH DIRECTION
 - COMMUNICATIONS TO ALL LOCATIONS
- CUSTOMER'S KSC PAYLOAD CONTROL STATION (VERTICAL PAYLOADS)
 - PAYLOAD COMMAND AND DATA EVALUATION
 - VOICE AND DATA COMMUNICATIONS TO LCC AND PAD
- OFF-SITE CONTROL
 - MISSION CONTROL AT JSC
 - PAYLOAD OPERATIONS CONTROL CENTER AT JSC
 - CUSTOMER'S MISSION CONTROL CENTER

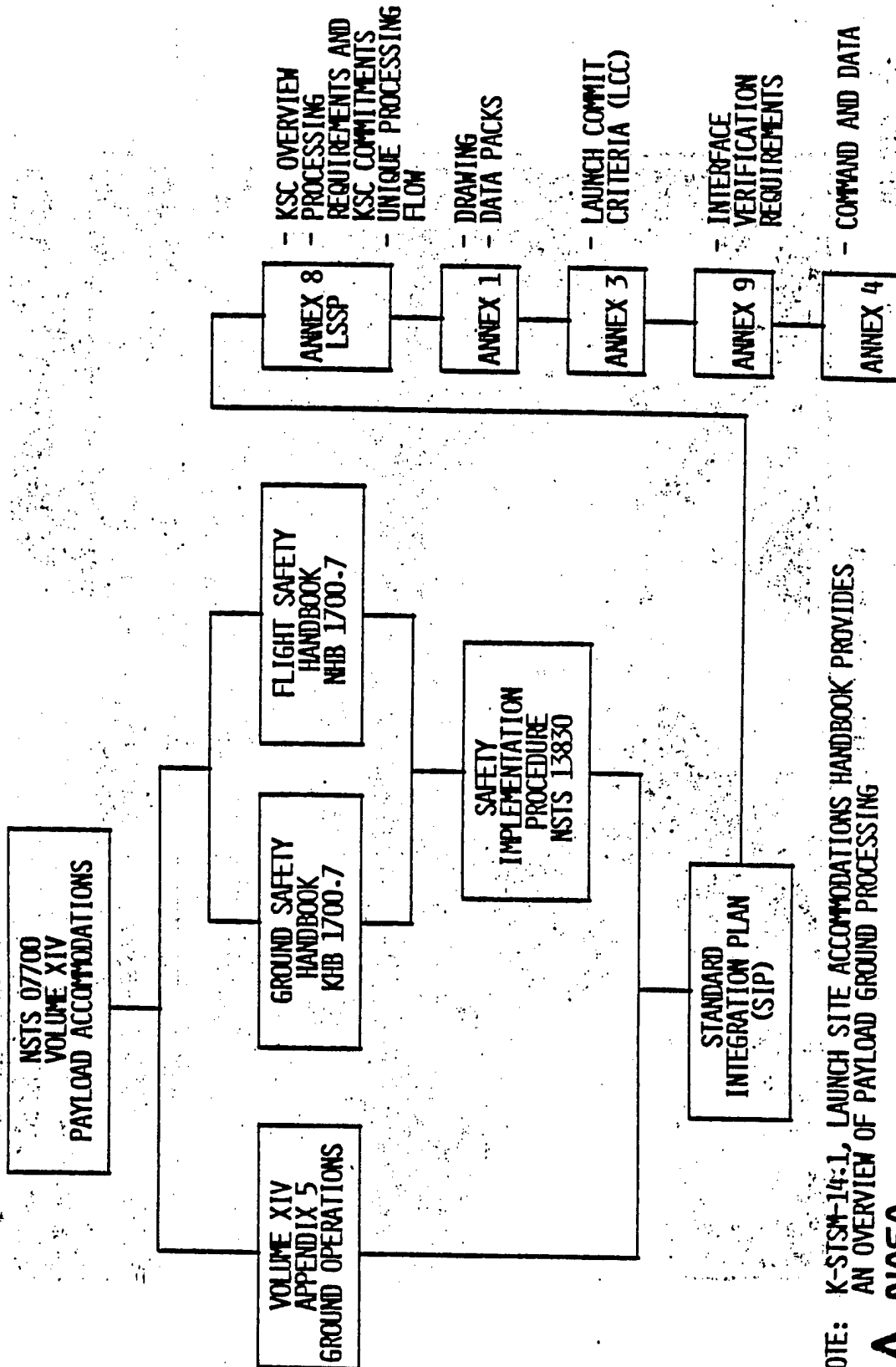


KSC FORM 4-607 (REV. 1/83)

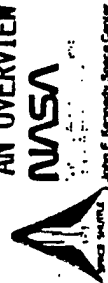
POSTLANDING OPERATIONS

- AFTER KSC OR DFRF LANDING AND CREW EGRESS:
 - PAYLOAD BAY ENVIRONMENTAL LIMITS ARE MAINTAINED BY EXTERIOR UNITS
 - ORBITER IS TOWED TO A PROCESSING FACILITY FOR SAFING
 - REMOVAL OF RETURNING PAYLOADS AND AIRBORNE SUPPORT EQUIPMENT - APPROXIMATELY 3 DAYS AFTER LANDING AT KSC (EITHER DIRECT LANDING OR SHUTTLE CARRIER AIRCRAFT LANDING AT KSC)
 - PAYLOADS CAN BE TURNED OVER TO PAYLOAD OWNERS AS FOLLOWS:
 - SOME MIDDECKS CAN BE REMOVED PRIOR TO ORBITER TOW (LANDING + 2 HOURS)
 - REMAINING MIDDECK LOCKERS CAN BE REMOVED WITHIN 24 HOURS
 - OTHER PAYLOADS/ASE ARE REMOVED AFTER THE PAYLOAD BAY DOORS ARE OPENED (LAND AT KSC + 3 DAYS)
- NON-KSC/DFRF LANDINGS ARE COVERED BY KVT-PL-0014 AND APPROPRIATE ANNEX, KSC OFF-SITE OPERATIONS PLAN AND KCS-PL-0012.0, PAYLOAD OPERATIONAL LOGISTICS PLAN





NOTE: K-STM-14-1, LAUNCH SITE ACCOMMODATIONS HANDBOOK PROVIDES AN OVERVIEW OF PAYLOAD GROUND PROCESSING



KENNEDY SPACE CENTER INTEGRATION ACTIVITIES

- CUSTOMER SUPPORT REQUIRED DURING ALL PHASES OF INTEGRATION ACTIVITIES FOR GROUND OPERATIONS AND RELATED PAYLOAD TESTING.

- REVIEWS REQUIRING CUSTOMER SUPPORT ARE:

- GROUND OPERATIONS REVIEW (GOR)
- PAYLOAD READINESS REVIEW (PRR)
- LAUNCH READINESS REVIEW (LRR)
- FLIGHT READINESS REVIEW (FRR)
- PAYLOAD MANAGEMENT COUNTDOWN REVIEW (PMCR)

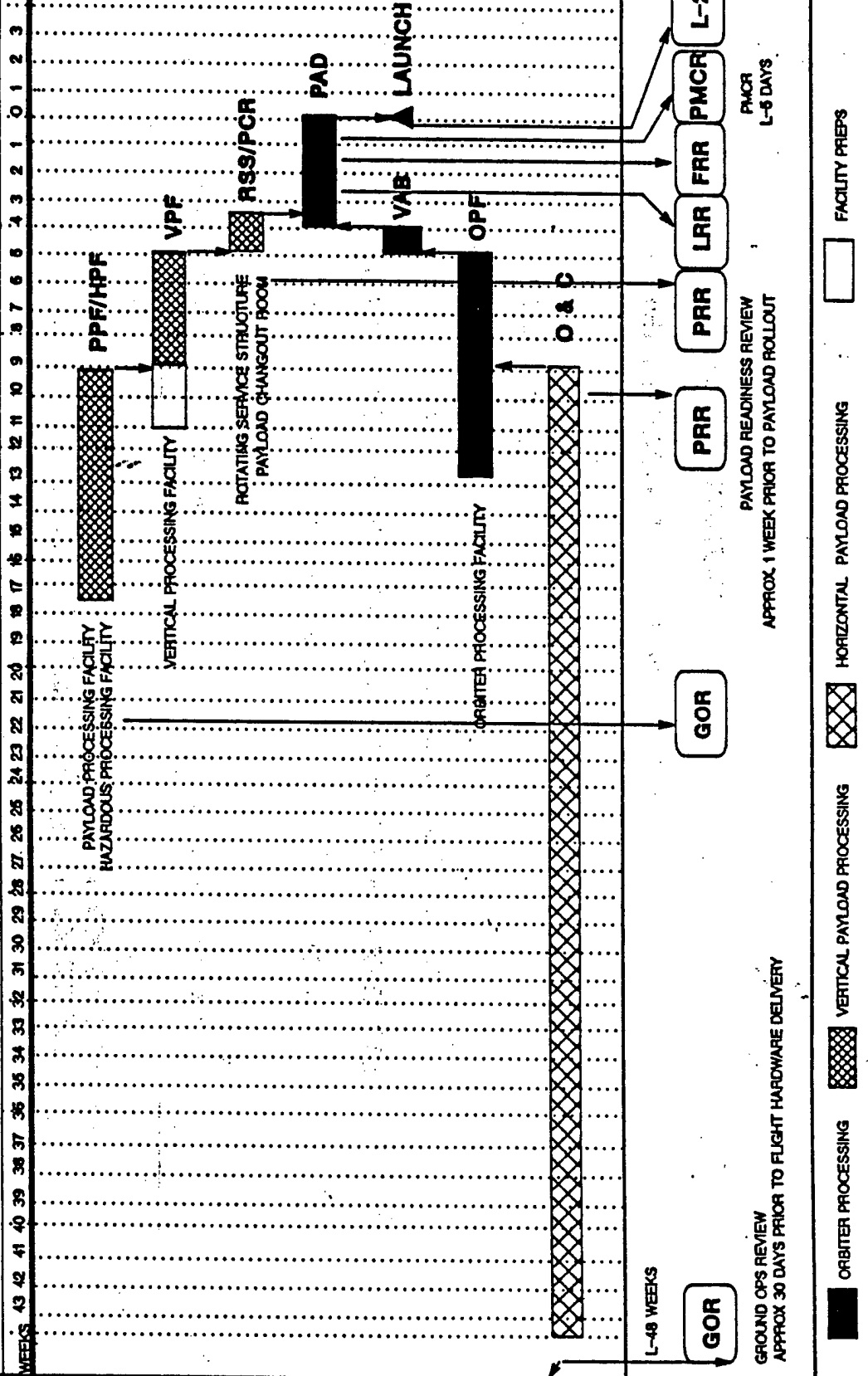


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GENERIC PAYLOAD PROCESSING REVIEWS

APRIL 21, 1988
CP-APO

NASA
KENNEDY SPACE CENTER



● BUILDING AE

- HIGH BAY WORK AREA: 43 FT. 10 IN. BY 51 FT. 6 IN.
- CRANE: 6-TON, 36 FT. 10 IN. LIFT
- CLEANLINESS: CLASS 10,000, CWA LEVEL 2
- ENTRY DOOR: 14 FT. 9 IN. WIDE BY 36 FT. 1 IN. HIGH

● HANGAR S

- HIGH BAY WORK AREAS
 - NORTH: 42 FT. 1 IN. BY 29 FT. 11 IN.
 - SOUTH: 45 FT. BY 55 FT.
- CRANES: 2-TON, 19 FT. 1 IN. LIFT
- CLEANLINESS: CLASS 100,000, CWA LEVEL 4
(CAN MAINTAIN CLASS 10,000, CWA LEVEL 2)
- ENTRY DOOR: 14 FT. 9 IN. WIDE BY 19 FT. 8 IN. HIGH

