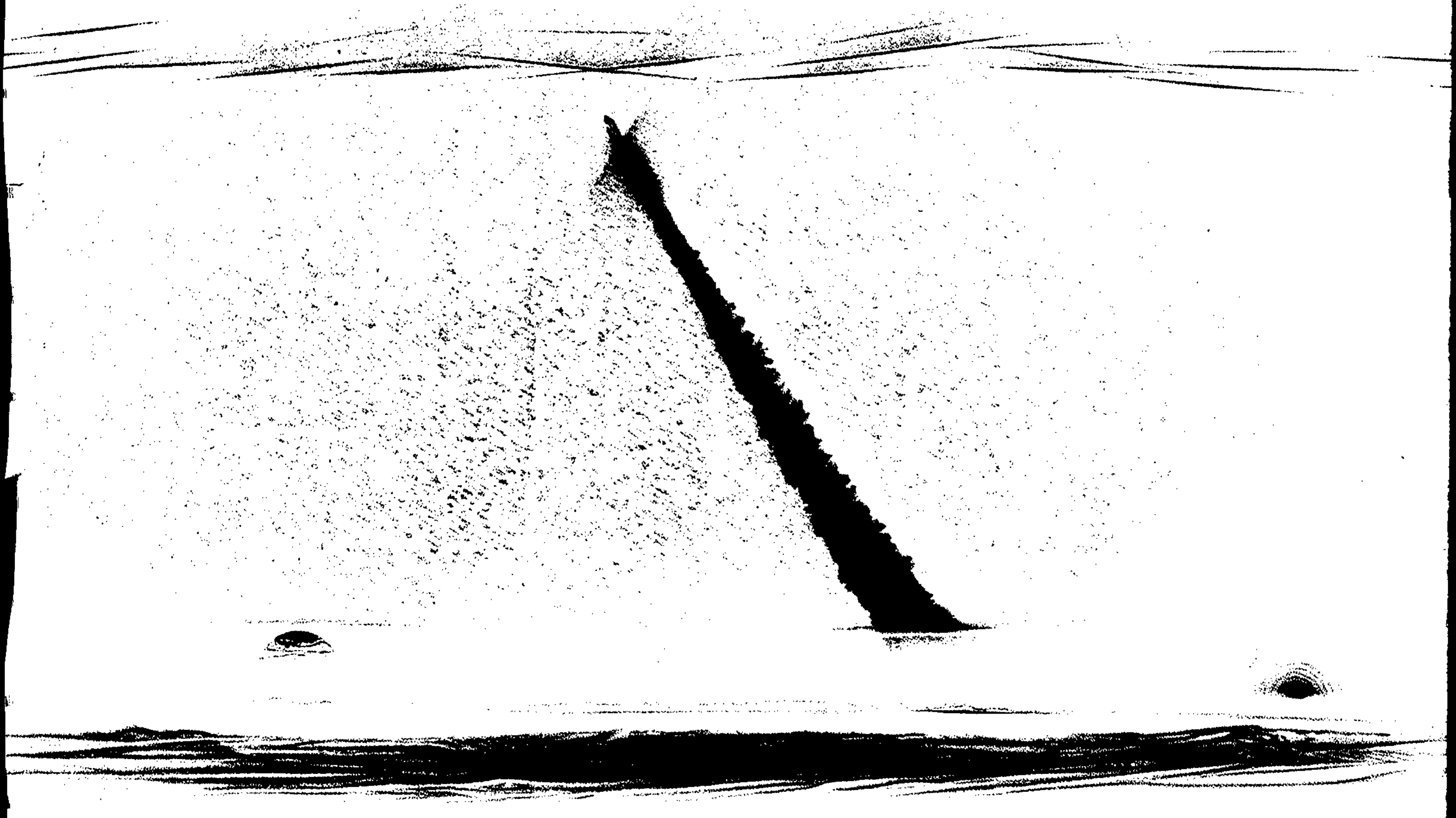
OAST
Technology For the Future

Executive Summary



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IN-SPACE TECHNOLOGY EXPE

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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

OAST IN-STEP 88 WORKSHOP

Executive Summary

INTRODUCTION

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 lists prepared at the Workshop were later supplemented by summaries of critical technology needs prepared in a uniform format by the theme leaders. 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: In-Reach/Out-Reach Experiments and Experiment Integration Process (Volume I); and Critical Technology Presentations (Volumes II and III)

The Executive Summary contains the Welcome and Workshop Instructions, Strategic Planning for the In-Space Technology Experiments, an overview of the space technology experiments being conducted in OAST and the solicitation process for IN-STEP, the proposed accommodation process for Space Station Freedom, the Keynote Address reproduced from the workshop banquet, and the critical technology needs summaries for each theme. The Welcome and Workshop Instructions describes the purpose, the process, and the product intended for the workshop. The Space Strategic Planning process describes the OAST space Research and Technology base programs which generate new technology concepts in the major discipline areas, the new focused programs of the Civil Space Technology Initiative (CSTI) and the Pathfinder, and the new fiscal year 1990 initiative of In-Space Technology Experiments Program (IN-STEP) which provides funding for the industry, university, and NASA space technology experiments. Overview charts of current OAST sponsored space flight experiments and specific information regarding the IN-STEP solicitation process are provided to establish an understanding of space technologies currently being validated and the proposed approach for initiating new experiments. An overview of the user/payload integration and accommodation process being established for use on the Space Station Freedom is documented to promote better understanding with the space experiment community. The keynote address was presented by Dr. Harrison H. Schmitt, a former U.S. Senator and Apollo astronaut on the 16th anniversary of his lunar launch. In his presentation, Dr. Schmitt outlined his vision for the future of the U.S. space program by describing a Millennium Project which would combine space ventures to the earth, moon, and Mars. The critical technology needs summaries for each theme are as described above, standardized format versions of the lists prepared "real-time" at the Workshop. In the appendices of this Summary are the final workshop agenda and a list of workshop attendees.

OPENING PRESENTATIONS

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WELCOME AND WORKSHOP INSTRUCTIONS

DR LEONARD HARRIS

CHIEF ENGINEER
OFFICE OF AERONAUTICS AND SPACE TECHNOLOGY

IN-STEP 88

- **PURPOSE**
  - IDENTIFY & PRIORITIZE IN-SPACE TECHNOLOGIES WHICH:
    - ARE CRITICAL FOR FUTURE NATIONAL SPACE PROGRAMS
    - REQUIRE DEVELOPMENT & IN-SPACE VALIDATION
  - REVIEW CURRENT NASA (IN-REACH) & INDUSTRY/ UNIVERSITY (OUT-REACH) EXPERIMENTS WITH THE AEROSPACE COMMUNITY
  - OBTAIN AEROSPACE COMMUNITY COMMENTS & SUGGESTIONS ON OAST IN-STEP PLANS
- **PRODUCT**
  - AEROSPACE COMMUNITY RECOMMENDED PRIORITY LISTING OF CRITICAL SPACE TECHNOLOGY NEEDS & ASSOCIATED SPACE FLIGHT EXPERIMENTS

TECHNOLOGY THEMES

IN-STEP 85 WORKSHOP	IN-STEP 88 WORKSHOP
SPACE STRUCTURES	SPACE STRUCTURES
SPACE ENVIRONMENT EFFECTS	SPACE ENVIRONMENT EFFECTS
ENERGY SYSTEMS & THERMAL MANAGEMENT	POWER SYSTEMS & THERMAL MGMT.
FLUID MANAGEMENT	FLUID MANAGEMENT & PROPULSION SYSTEMS
AUTOMATION & ROBOTICS	AUTOMATION & ROBOTICS
INFORMATION SYSTEMS	SENSORS & INFORMATION SYSTEMS
IN-SPACE OPERATIONS	IN-SPACE SYSTEMS
	HUMANS-IN-SPACE

RESULTS OF THE WORKSHOP

- STRENGTHEN COMMUNICATION WITH THE AEROSPACE COMMUNITY ON THE IN-SPACE TECHNOLOGY EXPERIMENTS PROGRAM
- IDENTIFY CRITICAL IN-SPACE TECHNOLOGY NEEDS FOR FUTURE RESEARCH & DEVELOPMENT
- PRIORITIZE SPACE TECHNOLOGY NEEDS & ASSOCIATION IN-SPACE TECHNOLOGY EXPERIMENTS

WORKSHOP AGENDA

Dec 6 (Tuesday Morning)	–	PROGRAM OVERVIEW
Dec 6 (Tuesday Afternoon)	–	REVIEW OF CURRENT IN-REACH & OUT-REACH EXPERIMENTS
Dec 7 (Wednesday & Thursday Morning)	–	THEME REVIEWS & DISCUSSIONS
Dec 8 (Thursday Afternoon)	–	EXPERIMENT INTEGRATION PROCESS
Dec 9 (Friday Morning)	–	CRITICAL TECHNOLOGY REQUIREMENTS

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Office of
Aeronautics and
Space
Technology

IN-SPACE TECHNOLOGY EXPERIMENTS IN NASA'S STRATEGIC PLANNING

Presentation to

THE IN-SPACE TECHNOLOGY EXPERIMENTS WORKSHOP

Dr. Judith H. Ambrus
Assistant Director
for Space
December 6, 1988

(presented by Dr. Leonard Harris)

SPACE R&T PROGRAM

GOAL

- RECOGNIZED LEADERSHIP IN SPACE R&T TO ENABLE AND ENHANCE FUTURE CIVIL SPACE MISSIONS

AND

- PROVIDE A SOILID BASE OF CAPABILITIES AND TALENT TO SERVE ALL NATIONAL SPACE SECTORS

STRATEGY

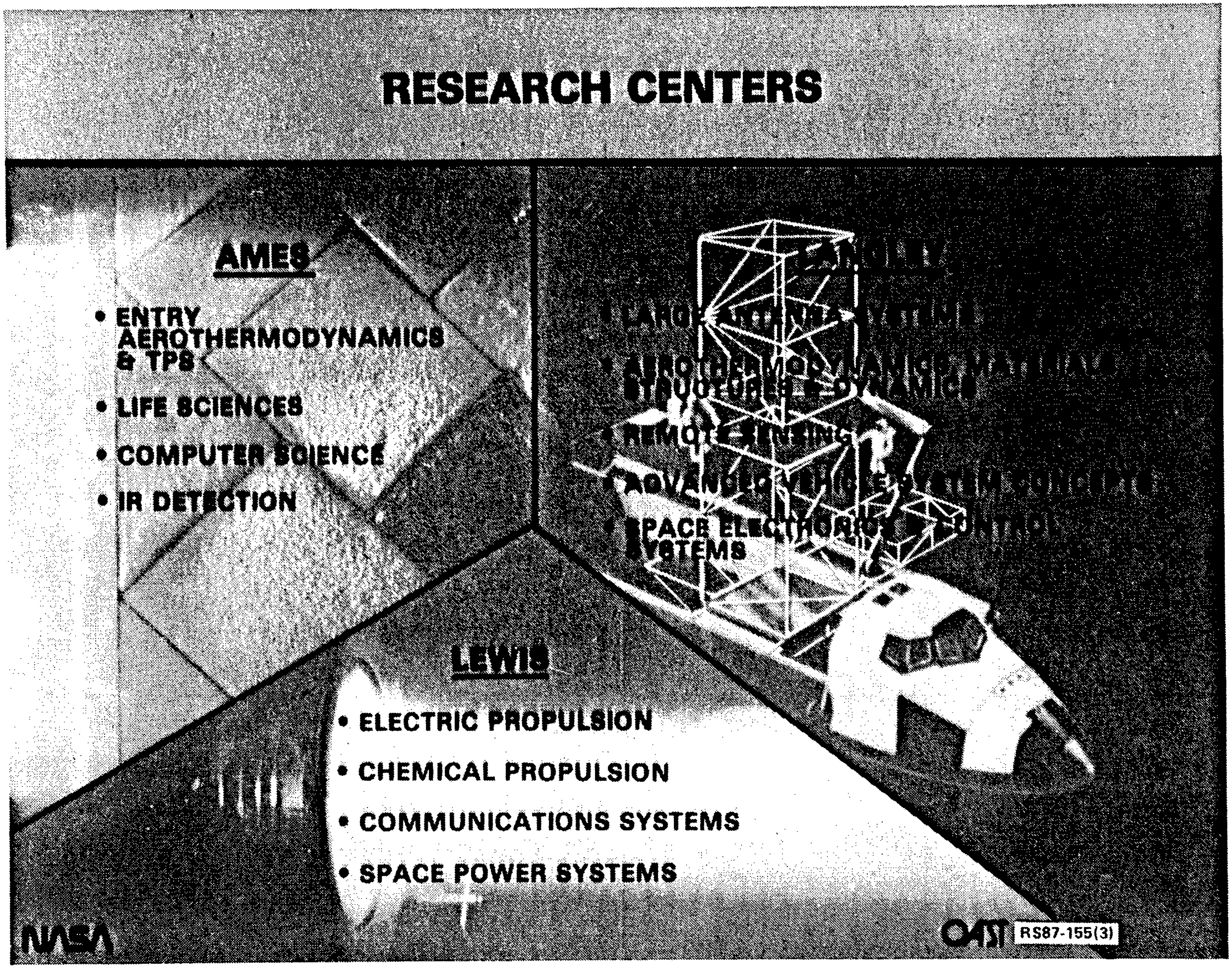
- ENSURE INNOVATIVE R&T BASE

LONG RANGE PLAN

- PURSUE NEW DIRECTIONS THROUGH ROLLOVER
- NURTURE NEW FOCUSED PROGRAMS
    - ULTRA-RELIABLE SYSTEMS
    - TECHNOLOGIES FOR MISSION TO PLANT EARTH
- ADVOCATE BUDGET GROWTH

R&T BASE CHARACTERISTICS

- LABORATORY RESEARCH
- GENERIC, FUNDAMENTAL
- ANALYTICAL MODELING
- ENGINEERING DATA BASE
- HIGH RISK, HIGH PAYOFF
- TECHNOLOGY OPPORTUNITIES



RESEARCH CENTERS

AMES

- ENTRY AEROTHERMODYNAMICS & TPS
- LIFE SCIENCES
- COMPUTER SCIENCE
- IR DETECTION

LANGLEY

- LARGE ANTENNA SYSTEMS
- AEROTHERMODYNAMICS, MATERIALS, STRUCTURES & DYNAMICS
- REMOTE SENSING
- ADVANCED VEHICLE SYSTEM CONCEPTS
- SPACE ELECTRONICS & CONTROL SYSTEMS

LEWIS

- ELECTRIC PROPULSION
- CHEMICAL PROPULSION
- COMMUNICATIONS SYSTEMS
- SPACE POWER SYSTEMS

NASA

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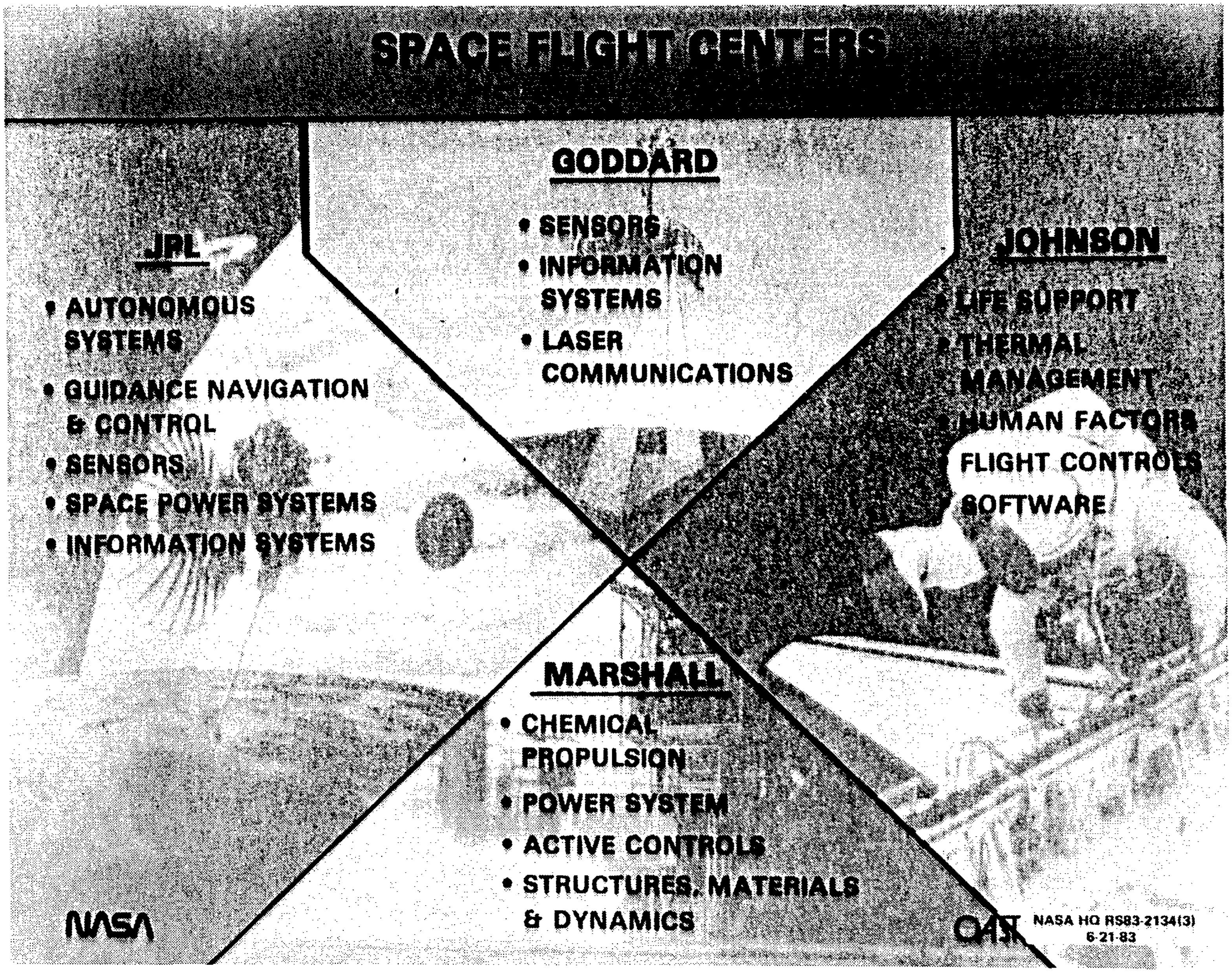

SPACE FLIGHT CENTERS

JPL

- AUTONOMOUS SYSTEMS
- GUIDANCE NAVIGATION & CONTROL
- SENSORS
- SPACE POWER SYSTEMS
- INFORMATION SYSTEMS

GODDARD

- SENSORS
- INFORMATION SYSTEMS
- LASER COMMUNICATIONS

JOHNSON

- LIFE SUPPORT
- THERMAL MANAGEMENT
- HUMAN FACTORS
- FLIGHT CONTROLS
- SOFTWARE

MARSHALL

- CHEMICAL PROPULSION
- POWER SYSTEM
- ACTIVE CONTROLS
- STRUCTURES, MATERIALS & DYNAMICS

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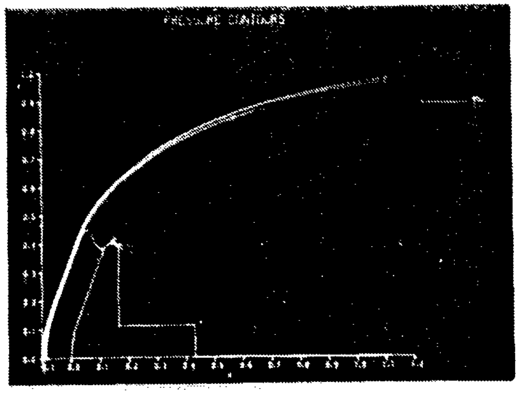
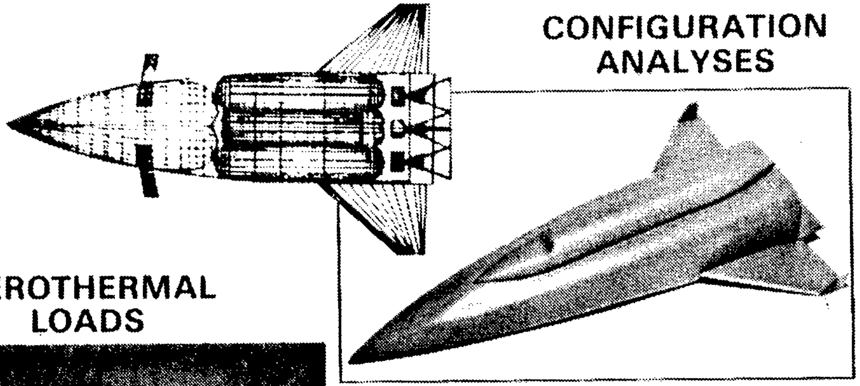
AEROTHERMODYNAMICS

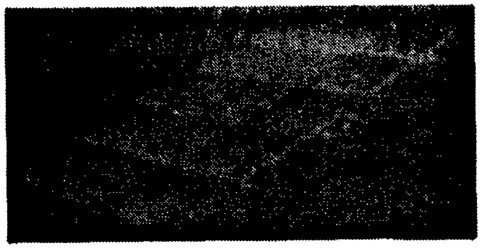
ADVANCED
COMPUTATIONAL METHODS



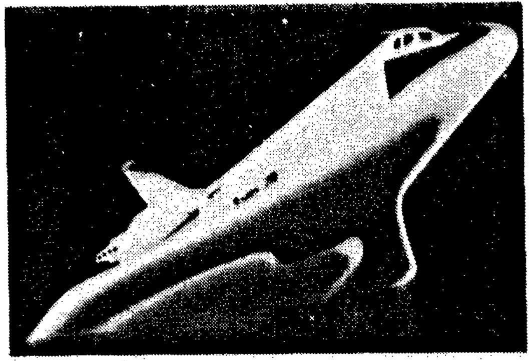


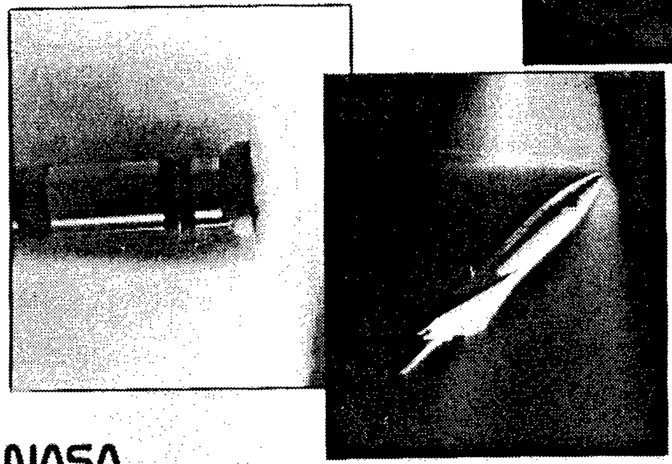
CONFIGURATION
ANALYSES

AEROTHERMAL
LOADS



FLIGHT DATA
ANALYSES



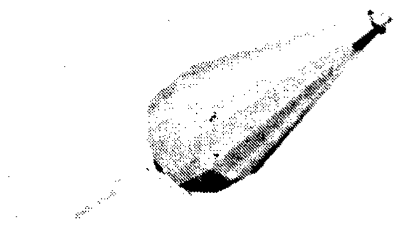


HYPERSONIC
WIND
TUNNEL
TESTING

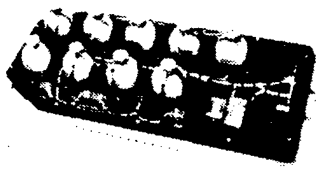
NASA

OAST
RF85 1263 (3)

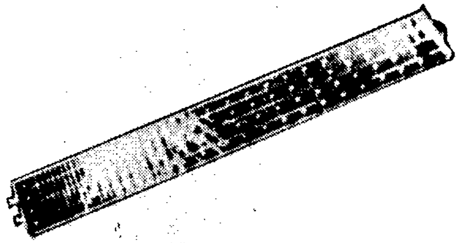
SPACE ENERGY CONVERSION



- SP-100
- SOLAR DYNAMICS

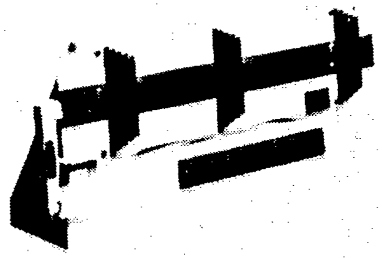


- PRIMARY/SECONDARY BATTERIES
- FUEL CELLS



- LIGHTWEIGHT ARRAYS
- CONCENTRATORS
- ADVANCED CELLS

- POWER DISTRIBUTION COMPONENTS



- TWO-PHASE HEAT PIPES
- ADVANCED RADIATORS

NASA

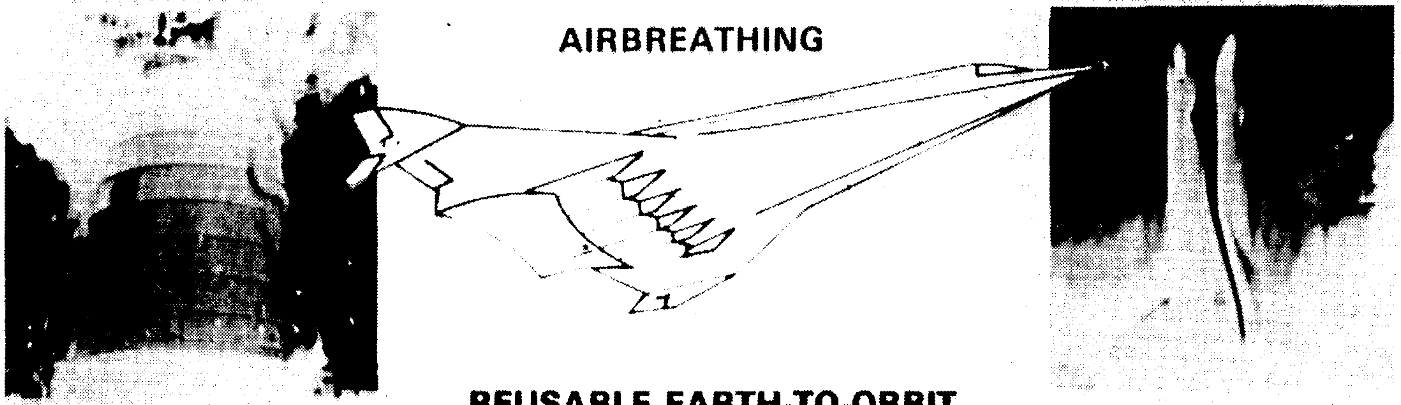
OAST
RP 85-587(3)

PROPULSION

LOX/HYDROGEN

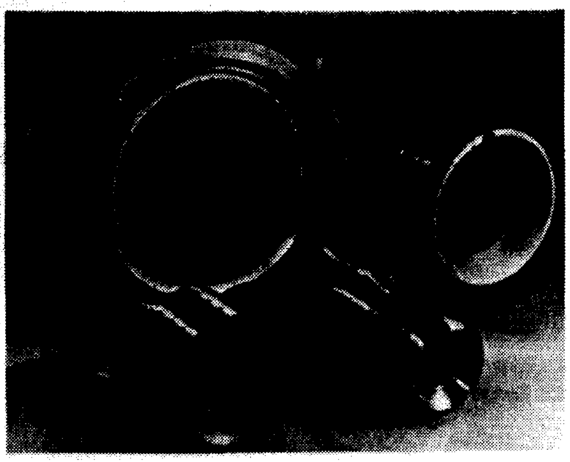
AIRBREATHING

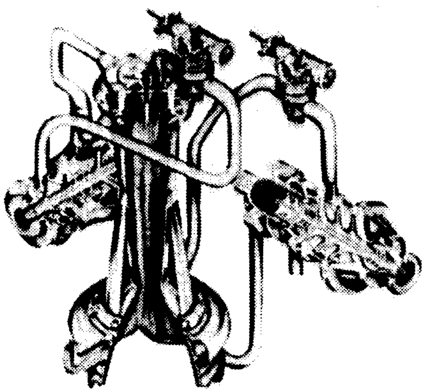
LOX/HYDROCARBON



REUSABLE EARTH-TO-ORBIT

LECTRIC
OPULSION



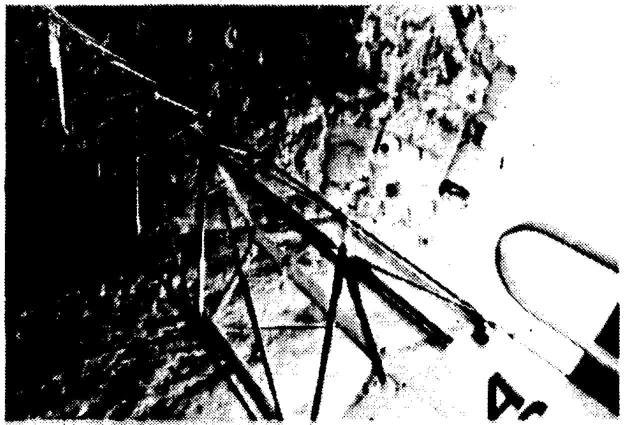


OTV
PROPULS

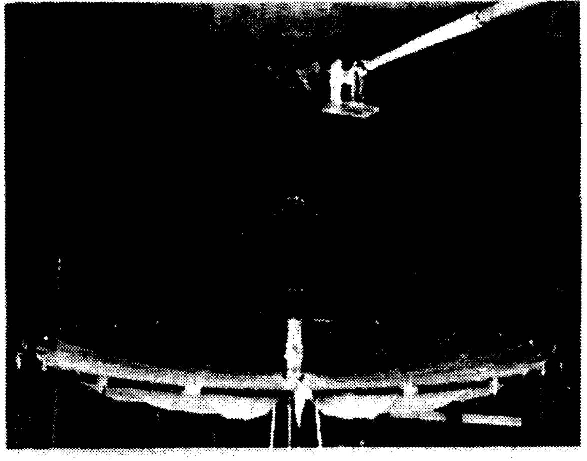
RP86 645 (3)

MATERIALS AND STRUCTURES

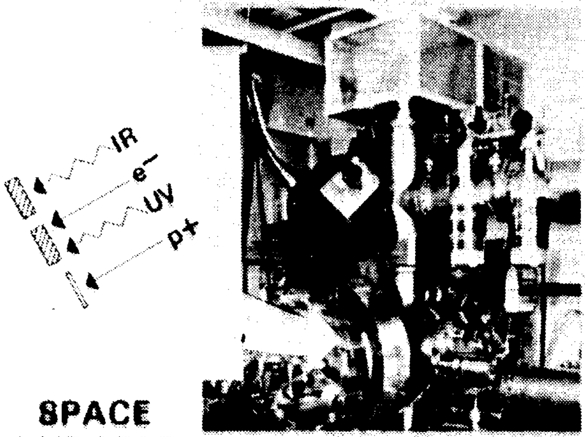
STRUCTURAL CONCEPTS



AEROTHERMAL STRUCTURES



DYNAMICS OF FLEXIBLE STRUCTURES



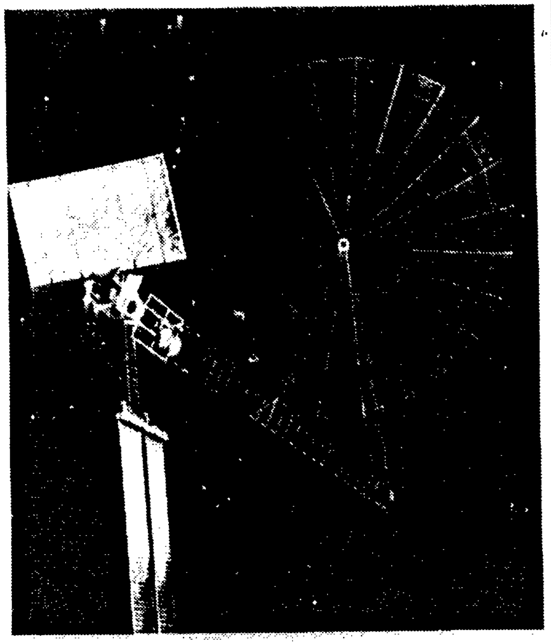
SPACE
DURABLE
MATERIALS

NASA

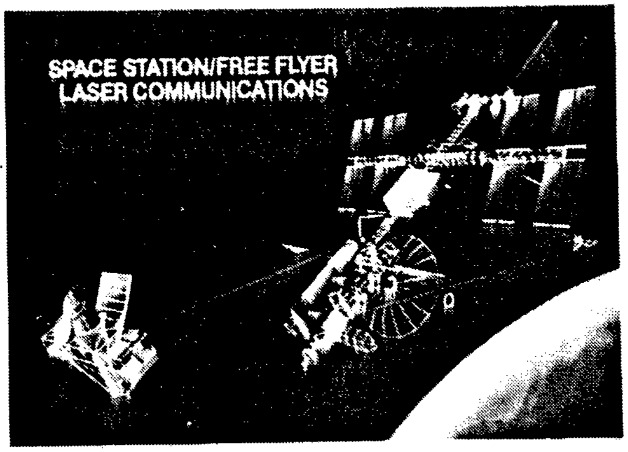
OAST
RM85 1288 (3)

SPACE DATA AND COMMUNICATIONS

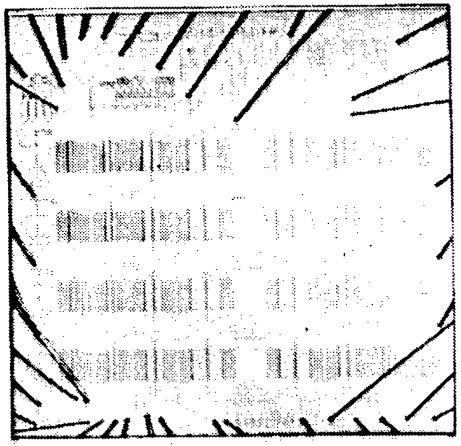
LARGE APERTURE ANTENNA

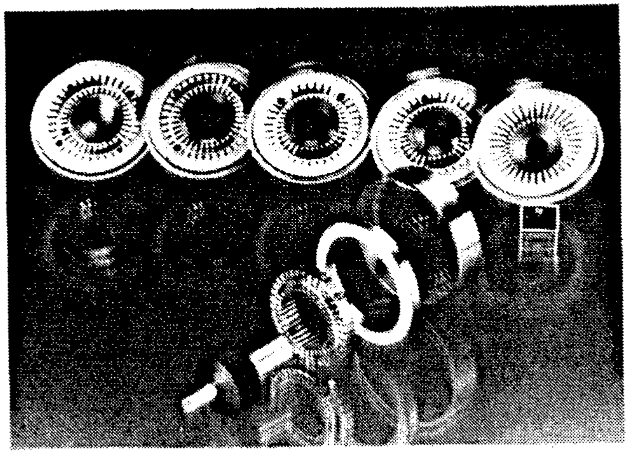


LASER COMMUNICATIONS



ON-BOARD PROCESSING COMPONENTS





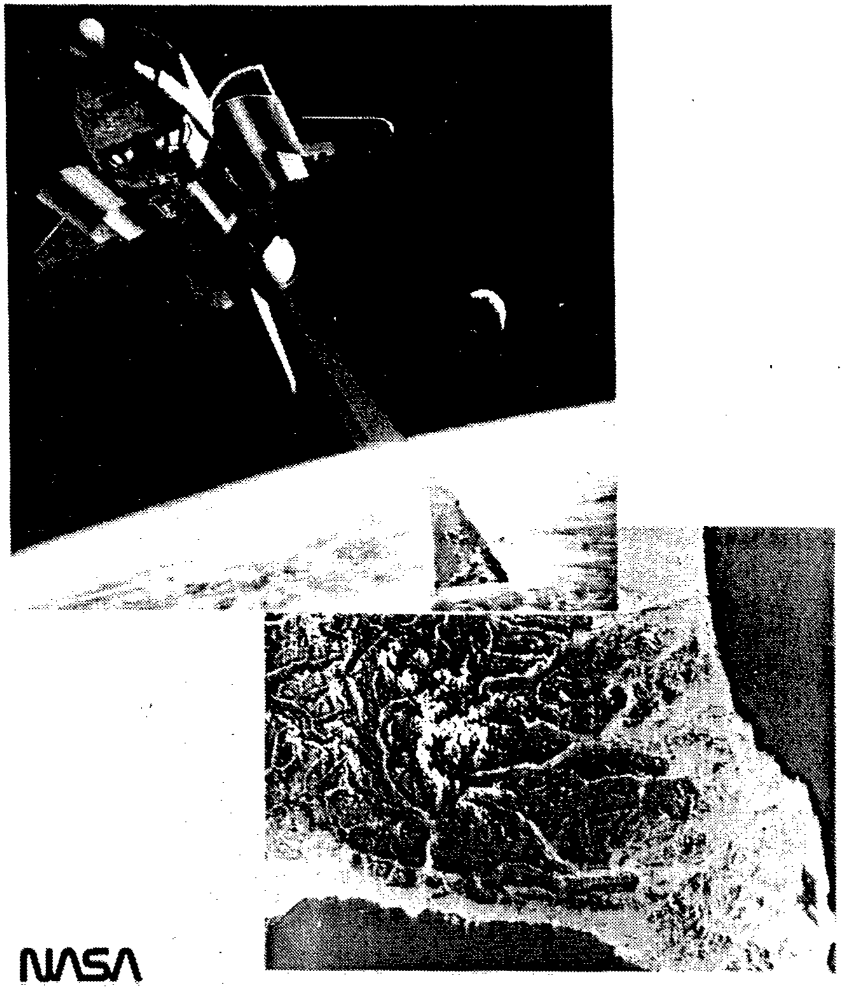
ADVANCED TRAVELING WAVE TUBE

NASA

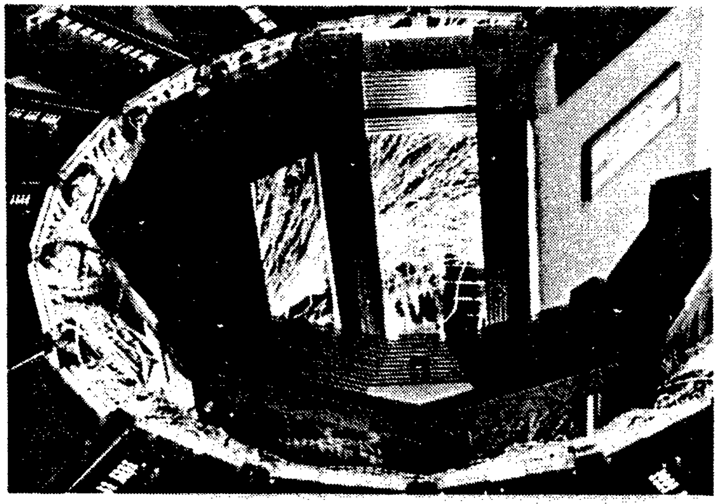
OAST
RC86-440(3)

INFORMATION SCIENCES

REMOTE SENSING



COMPUTER SCIENCES



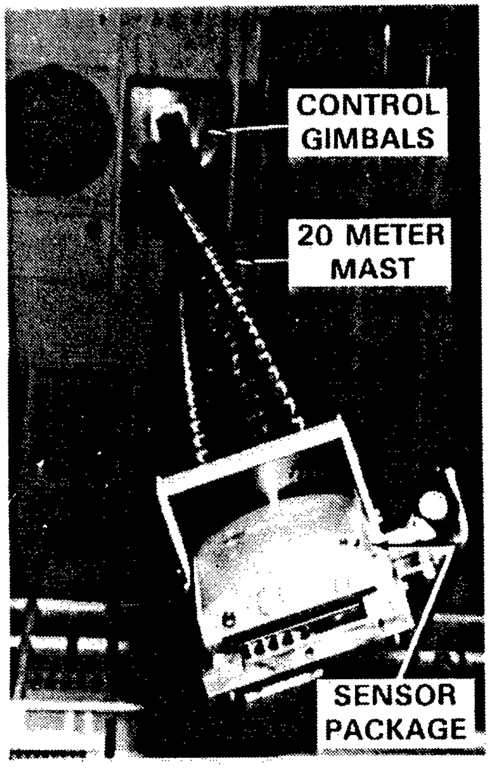
EXPERT SYSTEMS

NASA

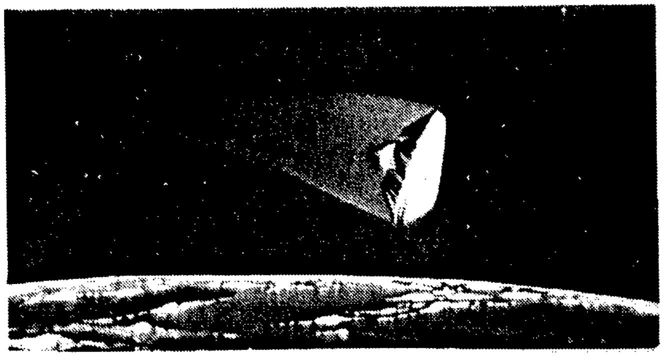
OAST
RC86-437(3)

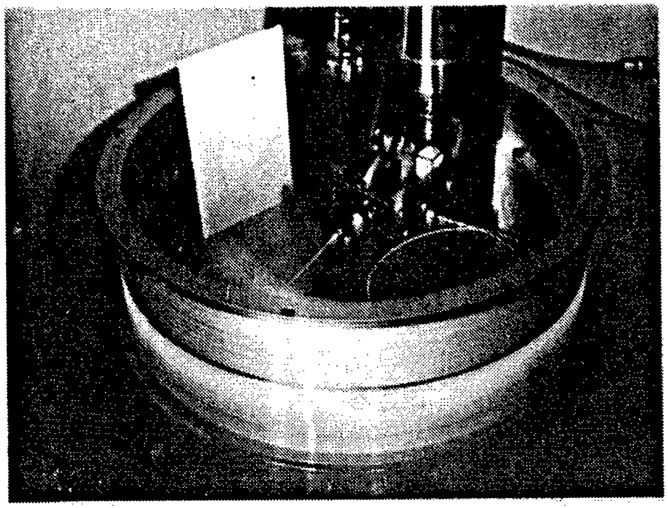
CONTROLS AND GUIDANCE

BEAM DYNAMICS



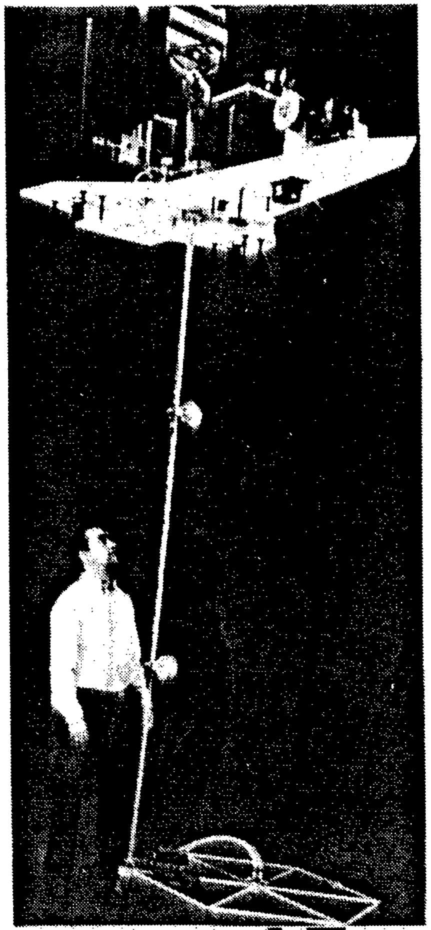
ADAPTIVE CONTROL (AFE)





LASER GUIDANCE
RESEARCH

SPACECRAFT CONTROL
LABORATORY
EXPERIMENT



NASA

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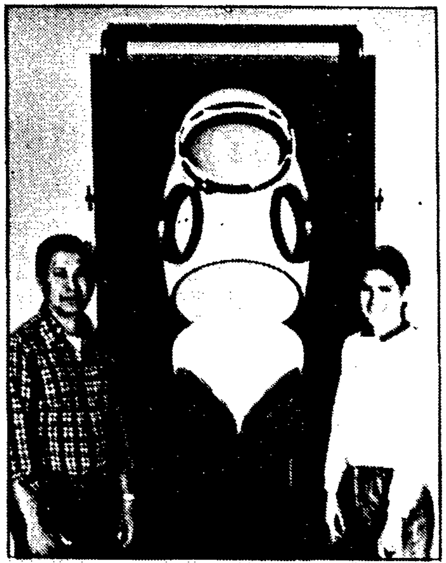
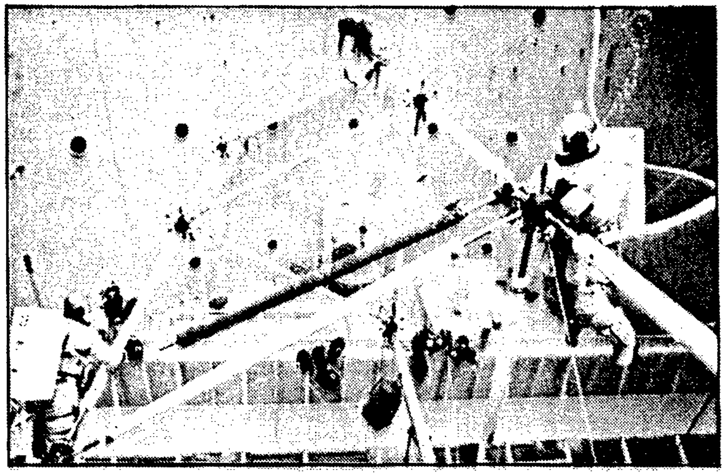
RC86-438(3)

HUMAN FACTORS

SPACE SUIT



EVA AIDS



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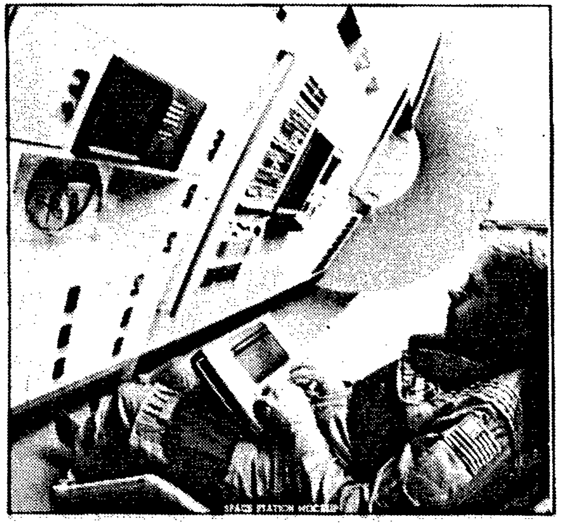
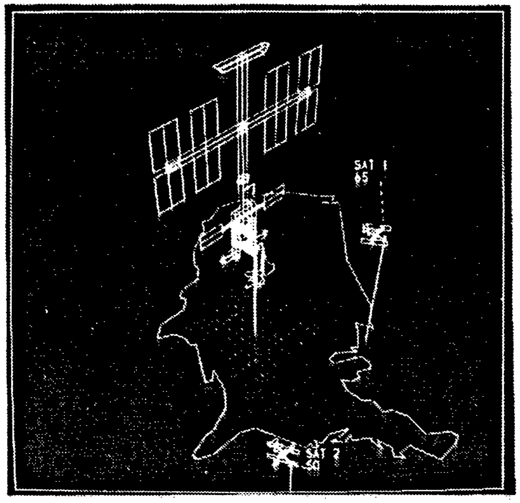


DISPLAY MODELING

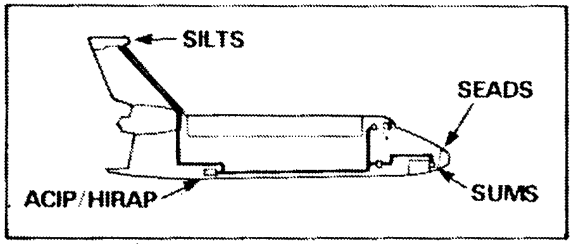


NASA

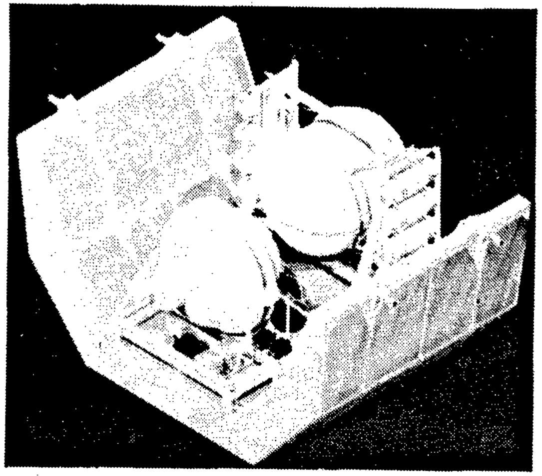
OAST
RC86-439(3)

SPACE FLIGHT SYSTEMS R&T

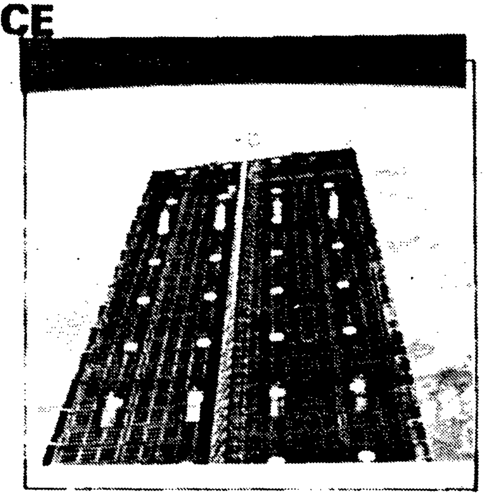
SPACE



ORBITER EXPERIMENTS
(OEX)

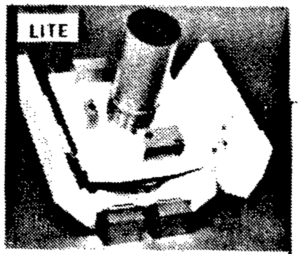


CRYOGENIC FLUID
MANAGEMENT



SOLAR
ELECTRIC
PROPLUSION
(SEP)

SPACE
FLIGHT
EXPERIMENTS



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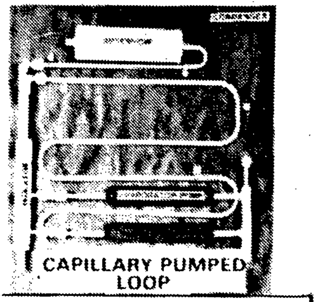
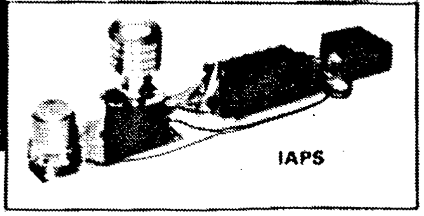


CAPILLARY PUMPED
LOOP



IAPS

NASA

OAST

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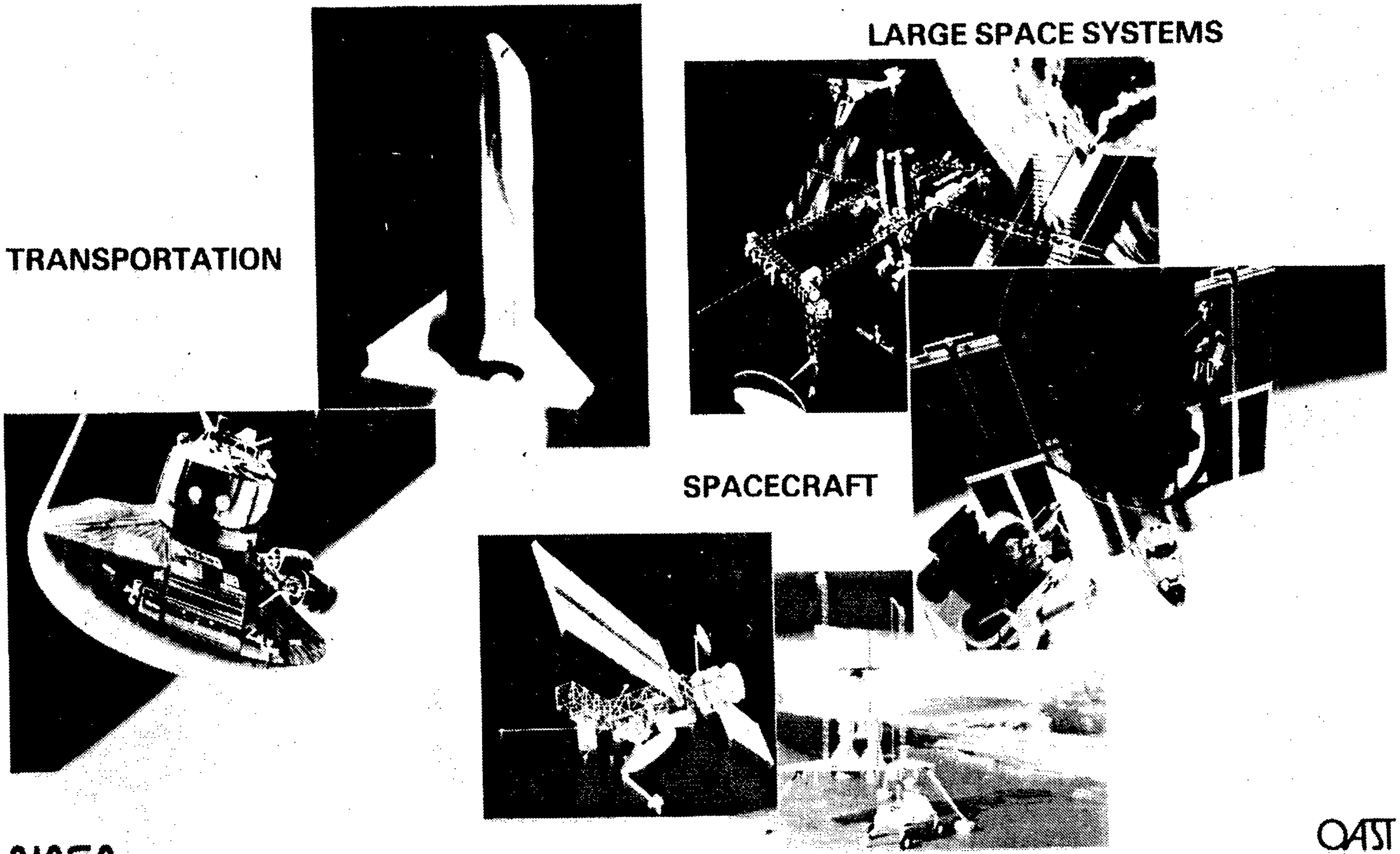
SYSTEMS ANALYSIS

TECHNOLOGY FOR FUTURE SPACE SYSTEMS



TRANSPORTATION

LARGE SPACE SYSTEMS

SPACECRAFT

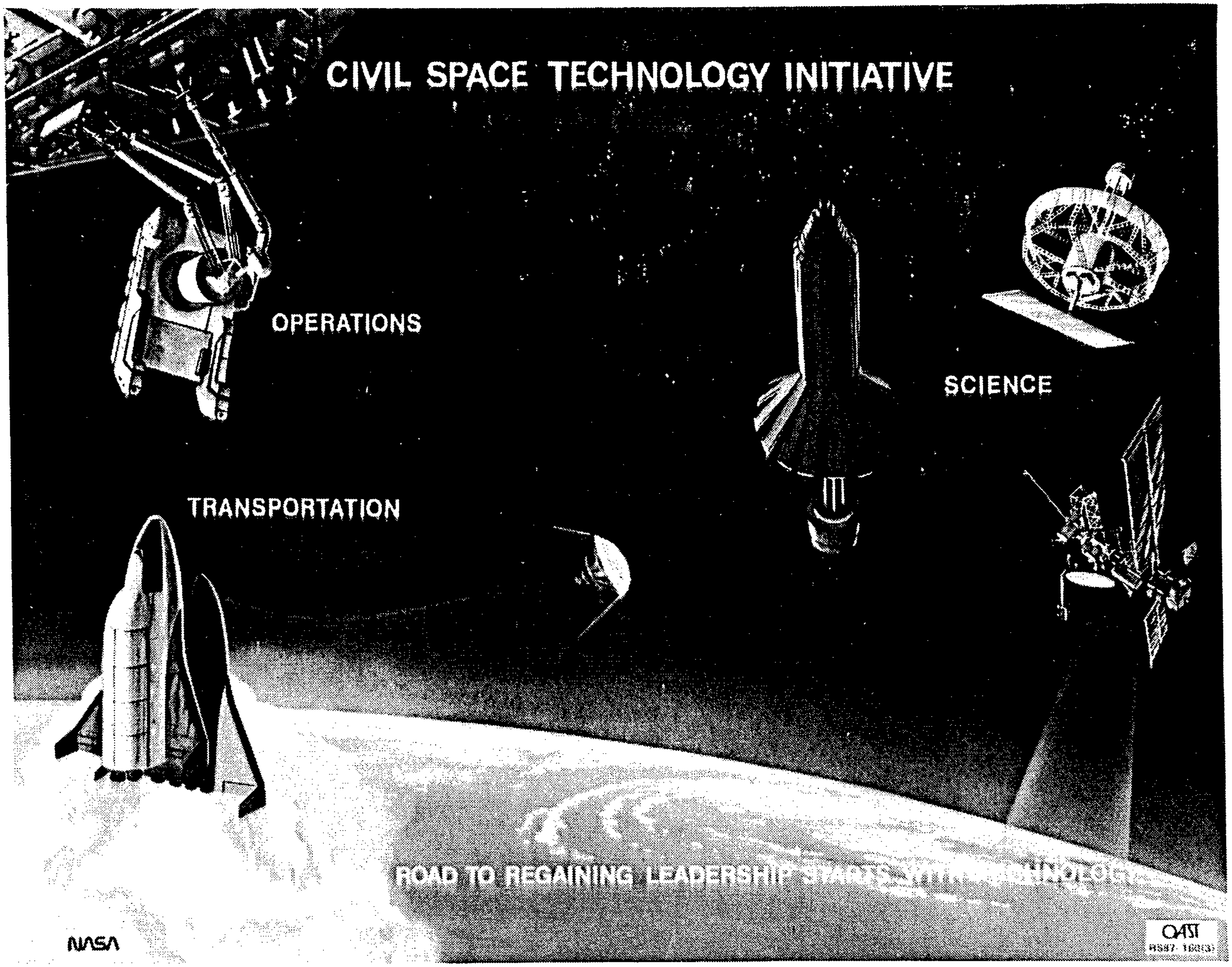
SPACE RESEARCH & TECHNOLOGY BASE

OAST IN-STEP 88

CANDIDATE EXAMPLES FOR FUTURE EMPHASIS

- SOFTWARE ENGINEERING
- HIGH TEMPERATURE SUPERCONDUCTORS
- OPTICS
- COMPUTATIONAL CONTROLS
- NDE/NDI
- TECHNOLOGY FOR SELF REPAIR
- BASIC RESEARCG IN "INHERENT RELIABILITY"
- MICROSAT TECHNOLOGY
- WORLD MODELING DATA SYSTEMS

CIVIL SPACE TECHNOLOGY INITIATIVE



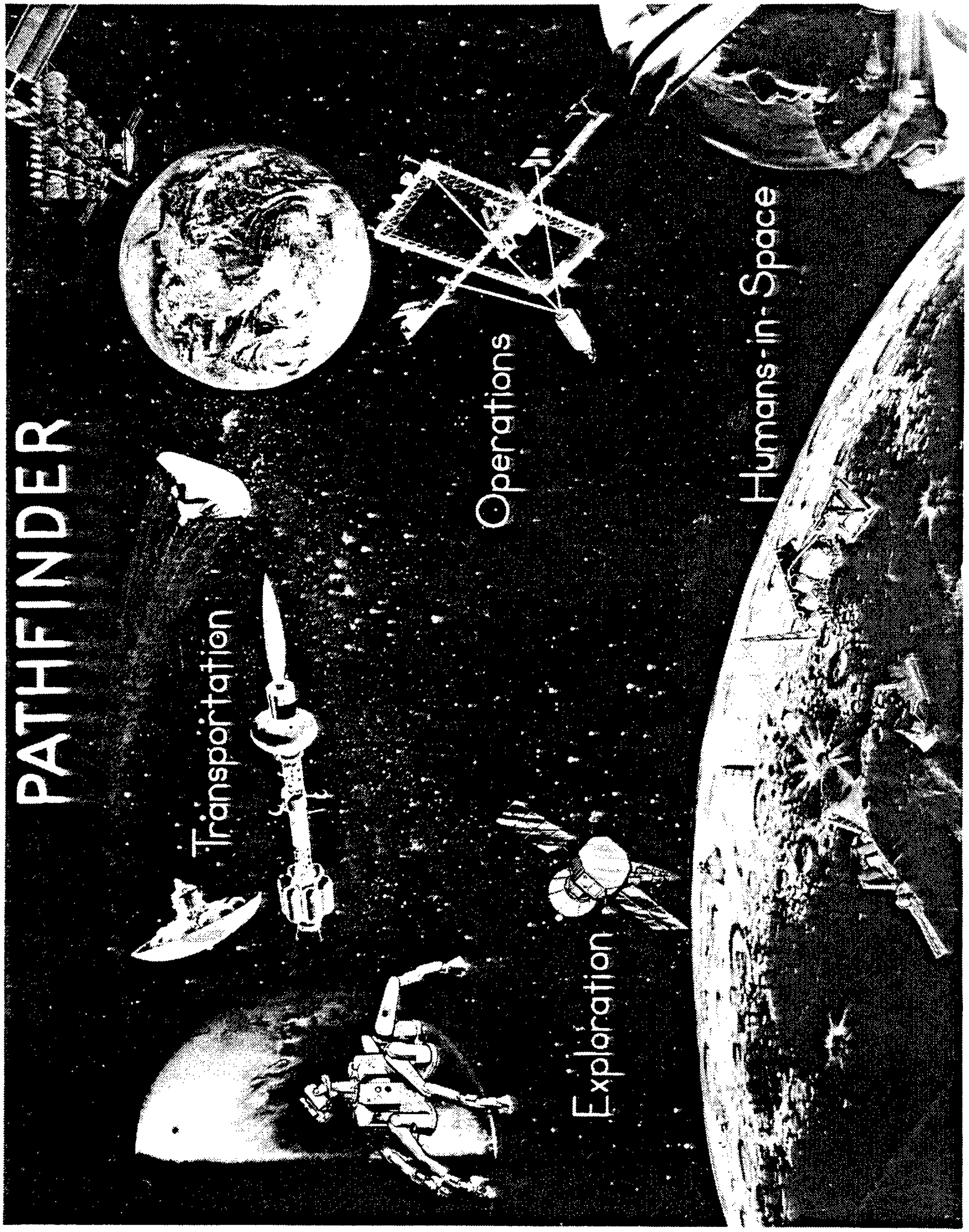
ROAD TO REGAINING LEADERSHIP STARTS WITH TECHNOLOGY

BACKGROUND

- THE FIRST STEP IN REVITALIZING THE NATION'S CIVIL TECHNOLOGY BASE
- WILL FILL IN GAPS IN MANY TECHNOLOGY AREAS
- FOCUSED TECHNOLOGY EFFORT, WILL RESULT IN DEMONSTARTED / VALIDATED TECHNOLOGIES

MISSION NEEDS

- TRANSPORTATION TO LOW EARTH ORBIT
  - PROPULSION
  - AEROBRAKING
- OPERATIONS IN LOW EARTH ORBIT
  - AUTONOMOUS SYSTEMS
  - TELEROBOTICS
  - POWER
- SCIENCE
  - STRUCTURES
  - SENSORS
  - DATA SYSTEMS


PATHFINDER
Transportation
Operations
Humans-in-Space
Exploration

PATHFINDER

- DEVELOPS HIGH LEVERAGE TECHNOLOGIES FOR PILOTED AND ROBOTIC SOLAR SYSTEM EXPLORATION
- CRITICAL ELEMENT OF THE PRESIDENT'S SPACE POLICY
- LONG-TERM PROGRAM, PROVIDING BOTH RESEARCH AND DEMONSTRATIONS
- NECESSARY TO MAINTAIN U.S. LEADERSHIP IN SPACE

STRATEGY

- VALIDATE TECHNOLOGY FOCUSED ON ENABLING AND ENHANCING NEW MISSIONS

LONG RANGE PLAN

- EMPHASIZE HEALTHY AND COMPLETE CSTI AND PATHFINDER PROGRAMS
- RESPOND TO EVOLVING NEW MISSION CONCEPTS
- REFINE AND ACCELERATE TECHNOLOGY DEVELOPMENT AND VALIDATION IN RESPONSE TO AGENCY DECISION ON BOLD NEW INITIATIVES

UNIVERSITY SPACE ENGINEERING RESEARCH PROGRAM

- INTEGRAL PART OF STRATEGY TO REBUILD R&T BASE
  - INCREASE NUMBER OF ENGINEERING GRADUATES
  - INCREASE INVOLVEMENT OF UNIVERSITIES IN CIVIL SPACE PROGRAM
- LONG TERM FUNDING ENCOURAGES UNIVERSITY COMMITMENT
- UNIVERSITY INVOLVEMENT ADDS VALUE
  - SPACE R&T
    - INNOVATIVE/CREATIVE APPROACHES
    - PARTICIPATION FROM WIDE RANGE OF ENGINEERING AND SCIENTIFIC FIELDS
  - UNIVERSITY
    - IMPROVES CURRICULA
    - GREATER RELEVANCE OF RESEARCH TO CIVIL SPACE NEEDS

UNIVERSITY SPACE ENGINEERING RESEARCH PROGRAM

NINE CENTERS SELECTED FOR FY 1988

UNIVERSITY OF ARIZONA	CENTER FOR UTILIZATION OF LOCAL PLANETARY RESOURCES
UNIVERSITY OF CINCINNATI	HEALTH MONITORING TECHNOLOGY CENTER FOR SPACE PROPULSION SYSTEMS
UNIVERSITY OF COLORADO, BOULDER	CENTER FOR SPACE CONSTRUCTION
UNIVERSITY OF IDAHO	VERY LARGE SCALE INTEGRATED HARDWARE ACCELERATION CENTER FOR SPACE RESEARCH
MASSACHUSETTS INSTITUTE OF TECHNOLOGY	CENTER FOR SPACE ENGINEERING RESEARCH FOCUSED ON CONTROLLED STRUCTURES TECHNOLOGY
UNIVERSITY OF MICHIGAN	CENTER FOR NEAR-MILLIMETER WAVE COMMUNICATION
NORTH CAROLINA STATE AT RALEIGH & NORTH CAROLINA AGRICULTURAL & TECHNICAL STATE UNIVERSITY	MARS MISSION RESEARCH CENTER
PENNSYLVANIA STATE UNIVERSITY	CENTER FOR SPACE PROPULSION ENGINEERING
RENSSELAER POLYTECHNIC INSTITUTE	INTELLIGENT ROBOTIC SYSTEMS FOR SPACE EXPLORATION

STRATEGY

- EXPAND UNIVERSITY PROGRAMS

LONG RANGE PLAN

- GROWTH FOR NINE INCUMBENT UNIVERSITY ENGINEERING RESEARCH CENTERS AWARDED IN APRIL, 1988
- ADD NEW AREAS OF PROGRAMMATIC INTEREST
- BROADEN UNIVERSITY SUPPORT TO INCLUDE INDIVIDUAL INNOVATION IN RESEARCH

IN-SPACE EXPERIMENTS IN OAST

- **IN-SPACE EXPERIMENTS HAVE ALWAYS BEEN PART OF OAST'S PROGRAM**
    - TO OBTAIN DATA THAT CAN NOT BE ACQUIRED ON THE GROUND
    - TO DEMONSTRATE FEASIBILITY OF CERTAIN ADVANCED TECHNOLOGIES
- **CONDUCTING TECHNOLOGY EXPERIMENTSS IN SPACE IS A VALUABLE AND COST EFFECTIVE WAY TO INTRODUCE ADVANCED TECHNOLOGY INTO FLIGHT PROGRAMS**
- **THE SHUTTLE HAS DEMONSTRATED THE FEASIBILITY AND TIMELY BENEFITS OF CONDUCTING HANDS-ON EXPERIMENTS IN SPACE**
- **SPACE STATION WILL BE A PERMANENT LABORATORY IN SPACE AND WILL PROVIDE LOGICAL AND EVOLUTIONARY EXTENSION OF GROUND BASED R&T IN SPACE**

IN-SPACE EXPERIMENTS PLANNING

ASEB PANEL ON NASA'S R&T PROGRAM	JUNE	1983
INDUSTRY/DOD WORKSHOP	FEB	1984
ADMINISTRATOR'S POLICY STATEMENT	APRIL	1984
ASEB PANEL ON IN-SPACE ENGINEERING AND TECHNOLOGY DEVELOPMENT	MAY	1985
OAST IN-SPACE TECHNOLOGY WORKSHOP	OCT	1985
INITIATION OF IN-REACH/OUT-REACH PROGRAMS	OCT	1985
SSTAC AD HOC COMMITTEE ON THE USE OF SPACE STATION FOR IN-SPACE ENGINEERING R&T	AUG	1987
SPACE STATION OPERATIONS TASK FORCE	OCT	1987
NASA MANAGEMENT STUDY GROUP (NMSG - 24)	DEC	1987
NASA CENTER SCIENCE ASSESSMENT TEAM	MAY	1988

ADVISORY GROUP RECOMMENDATIONS

..."NASA SHOULD PROVIDE ACCESS TO SPACE FOR EXPERIMENTAL PURPOSES AS A NATURAL EXTENSION OF AEROSPACE FACILITIES... ...AN EVOLUTIONARY PROGRAM OF ON-ORBIT RESOURCE EQUIVALENT TO .... THE WIND TUNNELS"...

ASEB, 1983

..."NASA SHOULD BETTER EXPLOIT THOSE SPACE FACILITIES THAT ARE UNIQUE .... THE SHUTTLE AND THE SPACE STATION FOR THE DEVELOPMENT OF TECHNOLOGY FOR NASA, DOD, AND THE INDUSTRY"...

DOD/INDUSTRY (HEARTH) WORKSHOP, 1984

..."OAST SHOULD PROVIDE THE LEADERSHIP.....TO SUPPORT THE ENGINEERING TECHNOLOGY NEEDS OF THE USER INDUSTRY, OTHER GOVERNMENT AGENCIES, AS WELL AS ITS OWN FOR ALL IN-SPACE ENGINEERING R&T"...

ASEB, 1985

NASA POLICY ON ROLE OF SPACE TECHNOLOGY

... "IT WILL BE NASA'S POLICY TO SUPPORT THE DOD AND SPACE INDUSTRY THROUGH COMPETITIVE R&T PROGRAMS JUST AS WE DO IN AERONAUTICS"...

..."WE CAN BE PARTICULARLY EFFECTIVE IN ESTABLISHING CLOSER TIES WITH INDUSTRY AND THAT IS THE USE OF THE SHUTTLE FOR IN-SPACE EXPERIMENTS.... WHICH WILL LEAD QUITE NATURALLY TO USING THE SPACE STATION FOR TECHNOLOGY AND ENGINEERING EXPERIMENTS"...

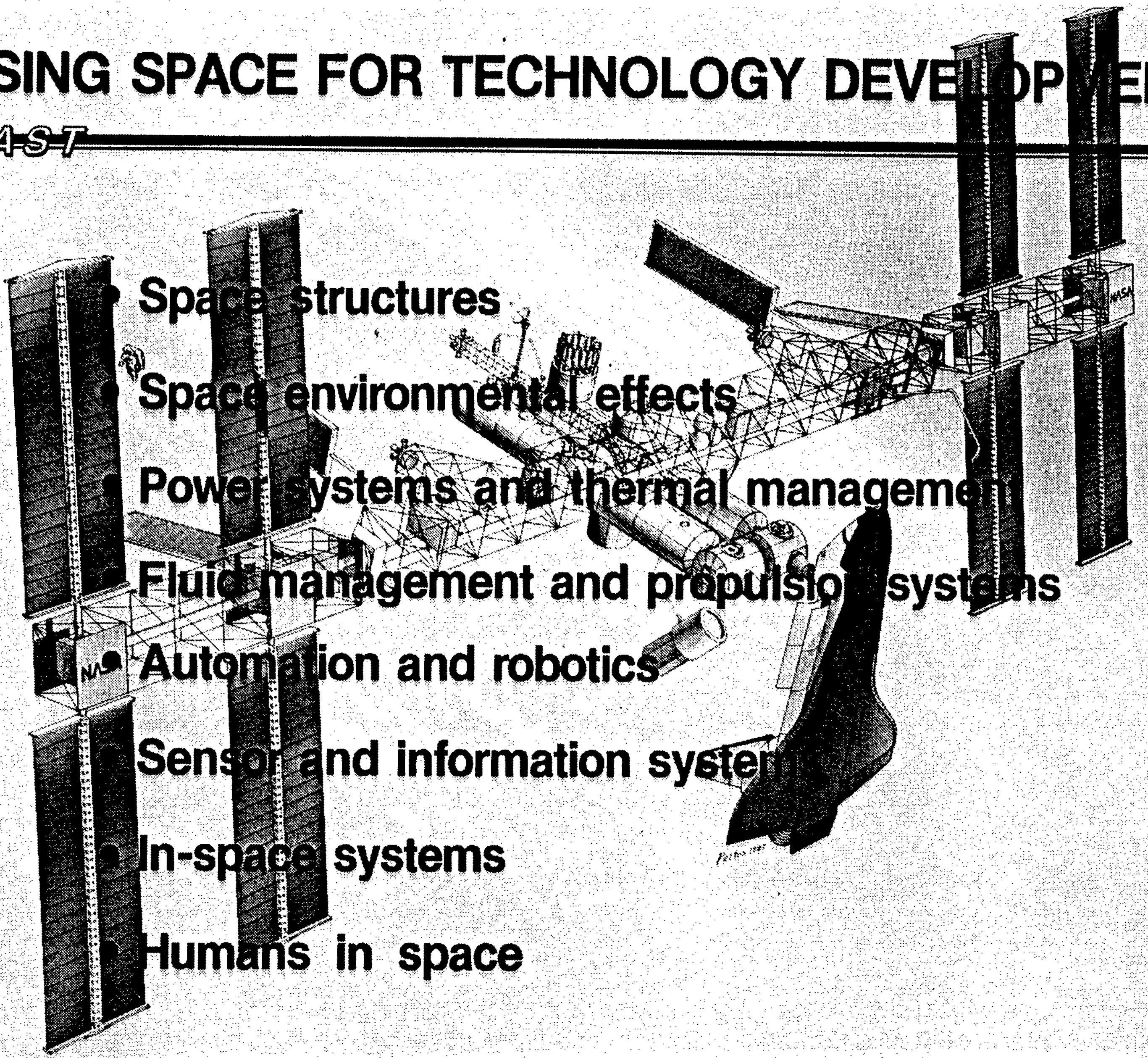
..."TO BEGIN IMPLEMENTING THIS POLICY, I HAVE ASKED ..(OAST).. TO INCREASE OUR EMPHASIS ON IN-FLIGHT EXPERIMENTS"...

MEMORANDUM FROM THE ADMINISTRATOR

APRIL 3, 1984

USING SPACE FOR TECHNOLOGY DEVELOPMENT

OAST



- Space structures
- Space environmental effects
- Power systems and thermal management
- Fluid management and propulsion systems
- Automation and robotics
- Sensor and information systems
- In-space systems
- Humans in space

IN-SPACE EXPERIMENTS INITIATIVE - PHASE I

- FLIGHT OPPORTUNITY RESTORED
- INITIATE MORE VIGOROUS PROGRAM ON SHUTTLE AND ELVs
  - OBTAIN DATA THAT CAN NOT BE OBTAINED ON THE GROUND
  - VALIDATE ADVANCED TECHNOLOGIES FOR EARLY USE IN FLIGHT PROJECTS
- GET A RUNNING START ON SPACE STATION
  - GEAR UP NASA, INDUSTRY, UNIVERSITY ACTIVITY
  - CONDUCT SPACE STATION PRECURSOR EXPERIMENTS

IN-SPACE TECHNOLOGY EXPERIMENTS PROGRAM

- NASA EXPERIMENTS
  - ARISE FROM THE R&T BASE OR FOCUSED PROGRAMS
  - INCLUDE PRESENTLY ONGOING EXPERIMENTS
- INDUSTRY/UNIVERSITY EXPERIMENTS
  - FOLLOWING THROUGH ON OUR COMMITMENTS IN THE OUT-REACH PROGRAM
- INTERNATIONAL EXPERIMENTS
  - COOPERATIVE ACTIVITIES WITH OUR ALLIES

NASA IN-SPACE TECHNOLOGY EXPERIMENTS

OAST IN-STEP 88

- INCORPORATES PRESENTLY ON-GOING IN-SPACE R&T PROGRAM
  - ORBITER EXPERIMENTS PROGRAM (OEX)
  - LONG DURATION EXPOSURE FACILITY (LDEF)
  - LIDAR IN-SPACE TECHNOLOGY EXPERIMENT (LITE)
  - ARCJET AUXILIARY PROPULSION SYSTEM
  - EXPERIMENTS SELECTED FROM IN-REACH SOLICITATION
- FUTURE EXPERIMENTS WILL CONTINUE TO ARISE AS A NATURAL EXTENSION OF R&T BASE AND FOCUSED PROGRAMS
  - CIVIL SPACE TECHNOLOGY INITIATIVE (CSTI)
  - PATHFINDER

INDUSTRY/UNIVERSITY IN-SPACE EXPERIMENTS

- PROVIDE ACCESS TO SPACE FOR INDUSTRY AND UNIVERSITIES TO DEVELOP SPACE TECHNOLOGY
    - ENTHUSIASTIC RESPONSE OF AEROSPACE COMMUNITY TO OUT-REACH SOLICITATION

- OAST HAS COMMITTED TO AEROSPACE COMMUNITY TO SERVE AS CONDUIT FOR TECHNOLOGY DEVELOPMENT IN SPACE
    - PERIODIC RESOLICITATIONS TO INDUSTRY/UNIVERSITY COMMUNITY FOR EXPERIMENT DEFINITION, DEVELOPMENT, AND FLIGHT

INTERNATIONAL IN-SPACE EXPERIMENTS

- PROMOTES COOPERATION WITH ALLIES
- LEVERAGES TECHNOLOGY DEVELOPMENT BY OTHERS IN KEY AREAS
- LEVERAGES AND HUSBANDS SCARCE FLIGHT OPPORTUNITIES

IN-SPACE EXPERIMENTS INITIATIVE - PHASE II

- ROUTINE OPERATIONS IN LOW EARTH ORBIT WILL INITIATE ERA OF BOLD NEW INITIATIVES
  - NEED FOR TECHNOLOGY DEMONSTRATIONS FOR ENABLING TECHNOLOGIES WILL INCREASE
  - THE RANGE OF TECHNOLOGIES TO BE DEMONSTRATED IN SPACE WILL INCREASE
  - SPACE STATION WILL PROVIDE THE FACILITY FOR SIMPLER, FASTER ACCESS TO SPACE
  - SPACE STATION WILL ENABLE EXPERIMENTS NEEDING LONG-TERM HUMAN INTERACTION
- EXPERIMENTS PLANNED AND DEFINED FOR SPACE STATION DURING PHASE I WILL ENTER HARDWARE DEVELOPMENT STAGE

SUMMARY

- TECHNICAL NEED IDENTIFIED 1983
- PLANNING COMPLETE 1983-86
- COMMITMENTS MADE 1986-88
    - INDUSTRY / UNIVERSITIES (VIA OUT-REACH)
    - CENTERS (VIA IN-REACH)
    - INTERNATIONAL COMMUNITY
- OPPORTUNITY FOR SPACE FLIGHT RESTORED
    - SHUTTLE, ELV MANIFESTING
    - SPACE STATION PLANNING

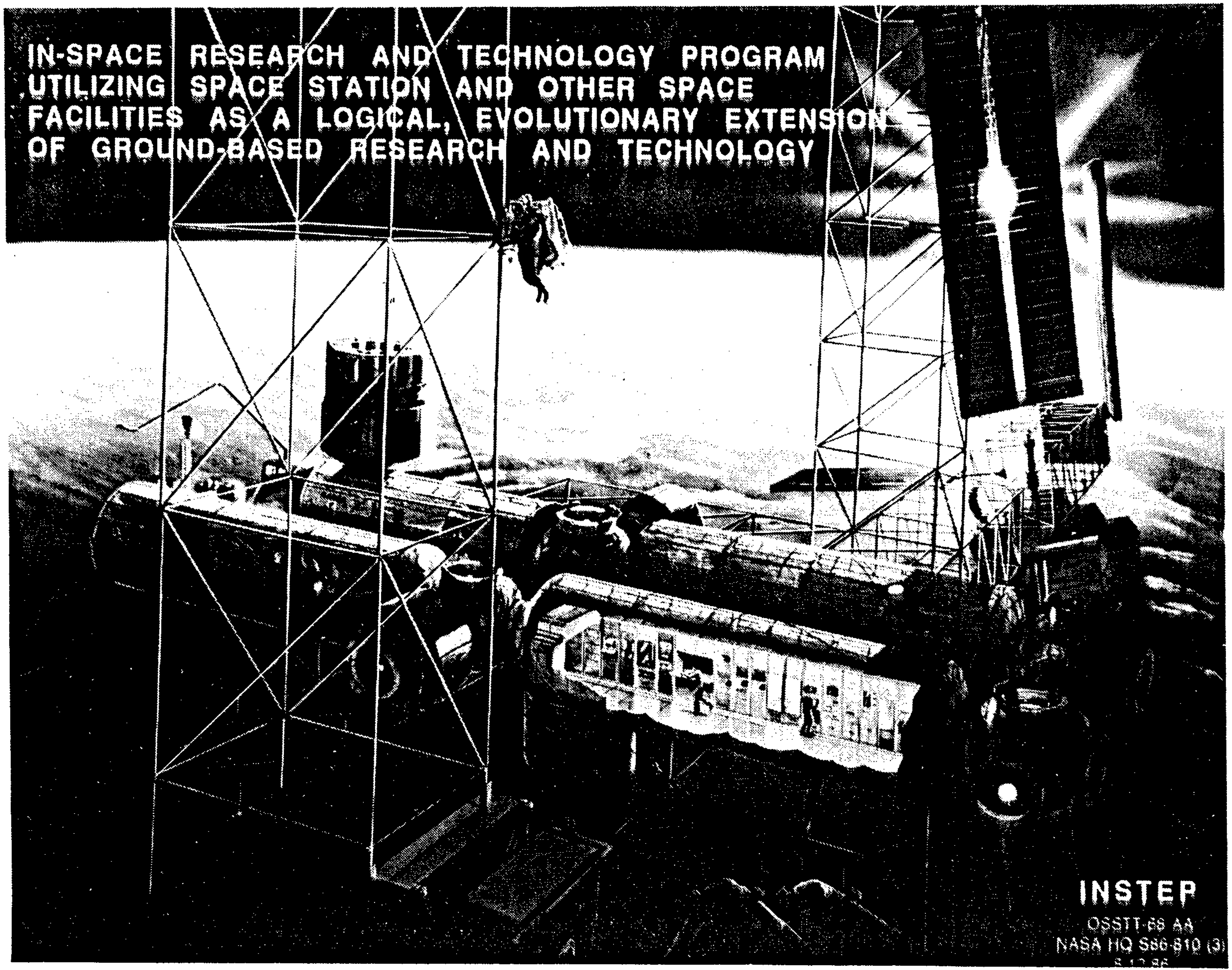
STRATEGY

- ENSURE INNOVATIVE R&T BASE
- VALIDATE TECHNOLOGY FOCUSED ON ENABLING NEW MISSIONS
- BUILD STRONGER LINKAGES TO EFFECTIVELY TRANSFER NEW TECHNOLOGIES TO USERS
- EXPAND UNIVERSITY PROGRAMS
- STEP UP TO COMMITMENT AS LEADER FOR TECHNOLOGY DEVELOPMENT ON SPACE STATION

SUMMARY

SPACE R&T: A FIVE YEAR OUTLOOK

- EQUITABLE AGENCY TECHNOLOGY INVESTMENT ESTABLISHED
- OAST IN TECHNOLOGY LEADERSHIP ROLE FOR AGENCYY
- COOPERATIVE TECHNOLOGY HAND-OFF AGREEEMENTS ESTABLISHED WITH USERS
- COORDINATION WITH NATIONAL SPACE SECTORS WELL ESTABLISHED
- OAST RECOGNIZED AS NATIONAL FOCAL POINT FOR IN-SPACE TECHNOLOGY DEVELOPMENT



IN-SPACE RESEARCH AND TECHNOLOGY PROGRAM UTILIZING SPACE STATION AND OTHER SPACE FACILITIES AS A LOGICAL, EVOLUTIONARY EXTENSION OF GROUND-BASED RESEARCH AND TECHNOLOGY

INSTEP

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IN-SPACE TECHNOLOGY EXPERIMENT PROGRAM

BY JACK LEVINE
DIRECTOR,
FLIGHT PROJECTS DIVISION
and
JON S. PYLE
MANGER,
IN-REACH & OUT-REACH PROGRAMS

OFFICE OF AERONAUTICS & SPACE TECHNOLOGY

CURRENT SPACE FLIGHT EXPERIMENTS

OAST — IN-STEP 88 WORKSHOP

FLIGHT EXPERIMENTS	HQ		LEAD CENTER
LONG DURATION EXPOSURE FACILITY	JOHN LORIA	—	LANGLEY
ORBITER EXPERIMENTS	RICHARD GUALDONI	—	JOHNSON
LIDAR IN-SPACE TECHNOLOGY EXPERIMENT	RICHARD GUALDONI	—	LANGLEY
AEROASSIST FLIGHT EXPERIMENT	JOHN SMITH	—	MARSHALL
ARCJET FLIGHT EXPERIMENT	JOHN LORIA	—	LEWIS
TELEROBOT INTELLIGENT INTERFACE FLIGHT EXPERIMENT	RICHARD GUALDONI	—	JPL
CRYOGENIC FLUID MANAGEMENT FLIGHT EXPERIMENT	JOHN LORIA	—	LEWIS
IN-REACH (NASA TECHNOLOGY EXPERIMENTS)	JON PYLE		
OUT-REACH (INDUSTRY/UNIVERSITY TECHNOLOGY EXPERIMENTS)	JON PYLE		

LDEF

LONG DURATION EXPOSURE FACILITY

OAST IN-STEP 88 WORKSHOP

OBJECTIVES:

- DETERMINE LONG-TERM SPACE EXPOSURE EFFECTS ON MATERIALS, COATINGS, & OPTICS
- MEASURE SPACE ENVIRONMENTAL PHENOMENA OVER EXTENDED TIME

STATUS:

- 34 EXPERIMENTS ADVERSELY AFFECTED BY LDEF RECOVERY DELAY
- 23 EXPERIMENTS EITHER IMPROVED OR NOT AFFECTED
- LDEF STRUCTURE AVAILABLE FOR STUDY OF ENVIRONMENTAL EROSION & DEBRIS IMPACT
- SCHEDULED FOR RETRIEVAL - NOVEMBER 1989

LEAD CENTER CONTACT:

- ROBERT L. JAMES, JR.
  LANGLEY RESEARCH CENTER
  PHONE NO. (804) 865-4987

OEX

OBITER EXPERIMENT PROGRAM

OBJECTIVES:

- OBTAIN BASIC AEROTHERMODYNAMIC & ENTRY ENVIRONMENT DATA FROM R&D INSTRUMENTATION INSTALLED IN SPACE SHUTTLE ORBITER
- FLIGHT-VALIDATE GROUND TEST RESULTS TO IMPROVE BASIS FOR DESIGN OF ADVANCED SPACECRAFT

STATUS:

- DATA COLLECTION ON-GOING SINCE 1985 - WILL CONTINUE INTO 1990'S
- SOME EXPERIMENTS STILL TO BE DESIGNED & DEVELOPED

LEAD CENTER CONTACT:

- ROBERT SPANN
  JOHNSON SPACE CENTER
  PHONE # (713) 483-3022

LITE

LIDAR IN-SPACE TECHNOLOGY EXPERIMENT

OAST IN-STEP 88 WORKSHOP

OBJECTIVE:

- EVALUATE CRITICAL ATMOSPHERIC PARAMETERS & VALIDATE OPERATION OF A SOLID-STATE LIDAR SYSTEM FROM A SPACEBORNE PLATFORM, MEASURING:
  - CLOUD DECK ALTITUDES
  - PLANETARY BOUNDARY-LAYER HEIGHTS
  - STRATOSPHERIC & TROPOSPHERIC AEROSOLS
  - ATMOSPHERIC TEMPERATURE & DENSITY (10KM TO 40KM)

STATUS:

- LASER TRANSMITTER MODULE, CASSEGRAIN TELESCOPE, & ENVIRONMENTAL MONITORING SYSTEM IN DEVELOPMENT
- FLIGHT MANIFESTED FOR 1993

LEAD CENTER CONTACT:

- RICHARD R. NELMS
  LANGLEY RESEARCH CENTER
  PHONE NO. (804) 865-4947

AFE

AEROASSIST FLIGHT EXPERIMENT

OBJECTIVE:

- INVESTIGATE CRITICAL VEHICLE DESIGN & ENVIRONMENTAL TECHNOLOGIES APPLICABLE TO THE DESIGN OF AEROASSISTED SPACE TRANSFER VEHICLES

STATUS:

- PHASE B DEFINITION COMPLETE
- EXPERIMENT/INSTRUMENT COMPLEMENT ESTABLISHED
- PRELIMINARY DESIGN INITIATED

LEAD CENTER CONTACT:

- LEON B. ALLEN
  MARSHALL SPACE FLIGHT CENTER
  PHONE NO. (205) 544-1917

ARCJET FLIGHT EXPERIMENT

OBJECTIVES:

- ASSESS ARCJET AUXILIARY PROPULSION SYSTEM OPERATION IN SPACE ENVIRONMENT
  - HYDRAZINE PROPELLANT
  - 1.4 KW, 50 mLB THRUST, Isp 450
- EVALUATE PLUME EFFECTS & THRUSTER/THERMAL INTERACTIONS ON A COMMERICAL COMMUNICATIONS SATELLITE

STATUS:

- PRELIMINARY DESIGN & ARCJET COMPONENT DEVELOPMENT COMPLETED
- FLIGHT HARDWARE DESIGN, DEVELOPMENT & TESTING SCHEDULED TO START IN 1989
- FLIGHT TEST TENTATIVELY PLANNED FOR 1991

LEAD CENTER CONTACT:

- JERRI S. LING
  LEWIS RESEARCH CENTER
  PHONE NO. (216) 433-2841

TRIIFEX

TELEROBOTIC INTELLIGENT INTERFACE FLIGHT EXPERIMENT

OBJECTIVES:

- EVALUATE & VALIDATE TELEOPERATION OF A ROBOTIC MANIPULATOR UNDER CONDITIONS OF MICRO-G & COMMUNICATION TIME DELAYS
- VALIDATE ADVANCED SPACE TELEROBOT CONTROLS INCLUDING HIGH-FIDELITY HYBRID POSITION & FORCE CONTROL TECHNIQUES

STATUS:

- CONCEPTUAL DESIGN IN PROGRESS AT JPL
- DEVELOPMENT & INTEGRATION SCHEDULED TO START IN LATE 1988
- FLIGHT TEST PLANNED IN COMBINATION WITH GERMAN ROTEX EXPERIMENT ON SPACELAB D-2 MISSION (1991)

LEAD CENTER CONTACT:

- DANIEL KERRISK
  JET PROPULSION LABORATORY
  PHONE NO. (818) 354-2566

CFMFE

CRYOGENIC FLUID MGMT FLIGHT EXP.

OBJECTIVES:

- DEVELOP TECHNOLOGY REQUIRED FOR EFFICIENT STORAGE, SUPPLY & TRANSFER OF SUBCRITICAL CRYOGENIC LIQUIDS IN LOW-GRAVITY SPACE ENVIRONMENT
- FLIGHT VALIDATE NUMERICAL MODELS OF THE PHYSICS INVOLVED

STATUS:

- CONTRACTOR FEASIBILITY STUDIES CURRENTLY UNDER WAY
- 1992 NEW START PROPOSED

LEAD CENTER CONTACT:

- E. PAT SYMONS
  LEWIS RESEARCH CENTER
  PHONE NO. (216) 433-2853

PROGRAM OBJECTIVES

- PROVIDE FOR IN-SPACE FLIGHT RESEARCH EVALUATION & VALIDATION OF ADVANCED SPACE TECHNOLOGIES

  OUT-REACH PROGRAM

  - INDUSTRY/UNIVERSITY FLIGHT TECHNOLOGY EXPERIMENTS

  IN-REACH PROGRAM

  - NASA FLIGHT TECHNOLOGY EXPERIMENTS

IN-REACH EXPERIMENTS

June 1986	LETTER TO CENTERS REQUESTING PROPOSED IN-SPACE TECHNOLOGY FLIGHT EXPERIMENTS
Aug. 1986	58 FLIGHT EXPERIMENT PROPOSALS FROM NASA CENTERS
Jan. 1987	COMPLETED EVALUATION OF PROPOSALS
Apr. 1987	ADVISORY COMMITTEE REVIEW & PRIORITIZATION OF PROPOSALS
Jul. 1987	SELECTION OF 6 DEFINITION & 1 DEVELOPMENT EXP.

- SPACE STATION STRUCTURAL CHARACTERIZATION
- LASER COMMUNICATION FLIGHT EXPERIMENT
- DEBRIS COLLISION SENSOR
- LASER IN-SPACE SENSOR EXPERIMENT
- CONTAMINATION FLIGHT EXPERIMENT
- EFFECT OF SPACE ENVIRONMENT ON THIN-FOIL MIRRORS

- THERMAL ENERGY STORAGE TEST EXPERIMENT

OUT-REACH EXPERIMENTS

Dec. 1985	IN-STEP 85 WORKSHOP
Oct. 1986	REQUEST FOR INDUSTRY/UNIVERSITY PROPOSALS
Jan. 1987	231 PROPOSALS FOR IN-SPACE EXPERIMENTS (140 FROM INDUSTRY & 91 FROM UNIVERSITIES)
Sept. 1987	SELECTED 5 PROPOSALS FOR DEVELOPMENT OF FLIGHT EXPERIMENT HARDWARE - TANK PRESSURE CONTROL EXPERIMENT BOEING AEROSPACE COMPANY/ LeRC - MID-DECK 0-G DYNAMICS EXPERIMENT MASSACHUSETTS INSTITUTE OF TECHNOLOGY/LaRC - INVESTIGATION OF SPACECRAFT GLOW LOCKHEED MISSILE & SPACE COMPANY/JSC - HEAT PIPE THERMAL PERFORMANCE HUGHES AIRCRAFT COMPANY/GSFC - EMULSION CHAMBER TECHNOLOGY EXPERIMENT UNIVERSITY OF ALABAMA IN HUNTSVILLE/MSFC
Sept. 1987	SELECTED 36 PROPOSALS FOR DEFINITION OF FLIGHT TECHNOLOGY EXPERIMENTS - STUDIES TO BE COMPLETED IN SEPT. 1989 - SOLICITATION FOR DEVELOPMENT OF FLIGHT HARDWARE OPEN TO ENTIRE COMMUNITY

FIRST SOLICITATION REVIEW

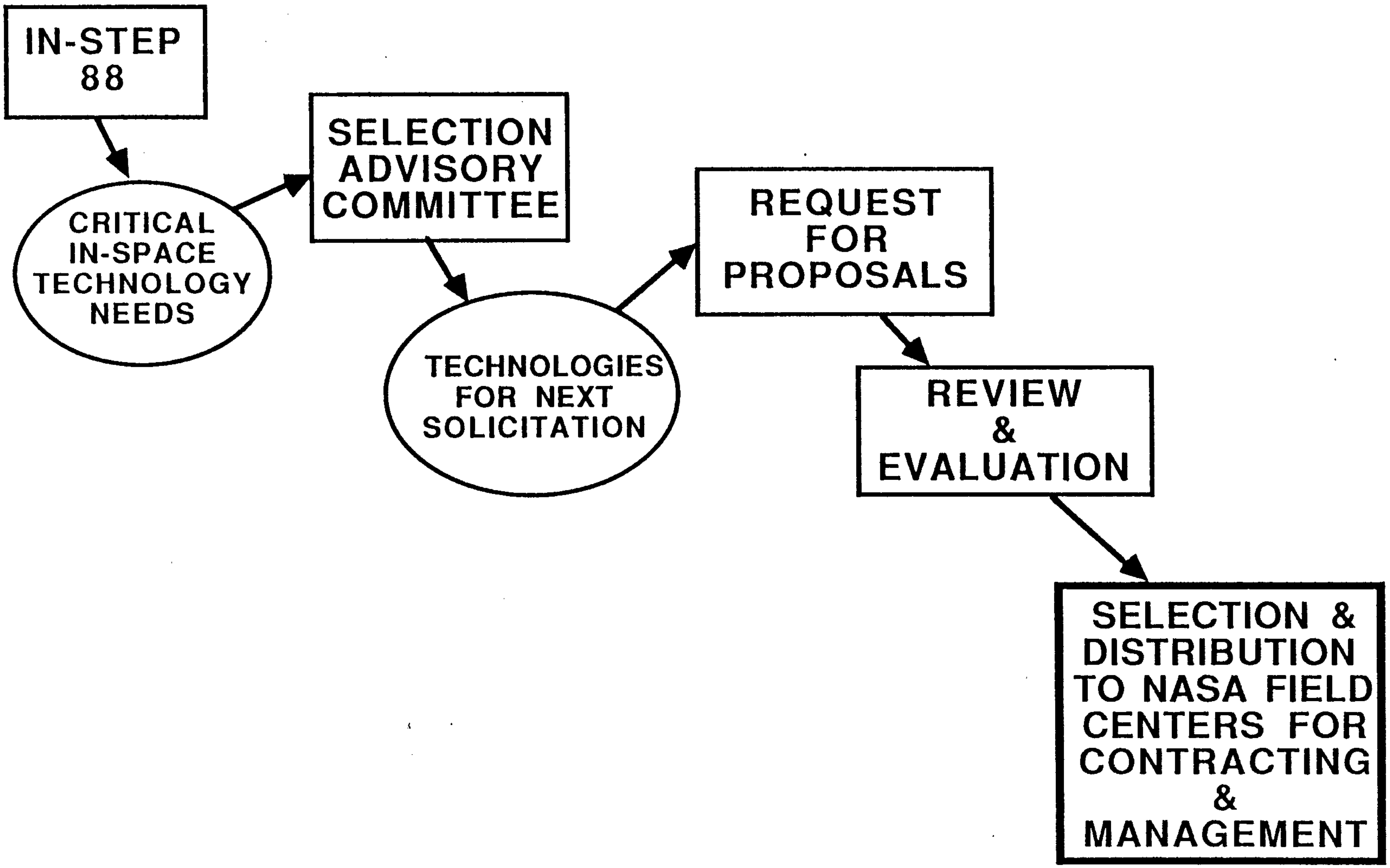
OBSERVATIONS

- SIGNIFICANT EXPENDITURE BY INDUSTRY & UNIVERSITIES (231 PROPOSALS)
- APPROX. 250 NASA SCIENTISTS & TECHNOLOGISTS INVOLVED IN TECHNICAL EVALUATIONS
- NEW SOLICITATION BETWEEN DEFINITION & DEVELOPMENT ADDS MORE PROPOSAL COSTS
- GENERAL TECHNOLOGY SOLICITATION TOO BROAD (SHOTGUN APPROACH TO TECHNOLOGY DEVELOPMENT)

REVISED APPROACH

- DEFINE & PRIORITIZE CRITICAL SPACE TECHNOLOGY DEVELOPMENT REQUIREMENTS FOR FUTURE SPACE MISSIONS
- USE PRIORITIZED LISTING TO FOCUS FUTURE TECHNOLOGY DEVELOPMENT & IN-SPACE FLIGHT TECHNOLOGY EXPERIMENTS
- FUTURE SOLICITATIONS FOR DEFINITION OF FOCUSED IN-SPACE FLIGHT TECHNOLOGY EXPERIMENTS
- DOWN-SELECT BETWEEN COMPETING EXPERIMENTS FOR CONCEPTUAL DESIGN PHASE & FLIGHT HARDWARE DEVELOPMENT PHASE

SOLICITATION PROCESS



IN-STEP 88

CRITICAL IN-SPACE TECHNOLOGY NEEDS

SELECTION ADVISORY COMMITTEE

TECHNOLOGIES FOR NEXT SOLICITATION

REQUEST FOR PROPOSALS

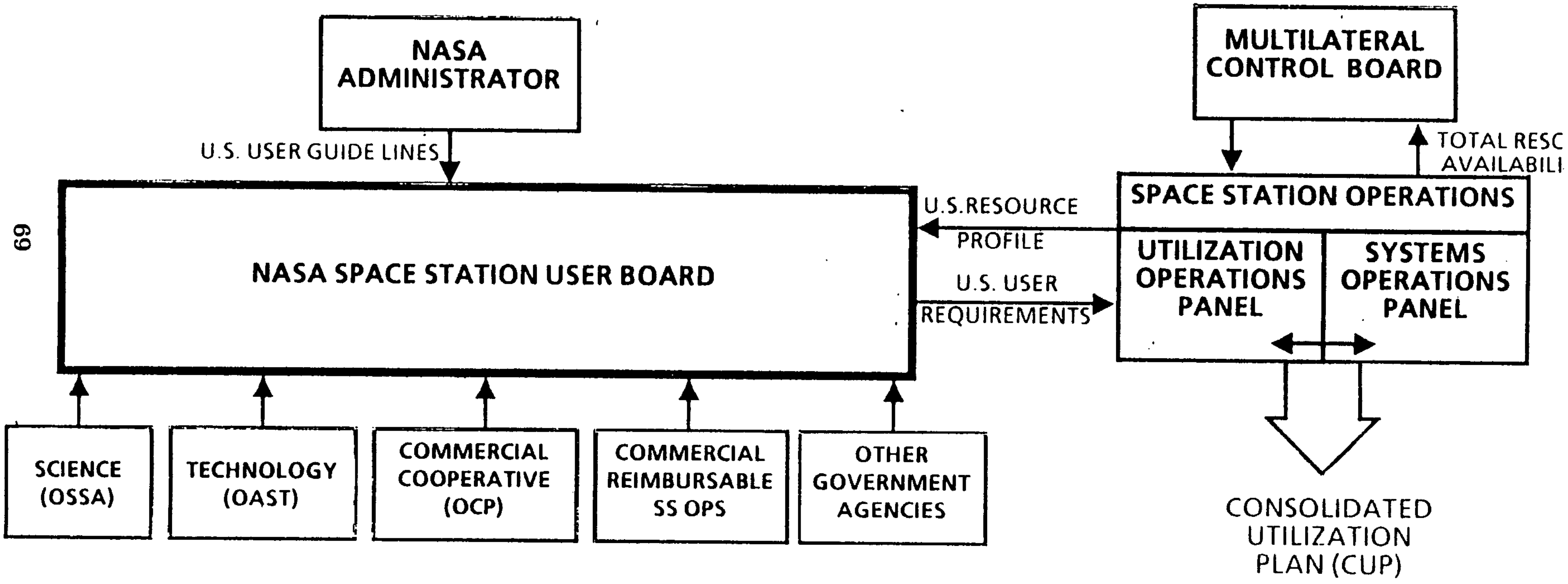
REVIEW & EVALUATION

SELECTION & DISTRIBUTION TO NASA FIELD CENTERS FOR CONTRACTING & MANAGEMENT

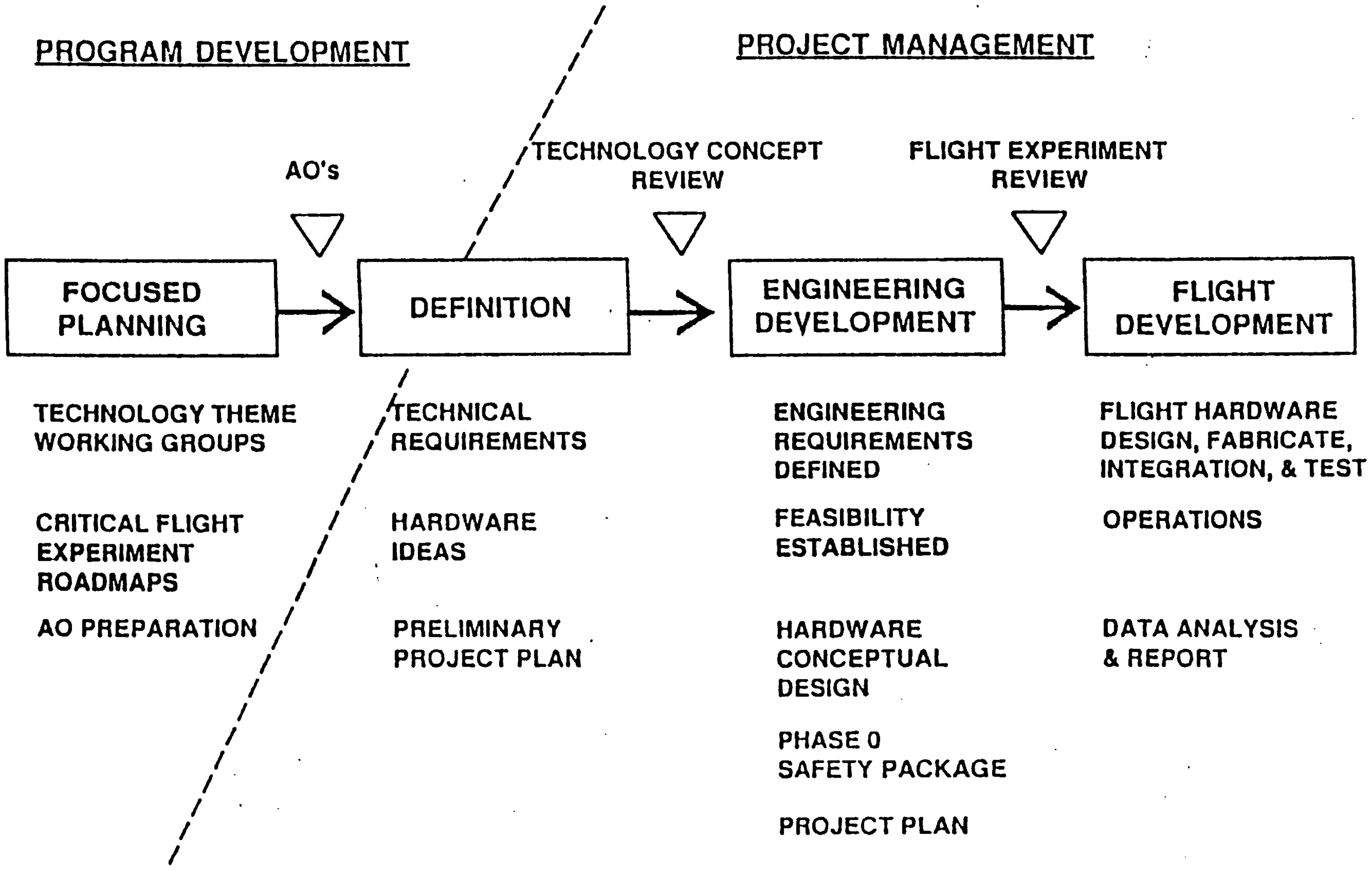
SUMMARY

- LONG & SUCCESSFUL HISTORY IN THE CONDUCT OF SPACE FLIGHT TECHNOLOGY EXPERIMENTS
- PROGRAM IS BEING EXPANDED TO EMPHASIZE THE DEVELOPMENT OF ADVANCED SPACE FLIGHT TECHNOLOGIES
- OAST PLANS TO PROVIDE ACCESS TO SPACE FOR THE AEROSPACE TECHNOLOGY COMMUNITY (NASA, DOD, INDUSTRY & UNIVERSITIES)

USER ROLE -- STRATEGIC PLANNING



OAST IN-SPACE TECHNOLOGY PROGRAM PHASES



PROGRAM DEVELOPMENT

PROJECT MANAGEMENT

AO's

TECHNOLOGY CONCEPT REVIEW

FLIGHT EXPERIMENT REVIEW

FOCUSED PLANNING

- TECHNOLOGY THEME WORKING GROUPS
- CRITICAL FLIGHT EXPERIMENT ROADMAPS
- AO PREPARATION

DEFINITION

- TECHNICAL REQUIREMENTS
- HARDWARE IDEAS
- PRELIMINARY PROJECT PLAN

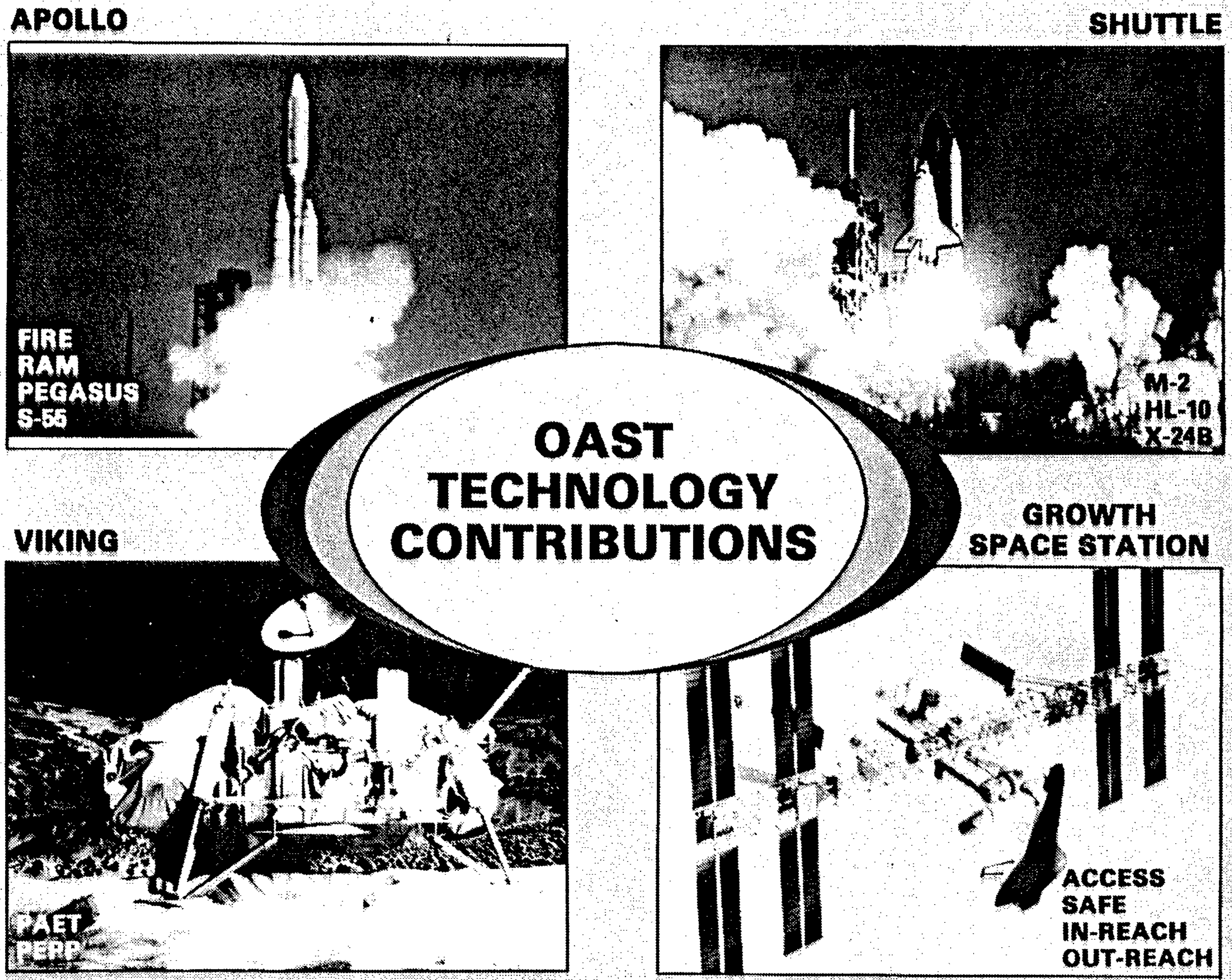
ENGINEERING DEVELOPMENT

- ENGINEERING REQUIREMENTS DEFINED
- FEASIBILITY ESTABLISHED
- HARDWARE CONCEPTUAL DESIGN
- PHASE 0 SAFETY PACKAGE
- PROJECT PLAN

FLIGHT DEVELOPMENT

- FLIGHT HARDWARE DESIGN, FABRICATE, INTEGRATION, & TEST
- OPERATIONS
- DATA ANALYSIS & REPORT

OAST TECHNOLOGY CONTRIBUTIONS



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SPACE STATION FREEDOM
USER/PAYLOAD INTEGRATION AND ACCOMMODATIONS

PRESENTATION TO THE
NASA OAST IN-SPACE TECHNOLOGY EXPERIMENTS WORKSHOP
DECEMBER 6, 1988

ALAN C. HOLT
DEPUTY DIRECTOR (ACT), USER INTEGRATION DIVISION
UTILIZATION & OPERATIONS GROUP
NASA SPACE STATION FREEDOM PROGRAM OFFICE
RESTON, VIRGINIA

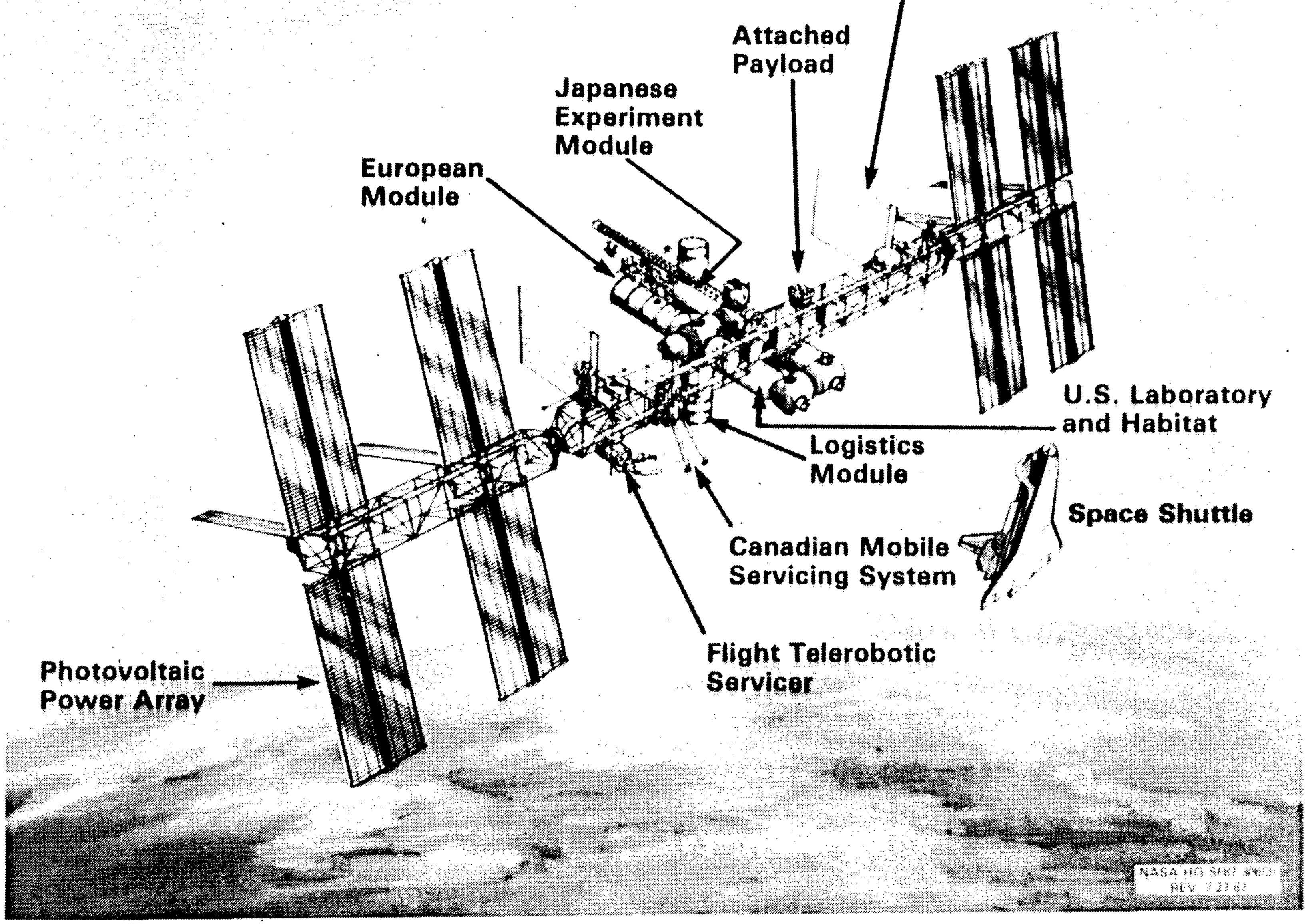
SSU-8814294
1582 11/29/88 M/JF

SPACE STATION FREEDOM TECHNOLOGY PAYLOADS

- CRITICAL TO THE SUCCESS OF THE SPACE STATION GROWTH OR DEVELOPMENT AND FUTURE SPACE PROJECTS AND MISSIONS.
- EFFECTIVE WAY OF AUGMENTING SPACE STATION PAYLOAD ACCOMMODATION CAPABILITIES - TEST AND CONVERSION TO OPERATIONAL USE.
- PROMOTE THE DEVELOPMENT OF TECHNOLOGICAL APPLICATIONS WHICH SUPPORT OTHER GOVERNMENT AND PRIVATE PROJECTS AND PRODUCTS.
- PROVIDES NEW EDUCATIONAL OPPORTUNITIES FOR NEW GENERATIONS OF SCIENTISTS, ENGINEERS, AND OTHER PROFESSIONS.

SSU-8814295
1582 11/29/88 M/JF

Revised Baseline Configuration

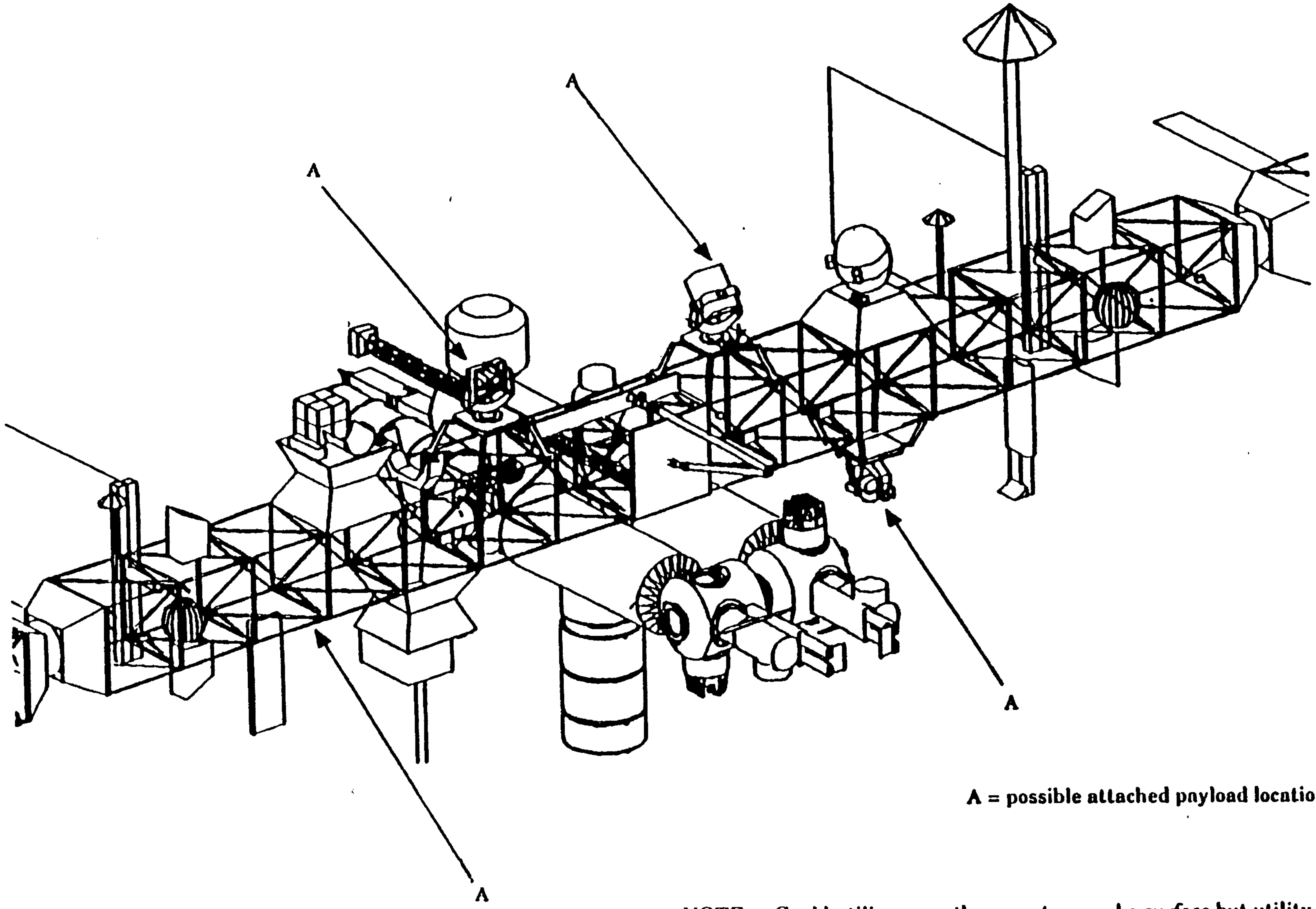


SPACE STATION FREEDOM
TECHNOLOGY PAYLOAD ACCOMMODATION

- MATERIALS R&D
- ADVANCED RADIATOR AND POWER SYSTEM
- ADVANCED PROPULSION SYSTEMS
- TECHNOLOGY PAYLOADS WITH STRONG MAGNETIC FIELDS
- LASER SYSTEMS - OPTICAL COMMUNICATION
- ELECTRON BEAMS, WAVE GENERATION, ETC.
- INTERNAL TECHNOLOGY PAYLOADS - RADIATION, SEU
- ADVANCED ECLS SUBSYSTEMS

SSU-8814297
1582 12/02/88 M/JF

Potential Attached Payload Locations



A = possible attached payload locations

NOTE: Could utilize more than one truss-cube surface but utility port provided resources would have to be shared.

SSU-8814316
1582 12/04/88 M/JF

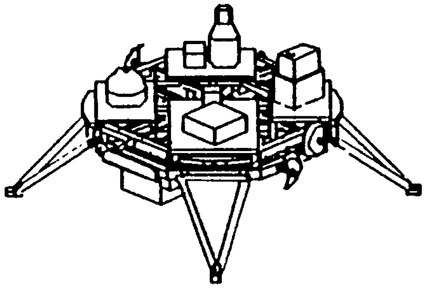
MANNED BASE ATTACHED PAYLOAD ACCOMMODATIONS

PAYLOAD CLASSIFICATION

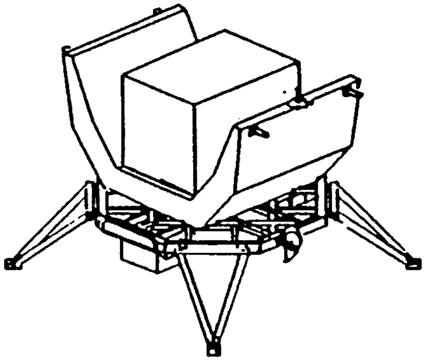
CLASS	PAYLOAD FEATURES
MAJOR	• LARGE • REQUIRES MAJOR APAE RESOURCES • ACTIVE THERMAL COOLING • SOME NEED PPS FOR POINTING • LONG STAY
SMALL AND/OR RAPID RESPONSE	• SMALL • NO ACTIVE THERMAL COOLING • MODEST POWER/DATA RESOURCES • VARIETY OF FIELDS OF VIEW • SET ASIDE RESOURCES
DISTRIBUTED SENSOR	• CAN BE VERY SMALL IN SIZE (LIKE ACCELEROMETER) • NON-STANDARD LOCATIONS • MODEST POWER/DATA RESOURCES • CAN BE ANALYTICALLY INTENSIVE • CAN HAVE UNIQUE PACKAGING

SSU-8814306
1582 12/04/88 M/CW

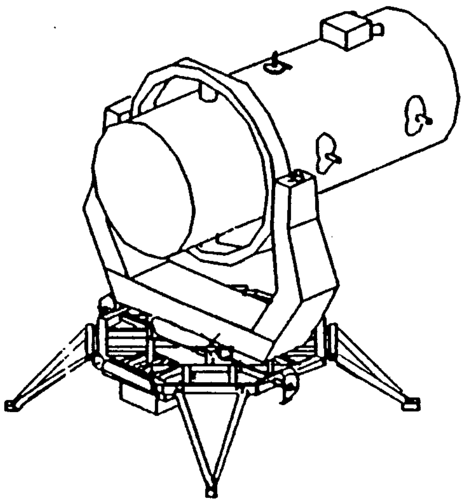
APAE TYPICAL CONFIGURATIONS



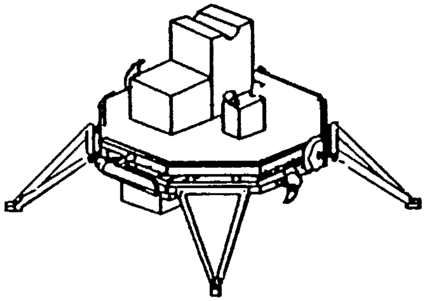
MULTIPLE PAYLOADS



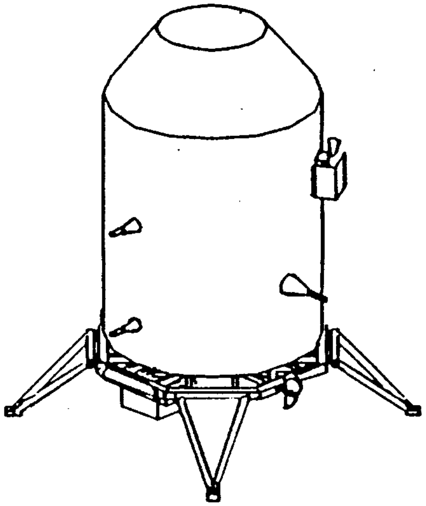
PALLET MOUNTED PAYLOAD



PAYLOAD AND PAYLOAD POINTING SYSTEM



SINGLE PAYLOAD



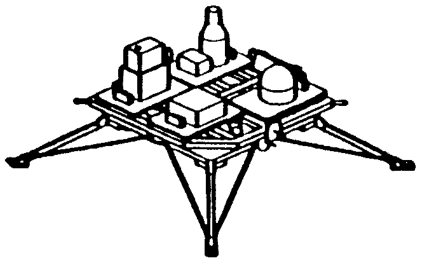
LARGE PAYLOAD

MANNED BASE ATTACHED PAYLOAD ACCOMMODATIONS

APAE DESIGN CAPABILITY

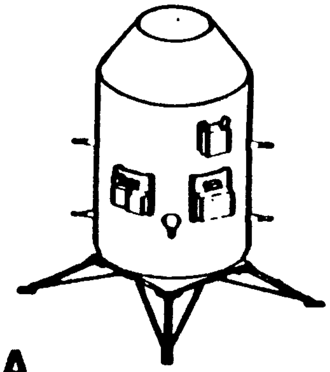
DESIGNED FOR:

MULTIPLE PAYLOADS

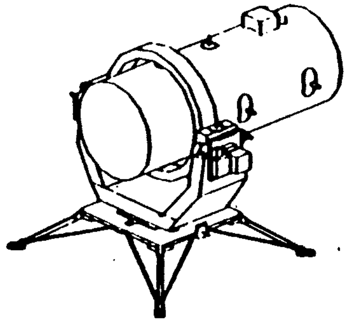


4 COMPATIBLE PAYLOADS VIA
MULTIPLE PAYLOAD ADAPTERS (MPAs)

MAJOR

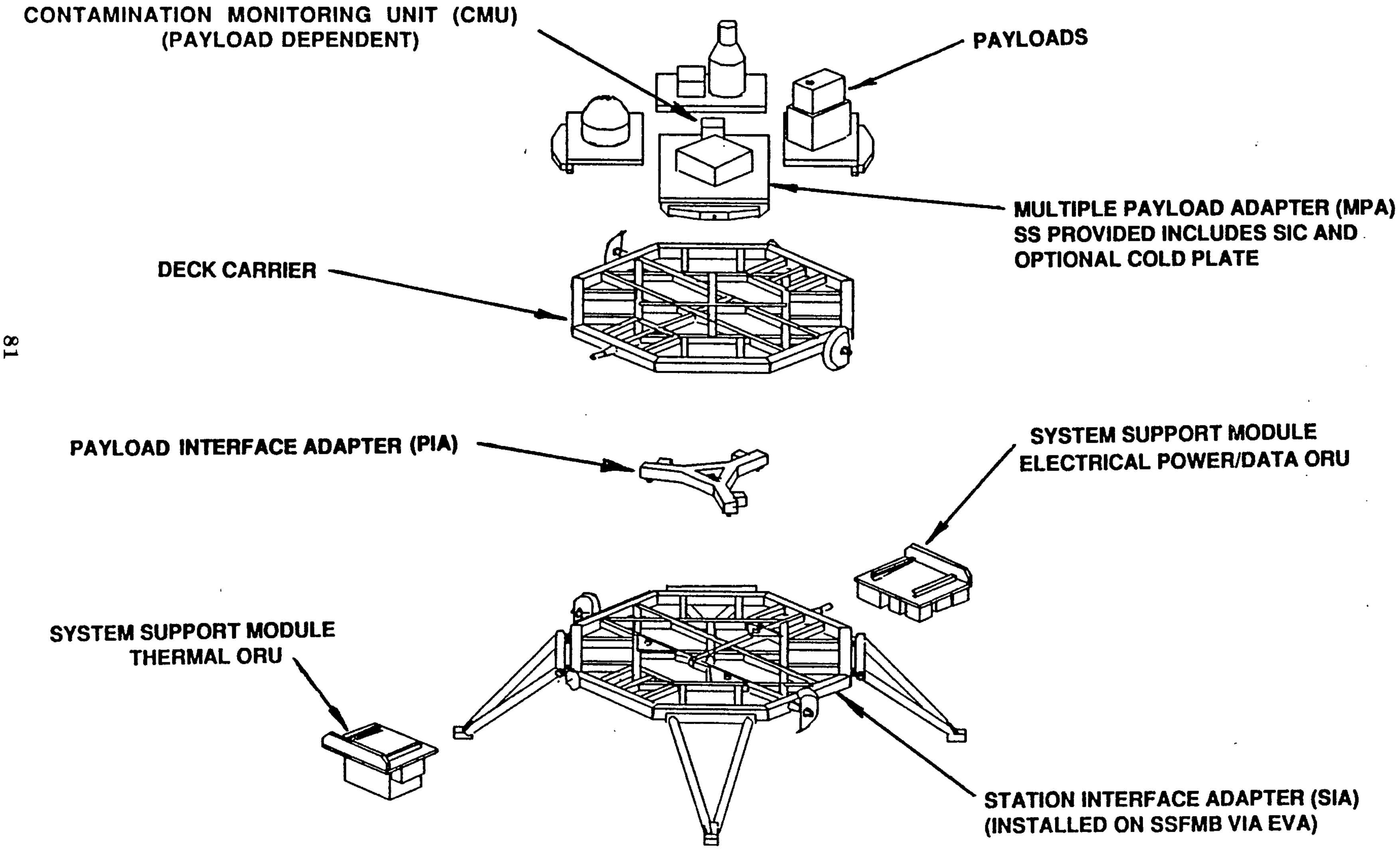


POINTING
PAYLOADS



- APAE DESIGNED TO SUPPORT UP TO 25,000 LB PAYLOAD
- PROVIDES: 10kW POWER
  50 MBPS DATA RATE
  10 kW ACTIVE COOLING
  } PAYLOAD(S)
- STRUCTURAL SUPPORT FOR POINTING CAPABILITY (60 ARC SEC ACCURACY) FOR 6000 kg PAYLOAD

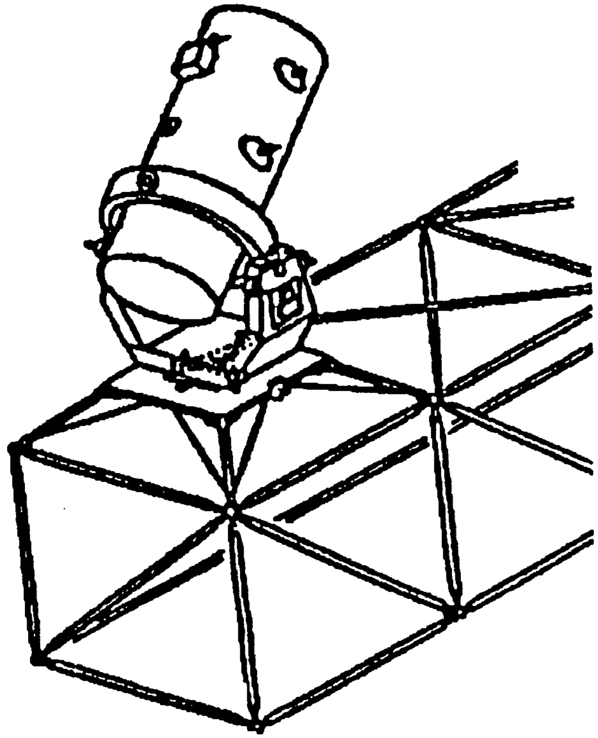
MULTIPLE PAYLOAD/DECK CARRIER CONFIGURATION



PAYLOAD POINTING SYSTEM (PPS)

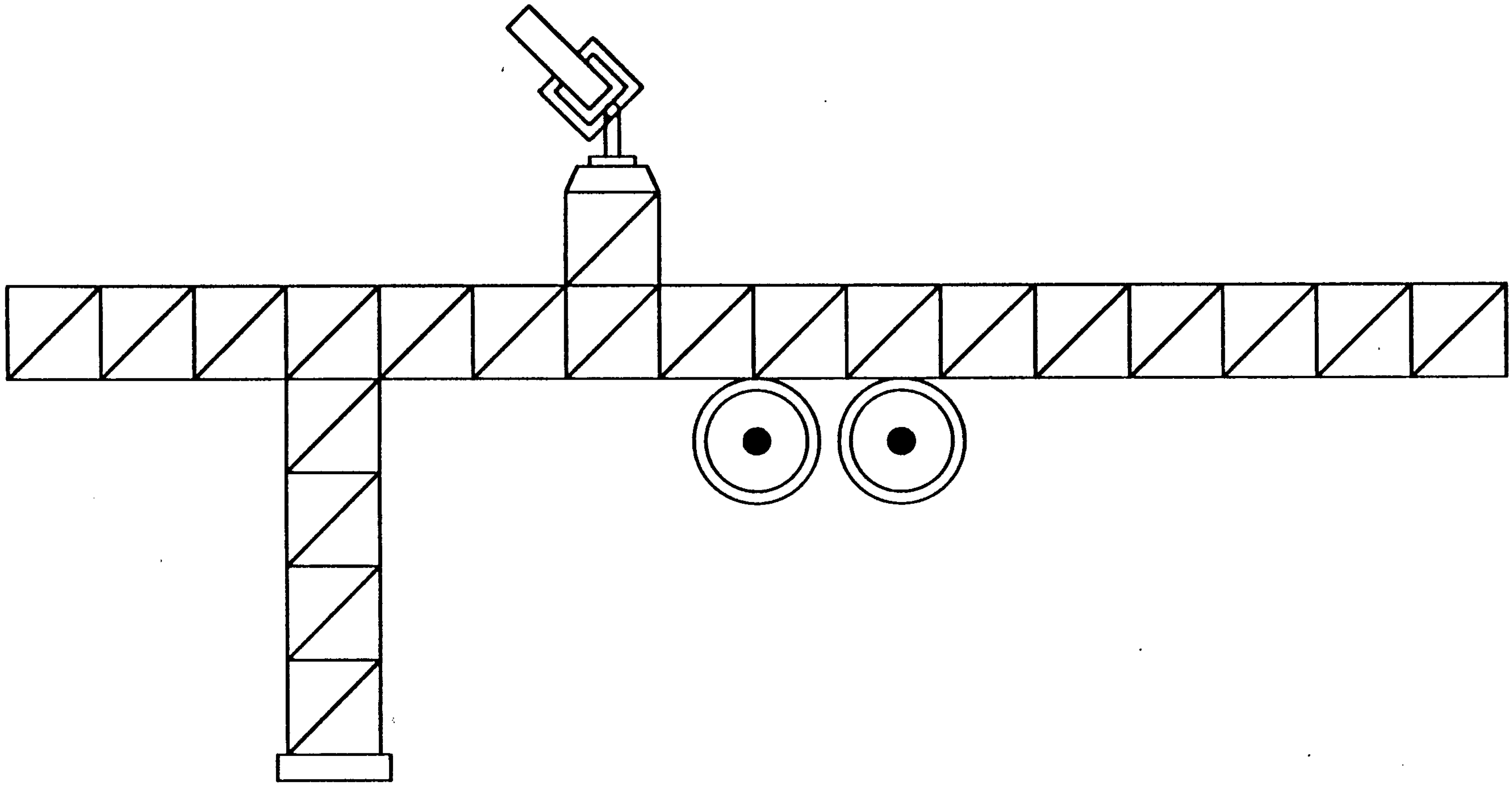
PPS PAYLOAD ACCOMDATION CAPABILITIES

- 1 ARC MINUTE POINTING ACCURACY
- 30 ARC SECOND PONTING STABILITY
  (OVER 1800 SECS)
- 15 ARC SECOND/SECOND JITTER
- 3 AXES
- 5 kW OF POWER/ACTIVE COOLING
- 50 MEGABITS HIGH RATE DATA/IMAGERY
- 6000 KG PAYLOAD - 3 METERS WIDE,
  C.G. TO BASE 2.5 METERS
- ACCEPTS PAYLOAD SENSOR INPUT FOR POINTING



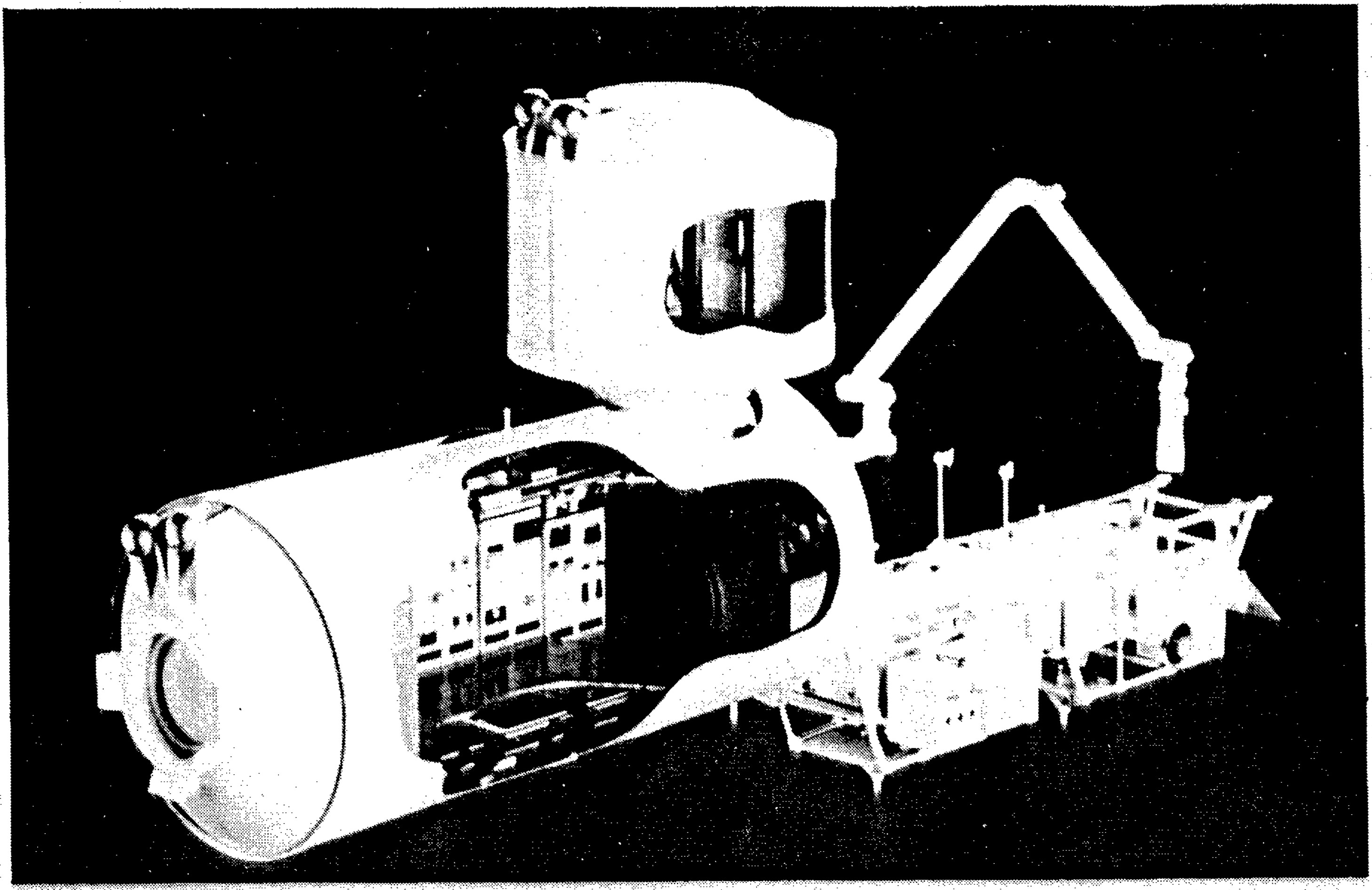
SSU-8814325
1582 12/4/88 M/AK

CAPABILITY TO ADD TRUSS STRUCTURE TO ENHANCE ATTACHED PAYLOAD VIEWING AND CLEARANCE



SSU-8814675
1582 12/04/88 M/CW

JAPANESE EXPERIMENT MODULE



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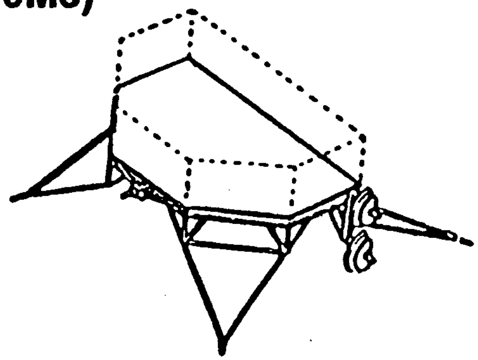
NASA HQ SF88 348(3)
4-26-88

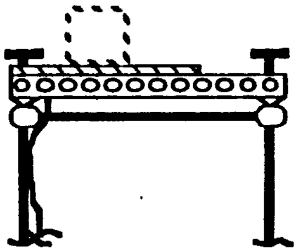
SMALL AND RAPID RESPONSE PAYLOADS

EXTERNAL SARR PAYLOAD ENVELOPE & PROPOSED CONSTRAINTS

- TRUNNION/KEEL (T/K) SARR PAYLOAD:
  - FIT INTO 4M X 1.25M X 2M ENVELOPE (MAX VOL <10M3)
  - ≤ 900 KG
  - ≤ 900 WATTS
  - ≤ 0.3 MBPS UPLINK/2.0 MBPS DOWNLINK
  - ≤ 100 MBYTES DATA STORAGE/ORBIT
  - CAN ACCOMMODATE MORE THAN ONE PAYLOAD
  - RMS GRAPPLE FIXTURE (ON T/K CARRIER)



- GENERIC (GEN) SARR PAYLOAD:
  - FIT INTO 1.25 M X 1.25 M X 1.25 M ENVELOPE (MAX VOL ≤ 2 M3)
  - ≤ 300 KG
  - ≤ 300 WATTS
  - ≤ 0.3 MBPS UPLINK/2.0 MBPS DOWNLINK
  - ≤ 100 MBYTES DATA STORAGE/ORBIT
  - ORU COMPATIBLE I/F (ORU TOOL)



SSU-8814308
1582 12/04/88 M/CW

SMALL AND RAPID RESPONSE PAYLOADS

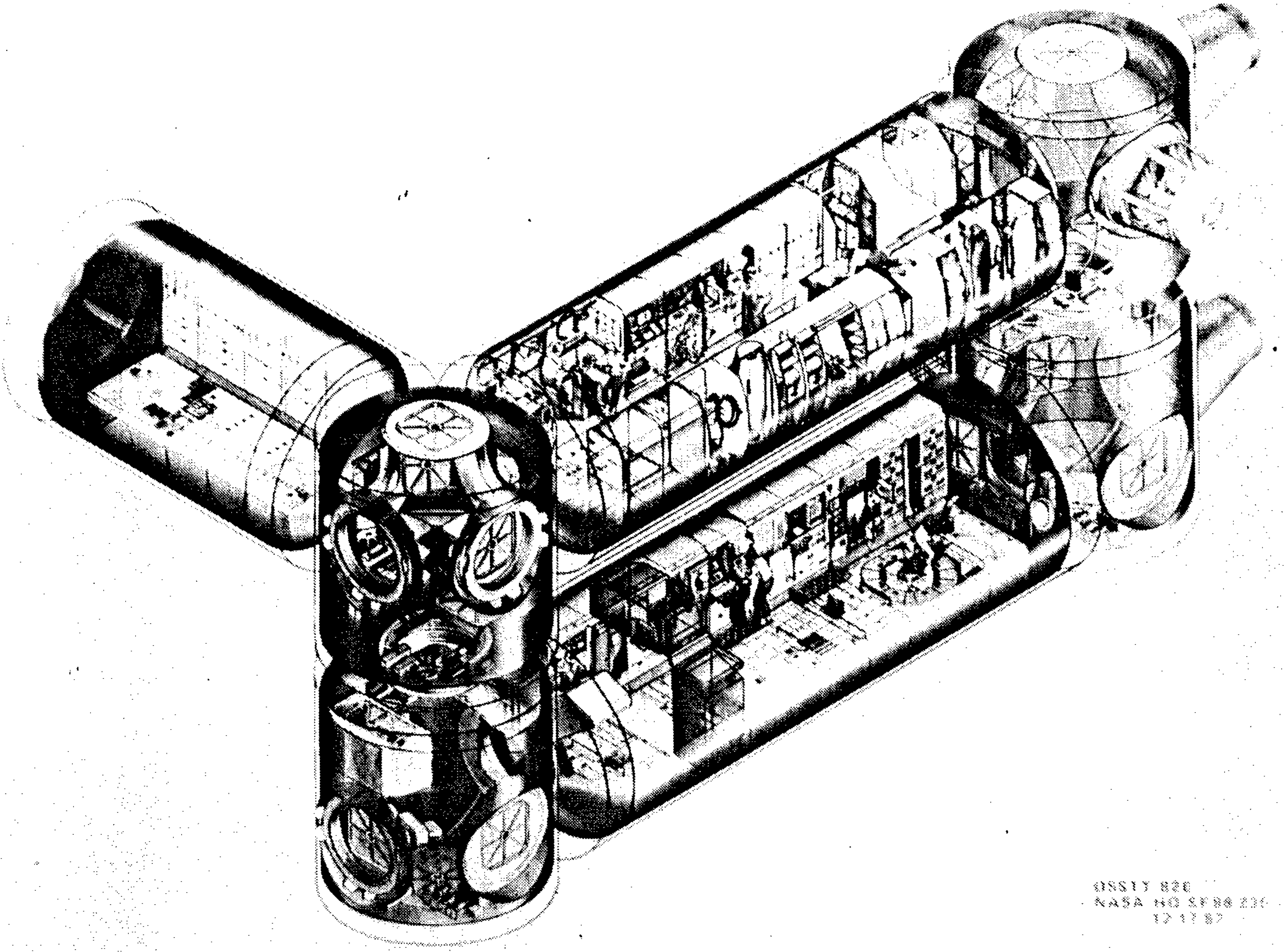
INTERFACE COMPARISON CHART FOR RELATIVELY SMALL ATTACHED PAYLOADS* ON TRUSS AND JEM EF (PROPOSED)

Interface or Physical Constraint	PAYLOAD		
	SARR Trunnion Keel	SARR Generic	JEM Exposed Facility
Weight	≤ 1980 lbs ≤ 900 kg	≤ 660 lbs ≤ 300 kg	typically 1100 lbs or 500 kg
Volume Limitations Physical Dimensions	~ 10m3 1.25m x 2.0m x 4.0m	~ 2m3 1.25m x 1.25m x 1.25m	~ 2m3 0.8m x 1.0m x 1.85m (0.8m x 1.0m footprint)
Thermal Cooling	only passive	only passive	≤ 6kW active cooling
Power Constraint	≤1.5kW	≤0.3kW	≤6.0kW
Data Rates			
Downlink	2.0 Mbps	1.4 Mbps	4 Mbps
Uplink	0.3 Mbps	0.3 Mbps	4 Mbps
Access to Pressurized Module	None	None	Possible thru JEM Airlock
Pointing Capability Provided	None	None	None

- These do not require an APAE

SSU-8814309
1582 12/04/88 M/CW

U.S. SPACE STATION PRESSURIZED MODULES



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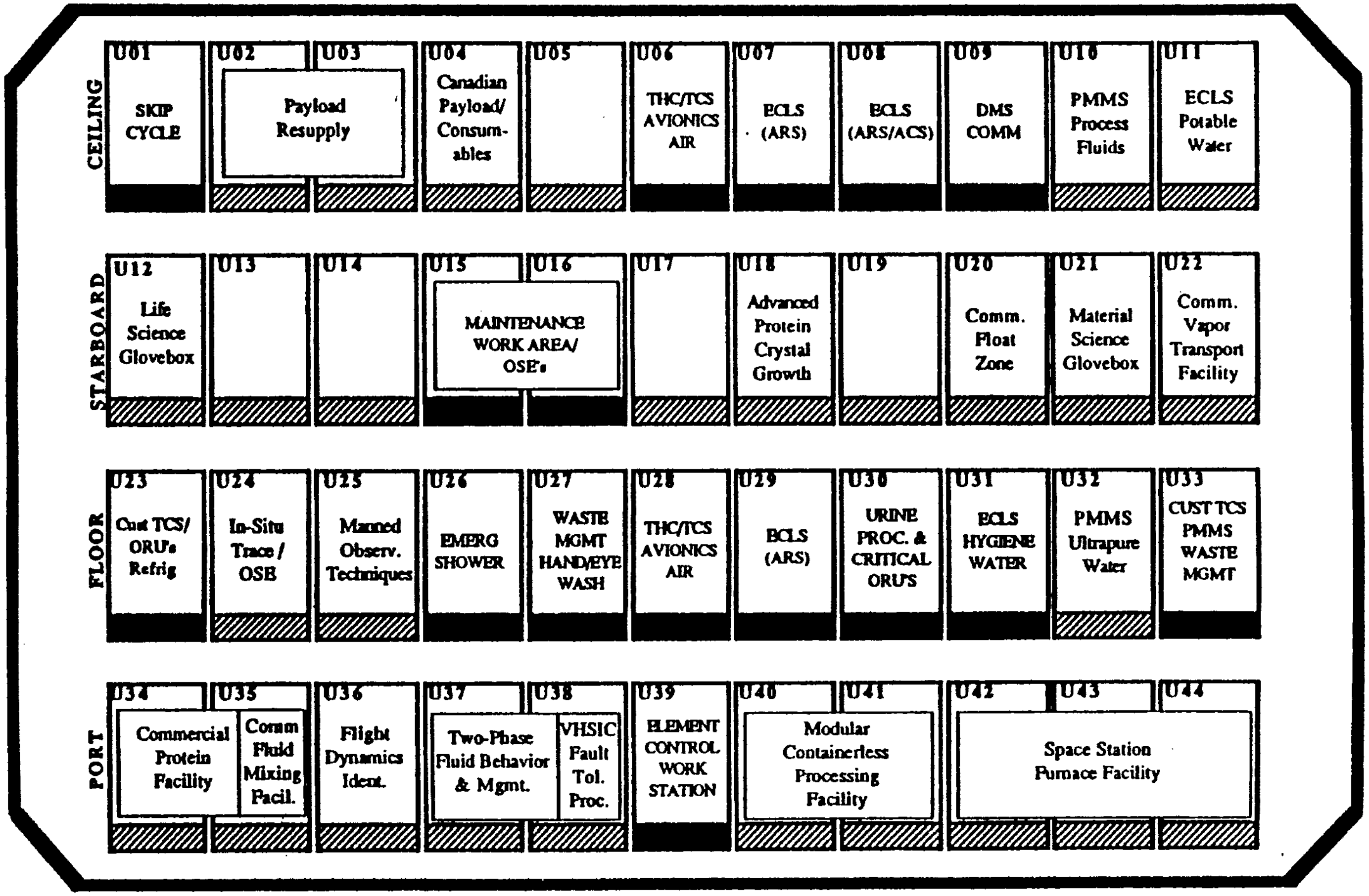
NASA HQ SF88 236-3
12 17 87

TRIAL PAYLOAD MANIFEST, U.S. LABORATORY MODULE: AFTER OUTFITTING FLIGHT OF-1

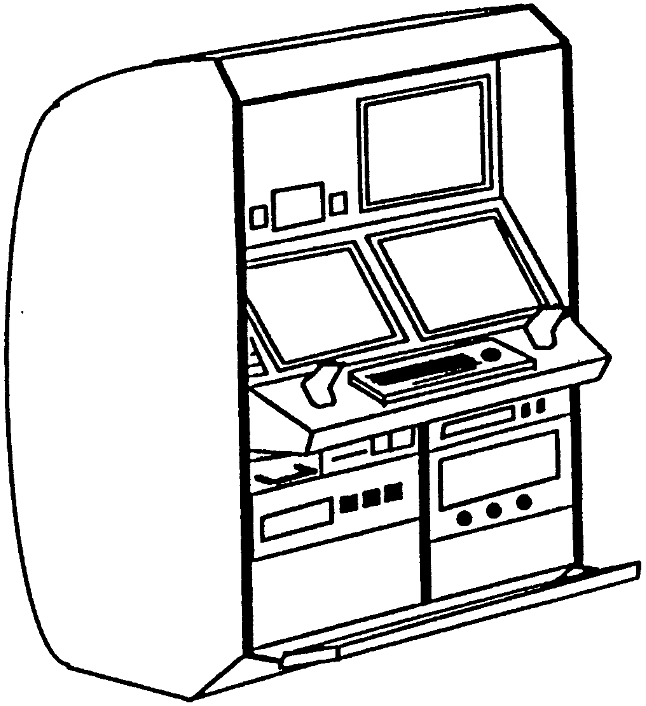


■ 16 STATION SYSTEM RACKS

▨ 28 USER PAYLOAD RACKS (28 NASA)

SSU-8814304
1582 12/04/88 M/CW

COMMAND/CONTROL WORKSTATION DESIGN CONCEPT



DMS Fixed MPAC Components

- Three 15" color CRTs
- QWERTY keyboard
- Trackball
- Hand controllers
- Processor
- Safety-critical D&C
- Hard-copy printer/plotter

Other Components

- Video recorders
- Audio recorders
- Lighting
- Crew restraints

Functions

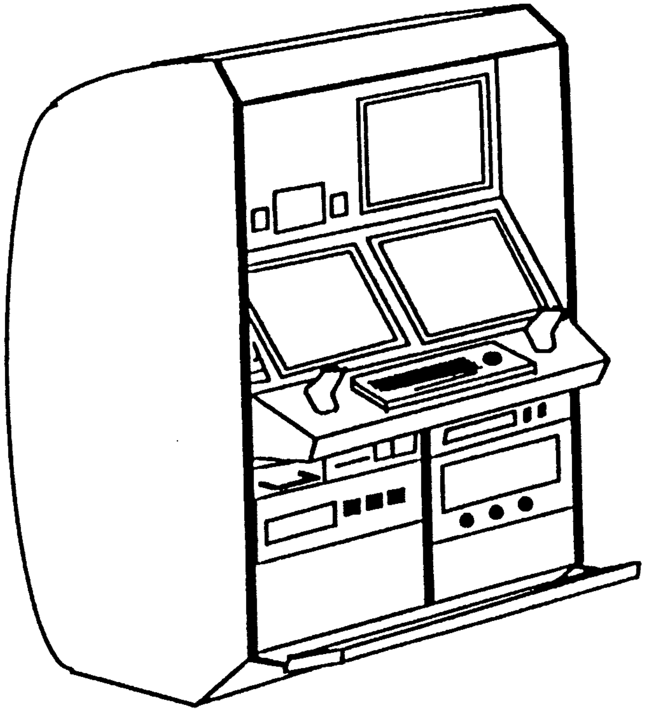
- Subsystem management, customer support, proximity operations, telerobotic (MSC, FTS) control, external operations support

SSU-8814312
1582 12/04/88 M/JF

COMMAND/CONTROL
WORKSTATION DESIGN CONCEPT

Key MPAC Requirements

- Alphanumerics
- Graphics
- Animation
- Integrated Video, Graphics, Text
- Color Displays
- Windowing
- Voice Input
- Voice Output
- 3D Graphics
- Run the DMS USE Software



National Aeronautics and
Space Administration

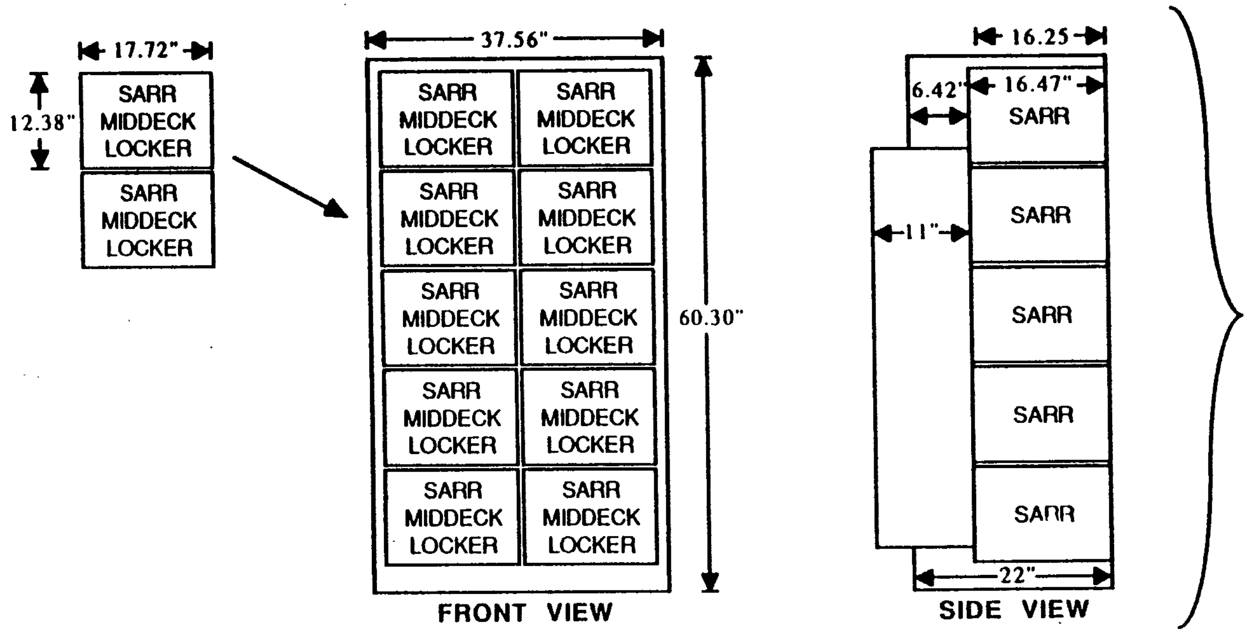
S88-44313

Lyndon B. Johnson Space Center
Houston, Texas 77058

INTERNAL SARR PAYLOAD REQUIREMENTS

- LOCATION REQUIREMENTS:
  DEDICATED STANDARD DOUBLE RACK FOR UP TO 10 INTERNAL SARR PAYLOADS. RACK SHALL BE CAPABLE OF BEING RECONFIGURED ON ORBIT TO SUPPORT STANDARD SARR PAYLOADS.

- RESOURCE PROVISIONS FOR DEDICATED STANDARD DOUBLE RACK:



MAXIMUM
RESOURCES
ARE
WITHIN
BASELINE
VALUES

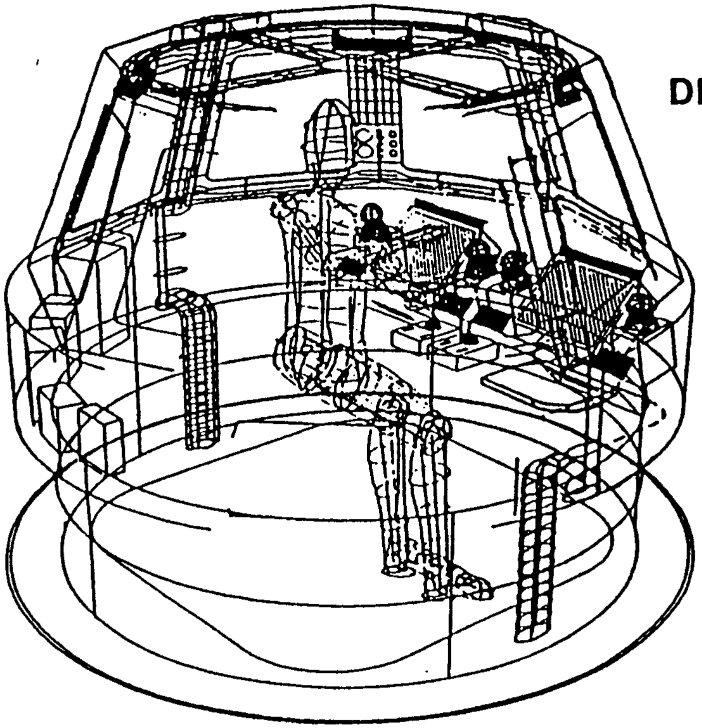
NO ACTIVE COOLING (STANDARD RACK AIR COOLING ONLY)

SSU-8814311
1582 12/04/88 M/CW

CUPOLA WORKSTATION CONCEPT

Key Cupola MPAC Reqts

- Alphanumerics
- Graphics
- Animation
- Video
- Telerobotics Control
- OMV Piloting
- MSC Control
- Run the DMS USE Software



DMS Cupola MPAC Component

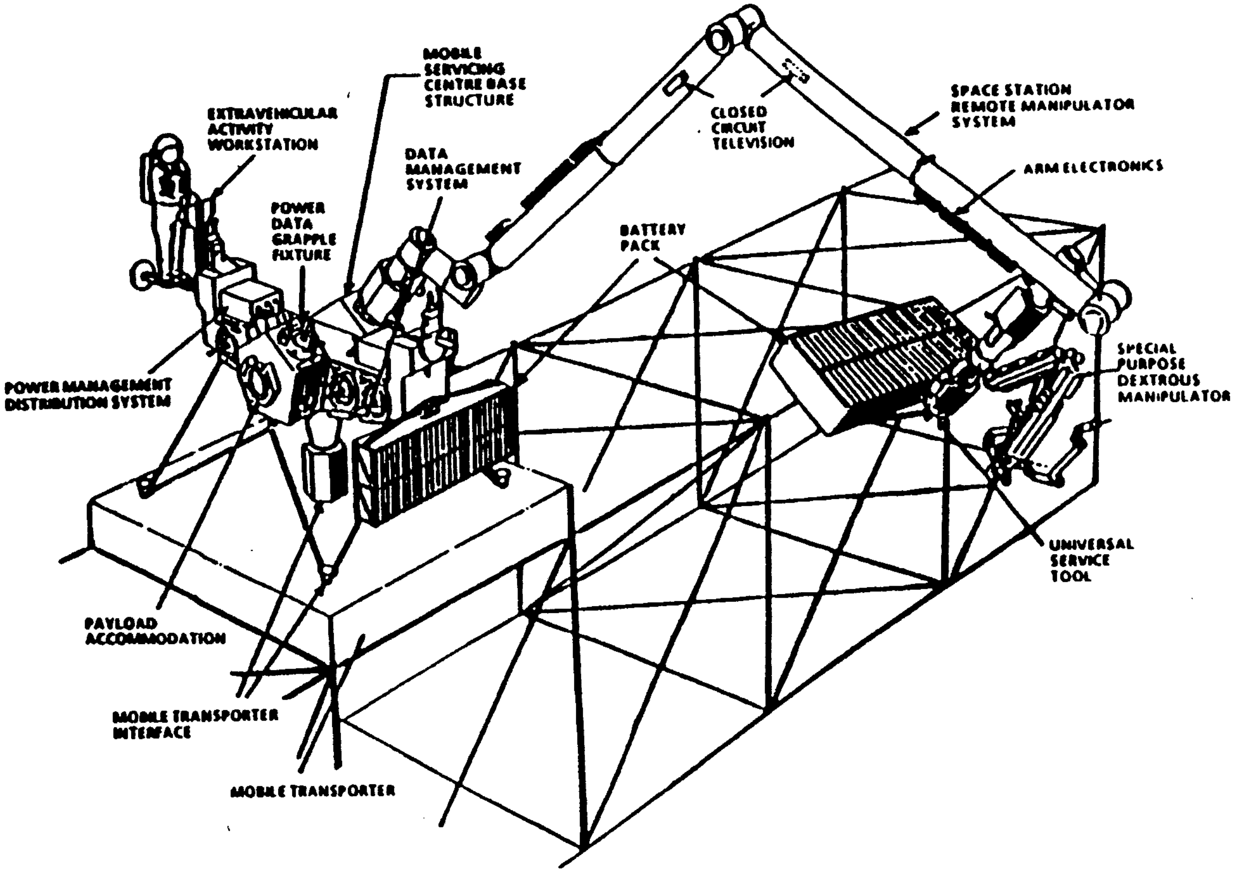
- Two 15" TFEL Displays
- Two QWERTY keyboards
- Two Trackballs
- Hand controllers
- Processor

Other Components

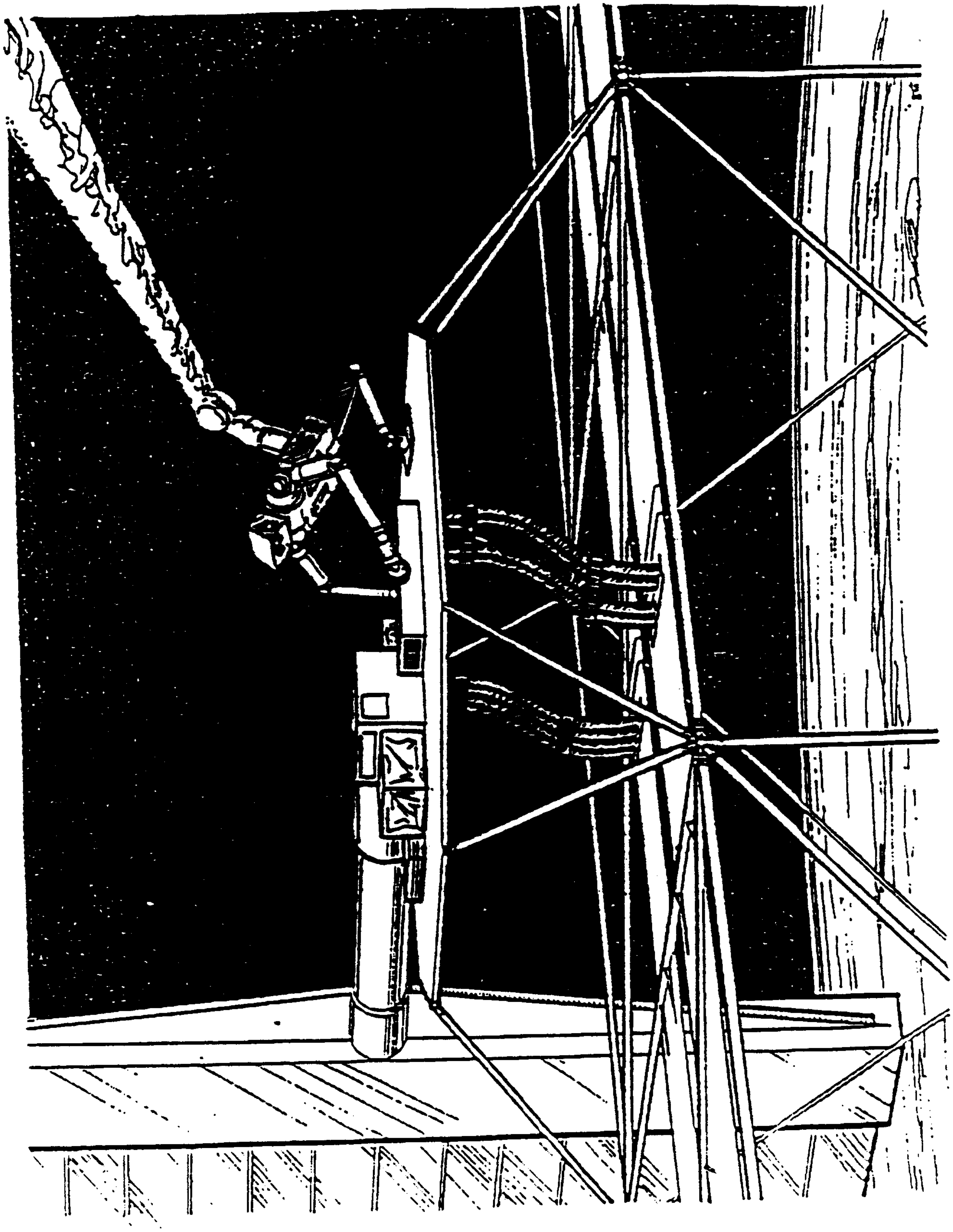
- Lighting
- Crew restraints

SSU-8814320
1582 12/04/88 M/JF

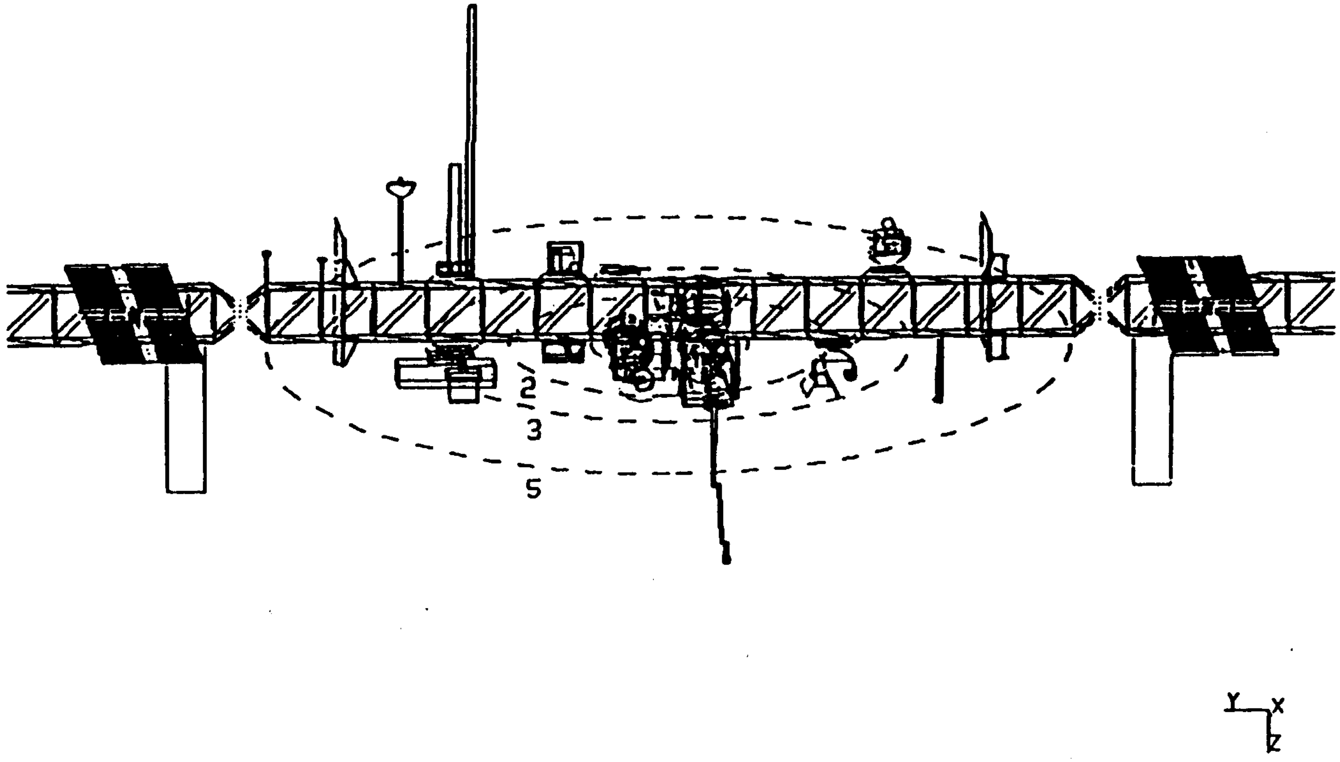
MOBILE SERVICING CENTER



SSU-8814321
1582 12/04/88 M/JF

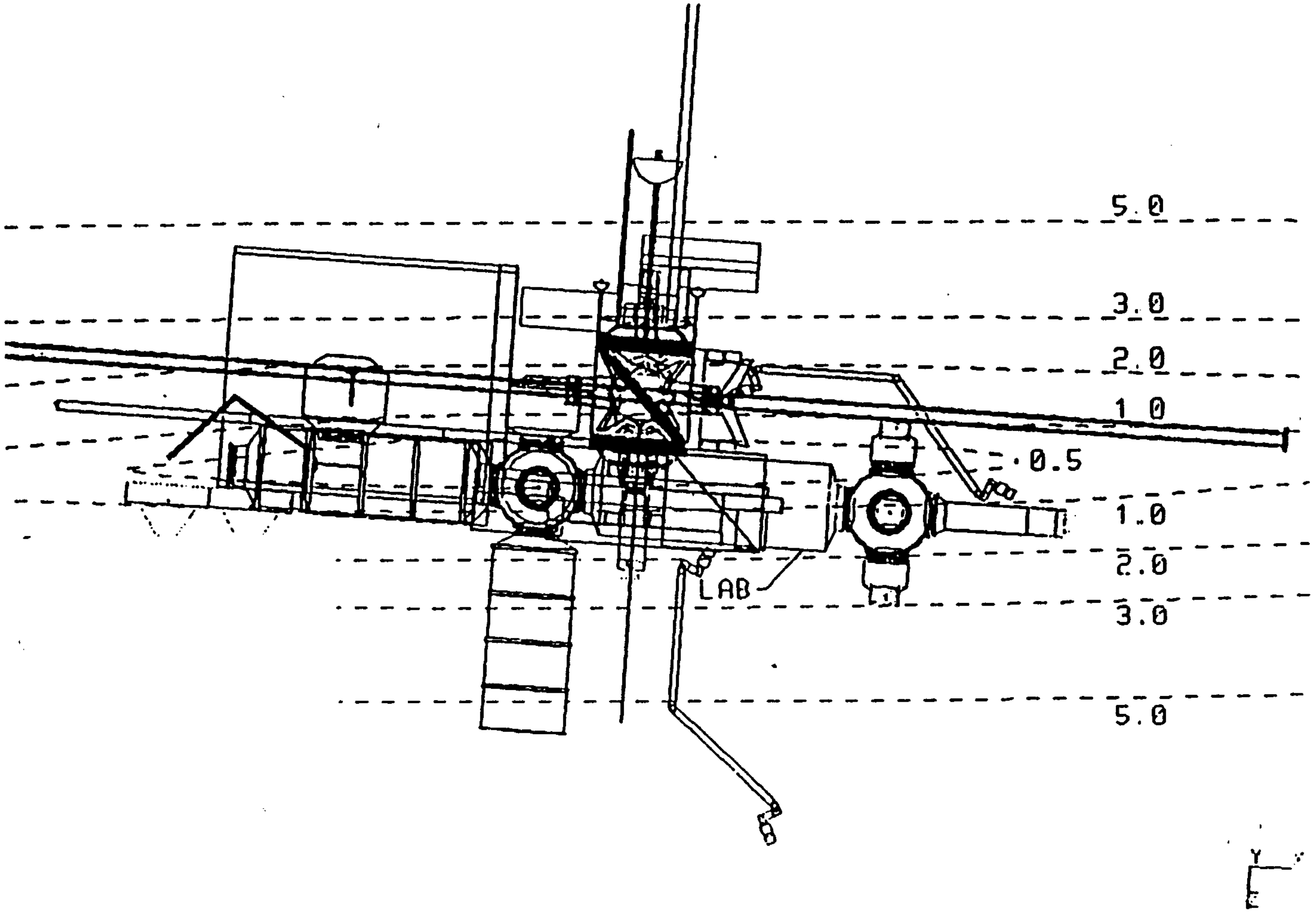


Microgravity Quasi-Static Isogravity Contours ($\times 10^{-6}$ G)
(June, 1999, Altitude 230 n. miles)
Front View



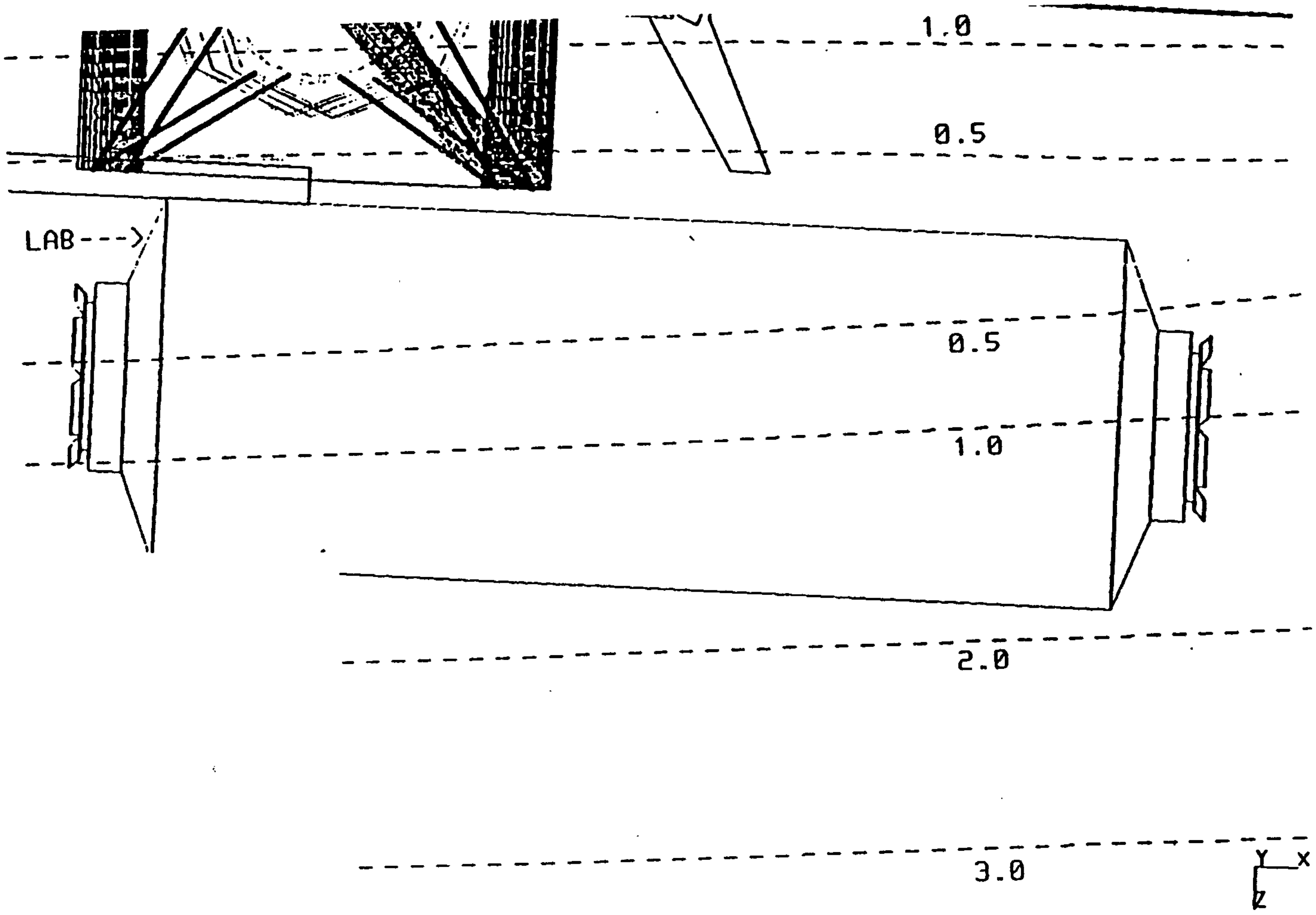
SSU-8814313
1582 12/04/88 M/JF

Microgravity Quasi-Static Isogravity Contours ($\times 10^{-6}$ G) (June, 1999, Altitude 230 n. miles) Side View



SSU-8814315
1582 12/04/88 M/JF

Microgravity Quasi-Static Isogravity Contours ($\times 10^{-6}$ G) (June, 1999, Altitude 230 n. miles) Close-up of U.S. Laboratory



SSU-8814314

SPACE STATION ELECTROMAGNETIC COMPATIBILITY AND ENVIRONMENTAL INTERACTIONS STUDY

<u>NATURAL ENVIRONMENTS</u>

- NEUTRAL
- PARTICULATE
- RADIATION
- MAGNETIC FIELD
- PLASMA
- EM RADIATION

<u>ENVIRONMENT PERGURBATIONS</u>

- THRUSTER FIRINGS
- VENTS AND OUTGASSING
- INDUCED CURRENTS
- COUPLING OF EM WAVES
- PLASMA BEAMS
- PARTICULATES
- RAM/WAKE

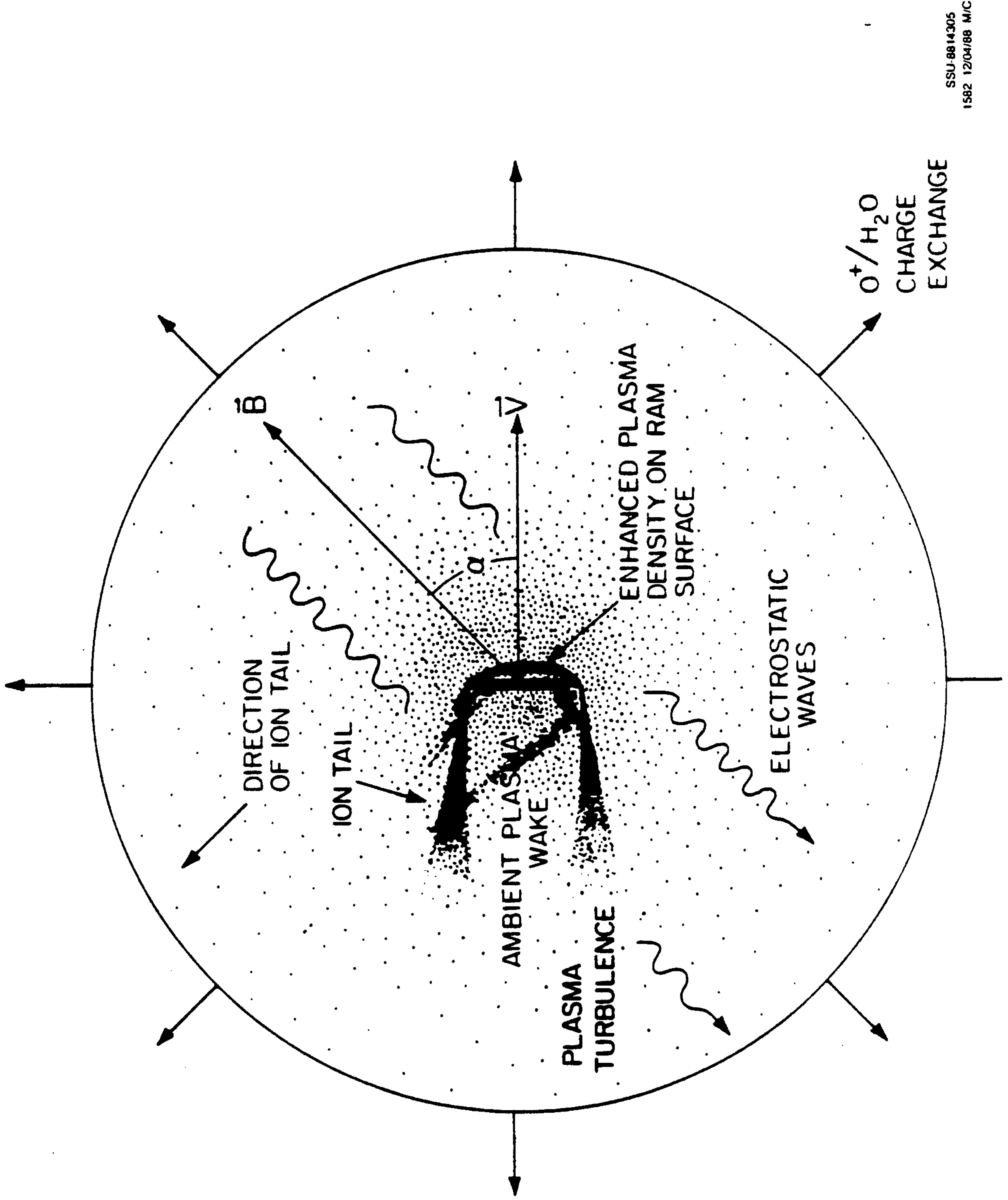
<u>ENVIRONMENT INDUCED PHENOMENA</u>

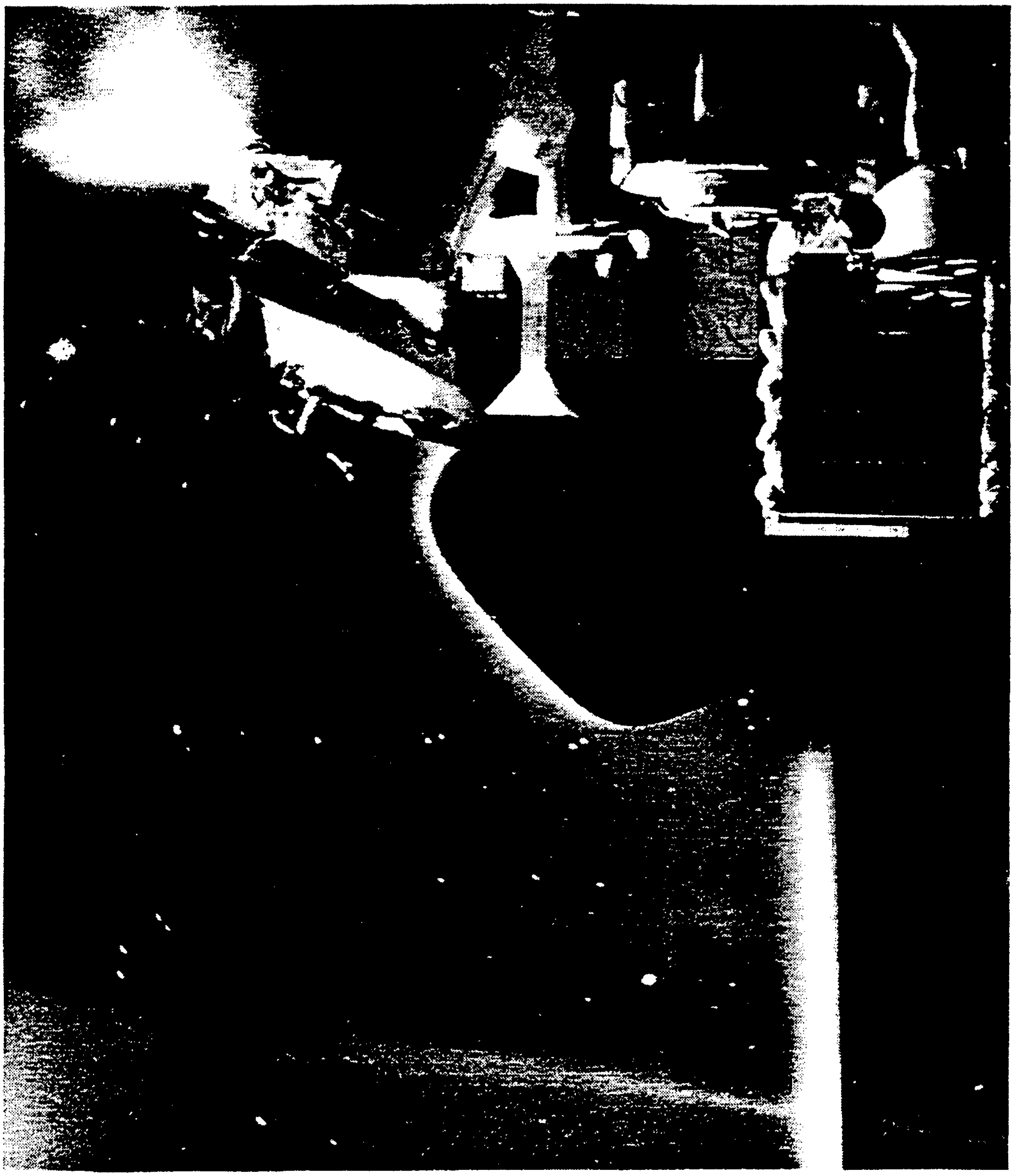
- CHARGING
- ESD
- EMI
- HIGH VOLTAGE SURFACES
- SURFACE CONTAMINATION
- LONG TERM DEGRADATION

SSU-8814302
1582 12/02/88 M/LK

INDUCED ENVIRONMENT NEAR LARGE SURFACES (ANDERSON [1984])

PARAMETERS	RAM	WAKE	COMMENT	EFFECT
NEUTRAL DENSITY, Torr	10^{-5}	10^{-7}	MEASURED	HIGH VOLTAGE SHORTS, CONTAMINATION
PLASMA DENSITY, cm^{-3}	AS HIGH AS 5×10^{6}	AS LOW AS 10	MEASURED	POWER LOSS, ARCING
PLASMA WAVES	20 Hz - 300 KHz $(22V/m)^{2}$/MHz AT PEAK	LOW	MEASURED ELECTROSTATIC WAVES	EM BACKGROUND NOISE
ENERGETIC PARTICLES	MEAN ENERGY OF ELECTRONS: 10 - 100 eV FLUX: ~$10^{8}/cm^{2}$ sec ster eV MEAN ENERGY OF IONS: 10 - 30 eV	LOW	HIGHER FLUXES PREDICTED; LITTLE NUMERICAL DATA PUBLISHED	PLASMA WAKE, DIFFERENTIAL CHARGING
GLOW, PHOTONS $(cm^{3}s)^{-1}$	10^{7} - 10^{8}	LOW	GLOWING LAYER IN RAM 10-20 cm THICK	OPTICAL (IR) CONTAMINATION


SSU-8814305
1582 12/04/88 M/CW
O^+/H_2O
CHARGE
EXCHANGE
$\vec{B}$
$\vec{V}$
α
ENHANCED PLASMA
DENSITY ON RAM
SURFACE
DIRECTION
OF ION TAIL
ION TAIL
ELECTROSTATIC
WAVES
AMBIENT PLASMA
WAKE
PLASMA
TURBULENCE



POTENTIAL ENVIRONMENTALLY ACTIVE PAYLOADS

ASTROMAG (EARLY ATTACHED PAYLOAD CANDIDATE)

- ENERGY STORED BY MAGNETIC FIELD: 10 MEGA JOULES
- MAXIMUM MAGNETIC FIELD INTENSITY: 70,000 GAUSS
- FIELD CONFIGURATION: QUADRUPOLE, DECREASES TO EARTH'S MAGNETIC FIELD INTENSITY AT 15 METER DISTANCE

SOLAR TERRESTRIAL OBSERVATORY: PLASMA PHYSICS GROUP (LATER ATTACHED PAYLOAD CANDIDATE)

- ELECTRON BEAMS
- WAVE GENERATORS - GROWTH VERSION UP TO 50 KW POWER REQUIREMENT

HIGH TEMPERATURE SUPERCONDUCTING MAGNETIC FIELD ENERGY STORAGE SYSTEM (CANDIDATE PAYLOAD ANTICIPATED)

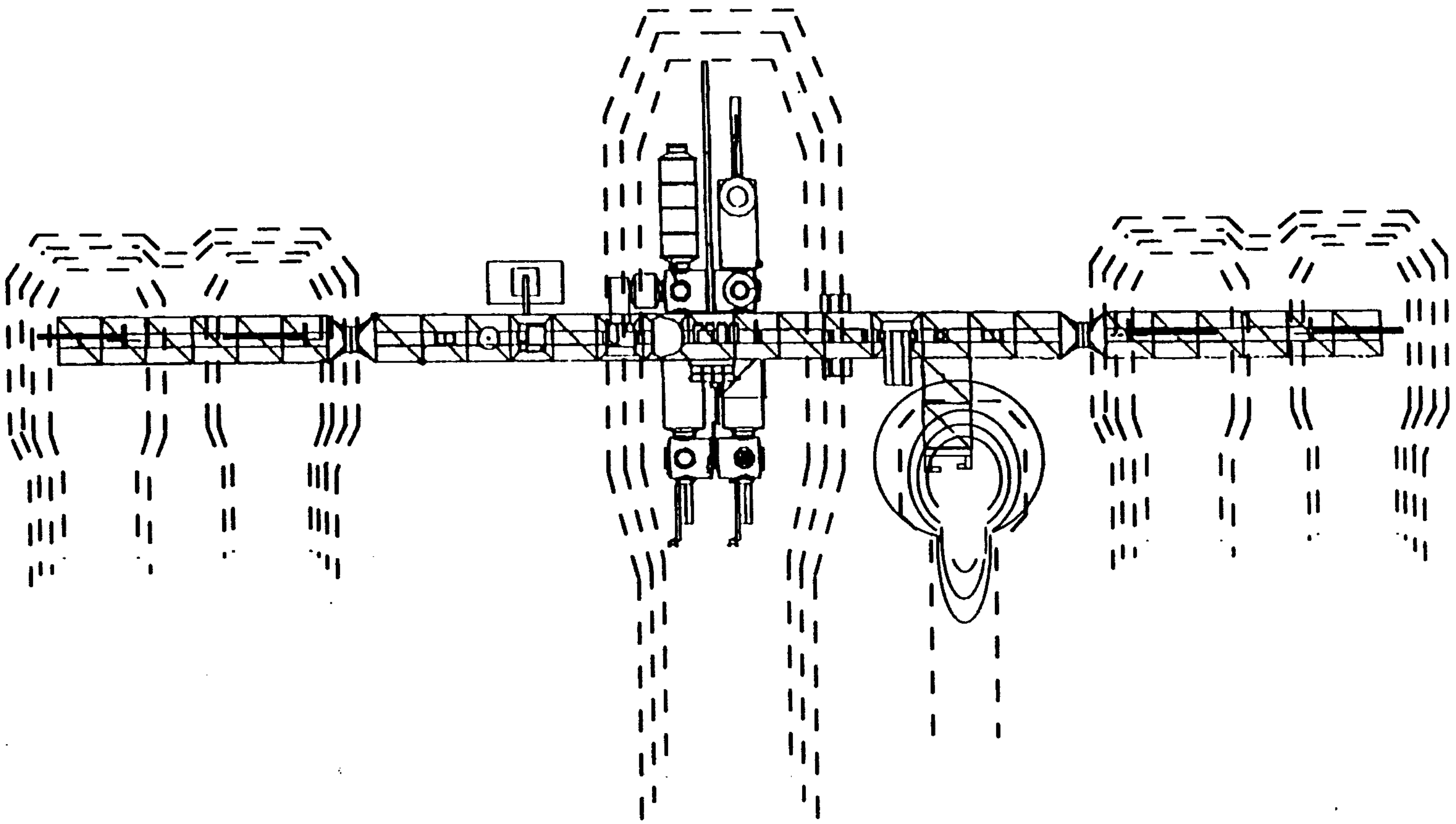
- HIGH MAGNETIC FIELD INTENSITIES

ADVANCED ELECTRIC AND ELECTROMAGNETIC PROPULSION SUBSYSTEM TECHNOLOGY TESTS (CANDIDATE PAYLOAD ANTICIPATED)

- HIGH MAGNETIC FIELD AND ELECTRIC FIELD INTENSITIES

SSU-8814300
1582 12/02/88 M/LK

INDUCED ENVIRONMENTAL EFFECTS OF ACTIVE TECHNOLOGY PAYLOADS - TOP VIEW



– – – PLASMA ISO DENSITY CONTOUR
——— MAGNETIC FIELD ISO INTENSITY COUNTOUR

SSU-8814674
1582 12/4/88 M/AK

SPACE STATION FREEDOM
GROWTH CAPABILITIES / TECHNOLOGY PAYLOADS

SERVICING FACILITY

- REPAIR AND CONDUCT RESUPPLY AND REFUELING OPERATIONS FOR FREE FLYERS AND CO-ORBITING PLATFORMS
- EXTENSIVE REPAIR WORK FOR ATTACHED PAYLOADS
- ASSEMBLY OF UPPER STAGES AND PAYLOADS

LARGE SPACE CONSTRUCTION FACILITY

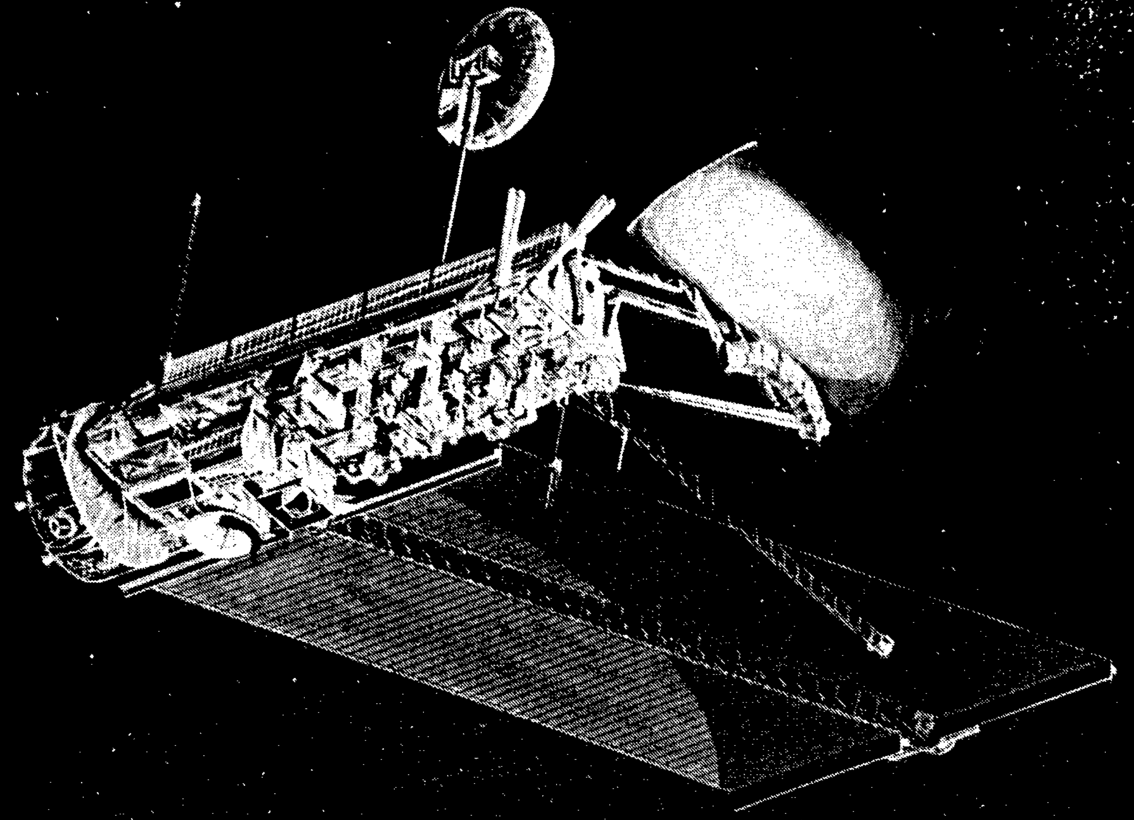
- LARGE CRANE FOR POSITIONING
- ADDITIONAL MOBILE ROBOTICS
- CAPABILITY TO ASSEMBLE LARGE ANTENNAS, PHASED-ARRAY OPTICAL SYSTEMS

CO-ORBITING PLATFORM, ADVANCED TECHNOLOGY TEST FACILITY

- USER-SUPPLIED OR STATION-SUPPLIED PLATFORM TO CONDUCT PARTIAL OR FULLUP TESTS OF ADVANCED PROPULSION AND POWER SYSTEMS
- TESTING OF TECHNOLOGY INVOLVING HAZARDOUS MATERIALS OR OPERATIONS OR REQUIRING ORBITAL DYNAMICS NOT SUPPORTED BY THE STATION

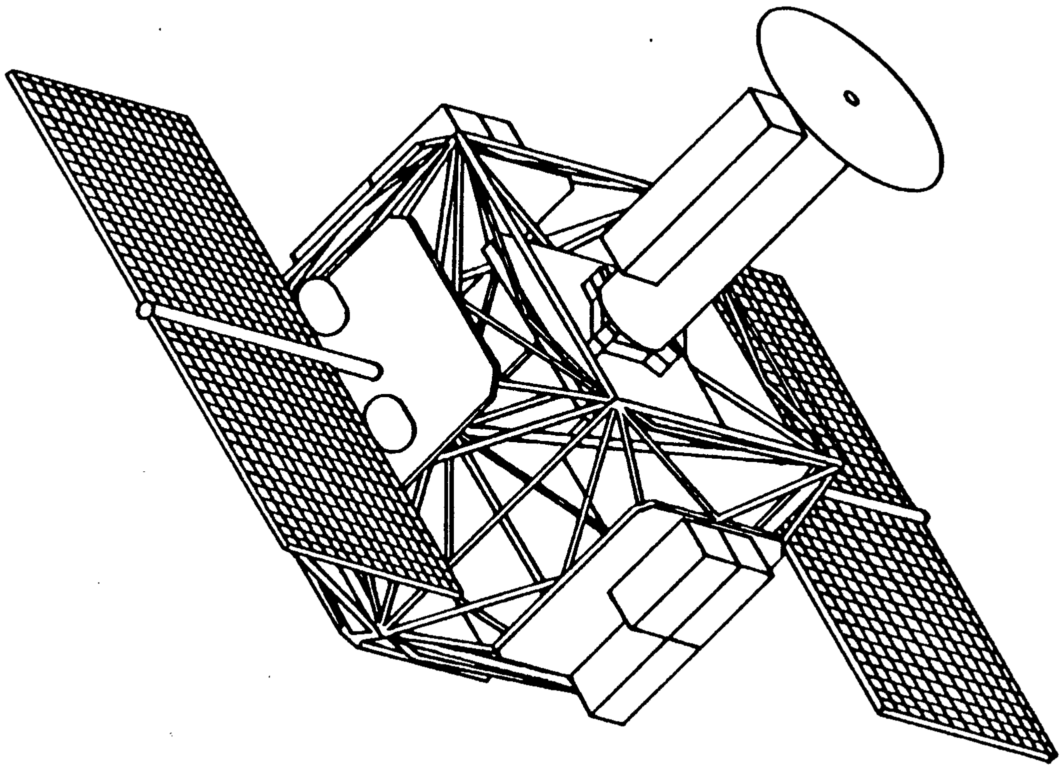
SSU-8814296
1582 11/29/88 M/JF

SPACE STATION FREEDOM POLAR PLATFORM



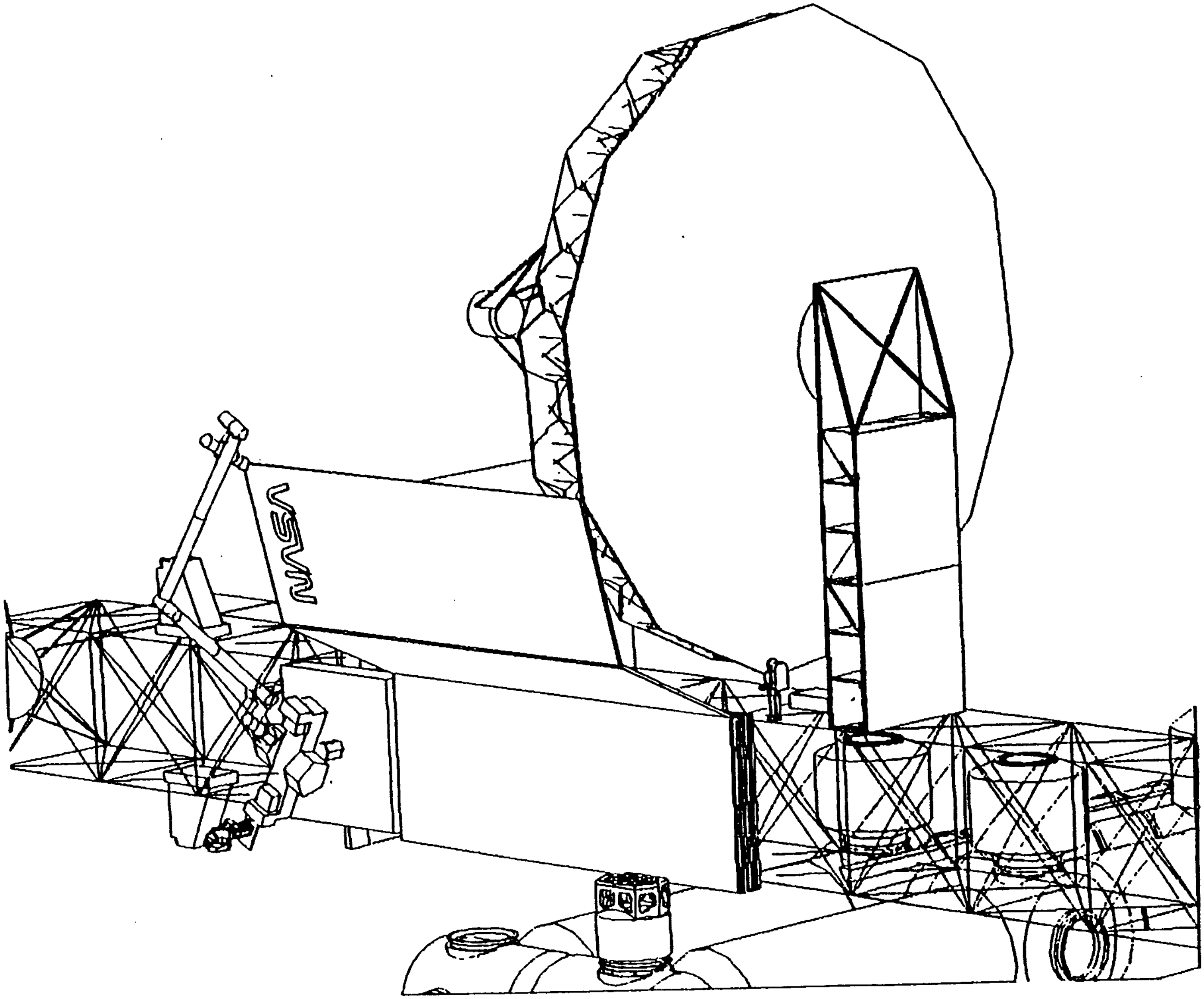
OSSTT 82D
NASA SF88-216 (3)
12-14-88

SKP TRUSS DERIVATIVE CONFIGURATION
(WITH HRSO)



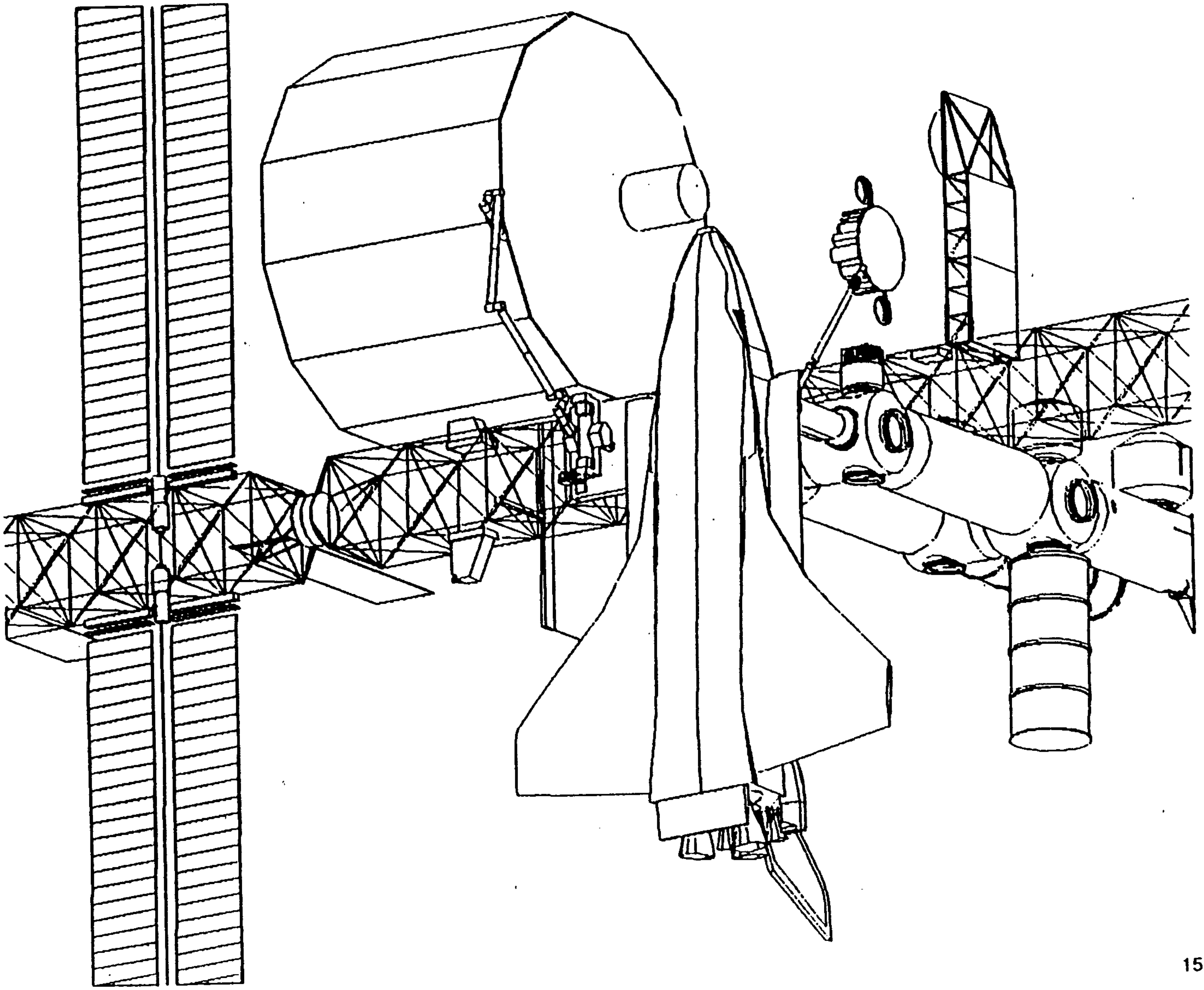
SSU-8814303
1582 12/04/88 M/CW

Assembly of Large Deployable Reflector - I



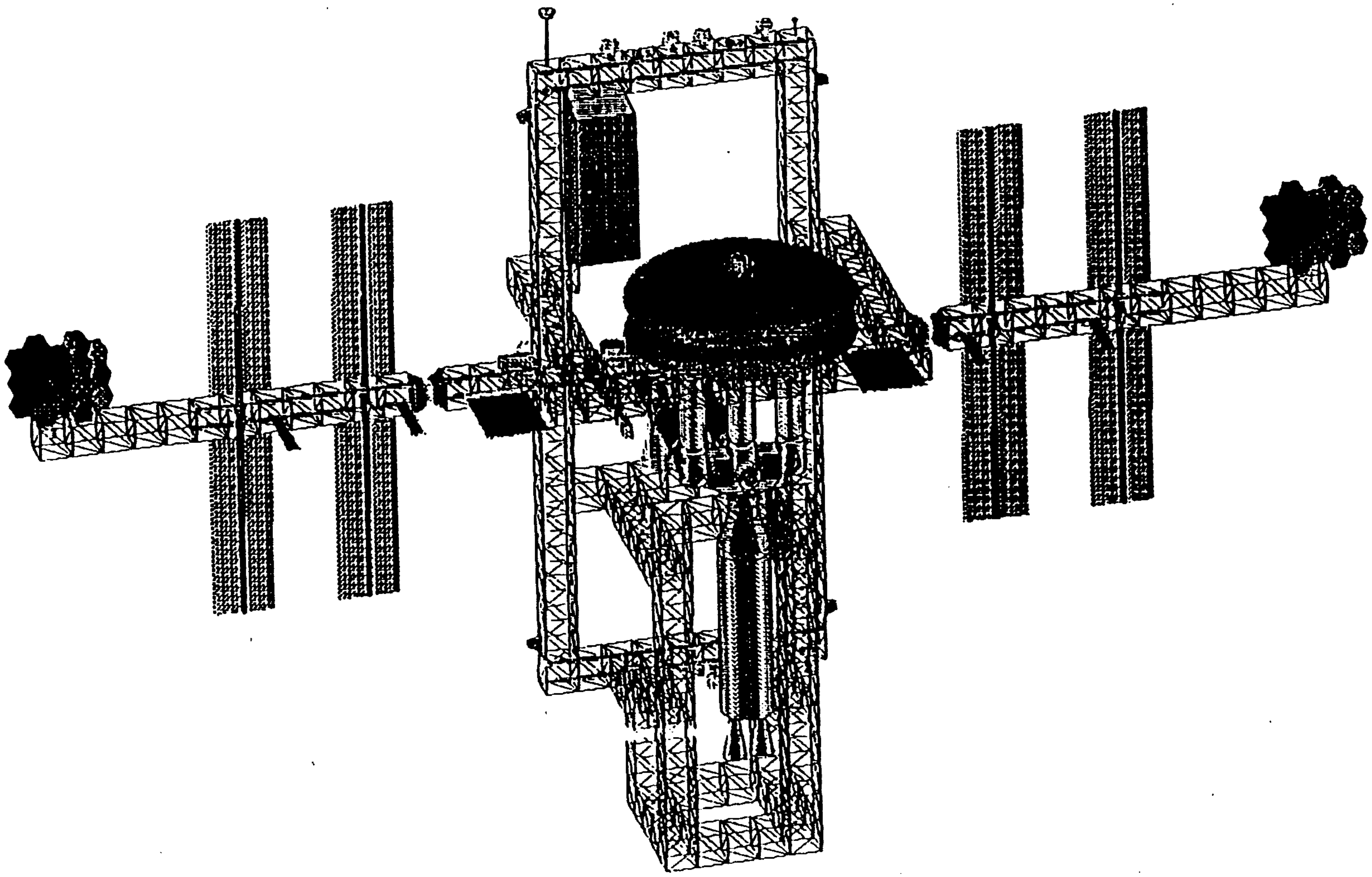
SSU-8814319
1582 12/04/88 M/JF

Assembly of Large Deployable Reflector - II



SSU-8814318
1582 12/04/88 M/JF

SPACE STATION WITH CANDIDATE MANNED MARS CONFIGURATION

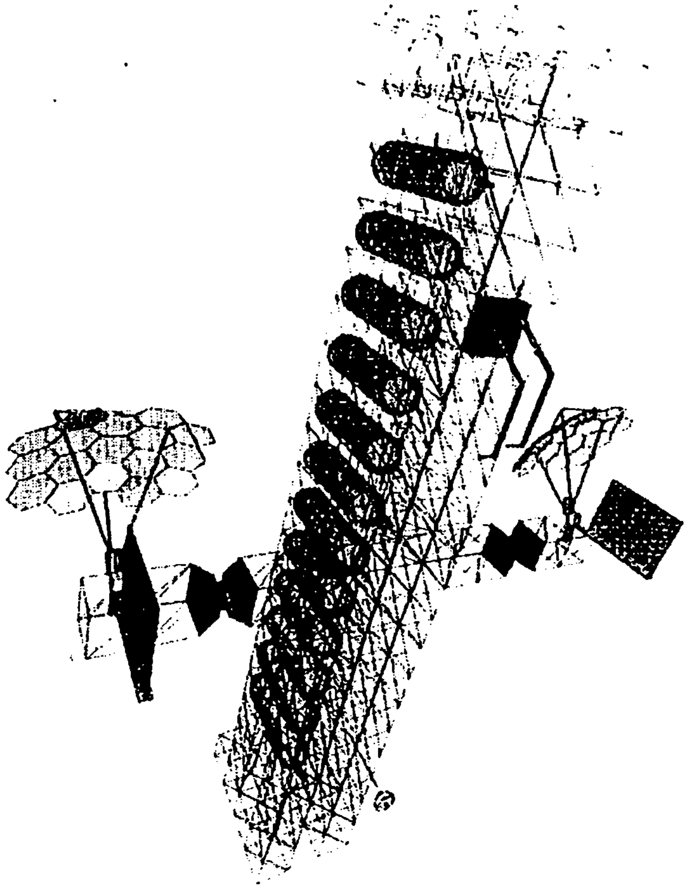


SSU-8814317
1582 12/04/88 M/JF

Manned Mars Accommodation Study

PROPELLANT TANK FARM

CO-ORBITING PROPELLANT TANK FARM RECOMMENDED TO STORE AND TRANSFER PROPELLANTS FOR MANNED MARS MISSION



CAPACITY

1./9 M LB H_2 - O_2

12 TANKS 16' X 60'

Process Description

- SCOPE
  - ◊ End to End User Integration Is the Process Which:
    - ▼ Enables a User to Conduct Research, Development or Commercial Activities on the Station.
    - ▼ Includes All Interactions Between the SSP and the User/User Sponsors
    - ▼ External Activities Beginning with the User's Initial Contact With the SSP and Continuing Until Exit from the Program.
  - ◊ The Integration Process Shall Provide a "Level Playing Field", with Payloads having similar Physical and Operational Requirements following the Same Path.

Process Description

- PROCESS DEVELOPMENT GOAL:
  - ◊ Provide a Process for User Integration Which:
    - ▼ Supports a Diverse User Community, Including Rapid Response Research (QIB)
    - ▼ Enables high priority research and development supporting national objectives and future missions.
    - ▼ **Minimizes the Burden on the Users** (Data, Meetings,etc.)
    - ▼ Provides single point of contact for Shuttle and Station Integration
    - ▼ Does Not Compromise Safety
    - ▼ Incorporates Lessons Learned from Past Programs
    - ▼ Recognizes Constraints Imposed by the Physical Requirements of Payload Integration

Integration Process Overview

- **Consider as Multiple Processes :**
  - ◊ **Payload Accommodation Assessment**
    - Verify station or platform capabilities can accommodate payload requirements
    - Identify deficiencies and potential station enhancements or potential reduction in payload requirements required
  - ◊ **Payload Development**
    - Payload DDT&E Conducted by Developer, PI
    - Driven by Experiment Goals, Development Resources
  - ◊ **Analytical Integration**
    - Engineering Analysis (Loads, Thermal, EMI, Contam., etc.)
    - Verify S/W Design
    - Analytical Support of Certification/Verification
  - ◊ **Payload Integration, Test & Verification**
    - Safety Certification
    - Verify P/L Design for Transportation, On-orbit Ops
    - Ensure that P/L Ops, Failures Will Not Endanger Crew, Station, Other Payloads (FMEA's, Failure Propagation, Debris Impacts, Etc.)

User Support Features

- ◊ **Standardized Flows for Payload Classes**
  - **Payloads Integration Flows Optimized for Level of P/L Complexity**
  - **Streamlined Flows for Rapid Response Research Payloads**
    - Payloads Meet Pre-defined Constraints
    - Users of Existing Facilities
- ◊ **Payload Accommodations Manager**
  - Single Point of Contact Between User/Sponsor & SSP
  - Assists User During All Phases After Selection
- ◊ **Science & Technology Centers**
  - Conduct Tests, Modelling, Physical Integration for User
  - Both Gov't and Commercial (NASA Approved) Entities
- ◊ **Payload Operations**
  - Payload Operations Conducted by User (Telescience)
  - Overall Coordination, Safety Monitoring Provided by POIC
  - Distributed User Locations
- ◊ **Computer Supported Document Preparation, Reviews**
  - Use of Expert Systems as Appropriate ("Smart Documents")

Integration Process Overview Con't

◊ **Physical Integration**
  - Perform Required P/L to Rack, Carrier Integration

◊ **Payload Operations**
  - On-orbit Payload Installation & C/O
  - Conduct Experiment Runs, Gather Data
  - Telescience & On-orbit Control
  - Safing, Deintegration & Return to Developer

◊ **Post Flight Debriefing, Lessons Learned, and Data Analysis**

"Beat The System"

◊ **TWO PATHS TO SIMPLE INTEGRATION, RAPID FLIGHTS**

- **Use an Existing "Facility Class Payload"**
  - ¶ Freedom is a Long Duration "Orbital International Research and Development Lab"
    - Analogous to: Argonne National Laboratory, LaRC, Kitt Peak, LeRC, etc.
  - ¶ Major Facilities and Lab Support Equipment Available:
    - Truss Payload Accommodation Equipment, Payload System, Mobile Servicing Center, Flight Telerobotic Servicer, SS Furnance Facility, EVA Servicing, Glovebox, etc.
  - ¶ Use of Existing Facilities Requires Integration of Sample, Procedures: No DDT&E, Certification of Unique Hardware

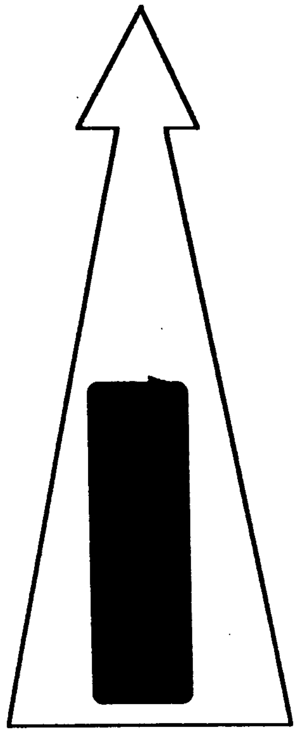
- **Design/Build an "R^3" Payload**
  - ¶ "R^3" = Rapid Response Research: Payloads Defined to Established Guidelines (extension of GAS, STS Mid deck) :
  - ¶ Simple, Standard Interfaces
  - ¶ Modest Resource Requirements
  - ¶ Standard Req'ts for Safety, Physical Integration, Crew Support
  - ¶ Both Internal and External

Space Station User Integration Process

SPACE STATION FREEDOM
UTILIZATION & OPERATIONS

SSU

User/Payload Integration Complexity

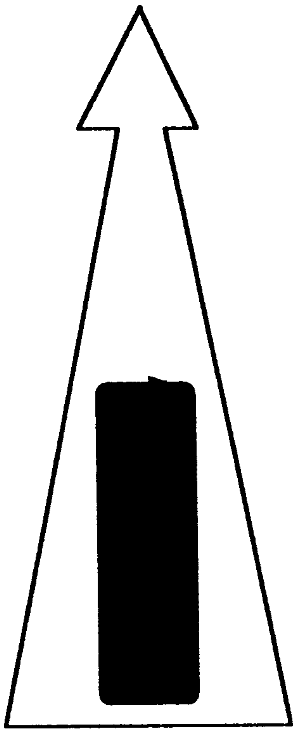


Longest Duration
(2 - 5 Years)

[redacted]

Shortest Duration

- ◊ User Designs/Supplies Facility Class (Multiple User) Payload for Station
- ◊ User Designs/Supplies Standard (Single User) Payload for Station
- ◊ User Modifies Facility P/L Hardware, Software and Operations and Provides Samples, Specimens
- ◊ User Designs/Supplies R^3 Payload
- ◊ User Modifies Existing Facility Payload Software and Operations, Provides Samples
- ◊ User Modifies Facility Operations and Provides Samples, Consumables



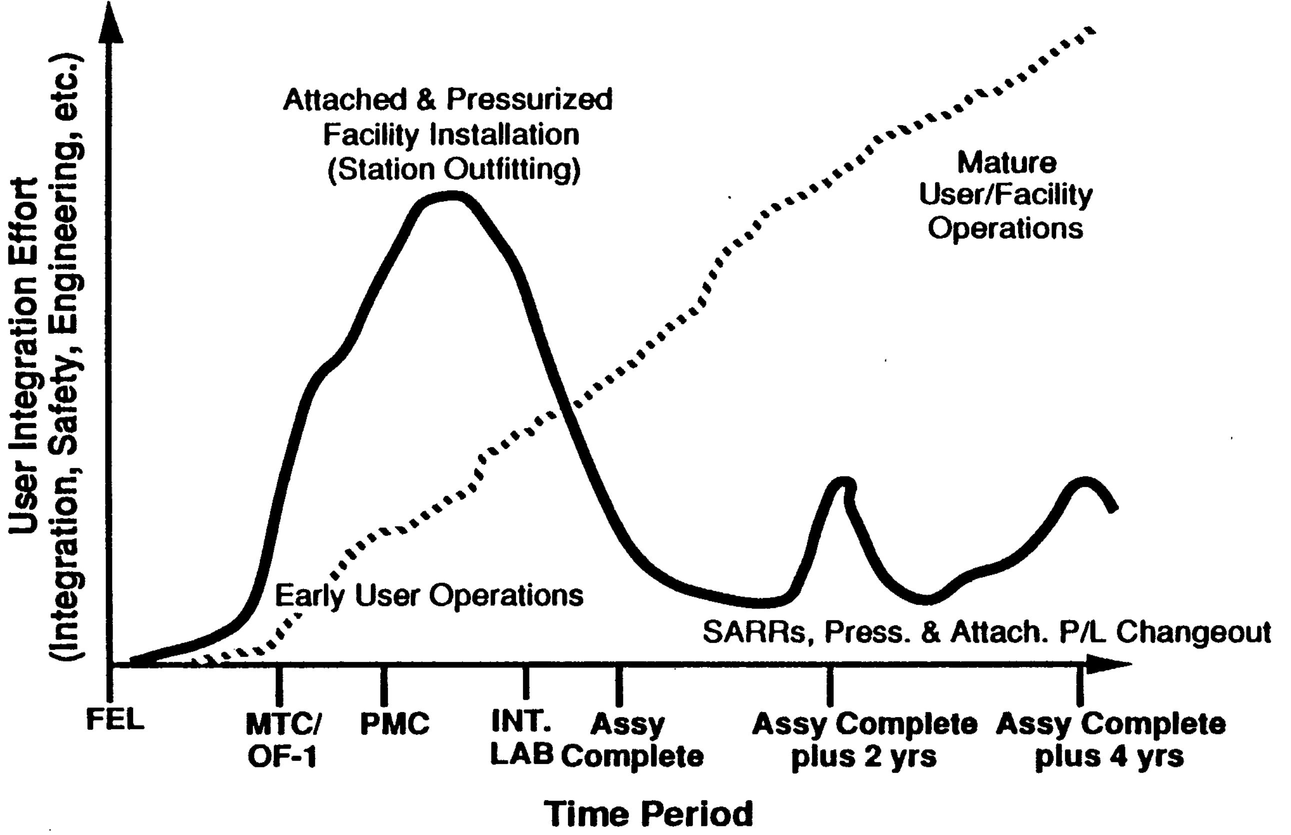
Most Complex

[redacted]

Least Complex

Space Station User Integration Process

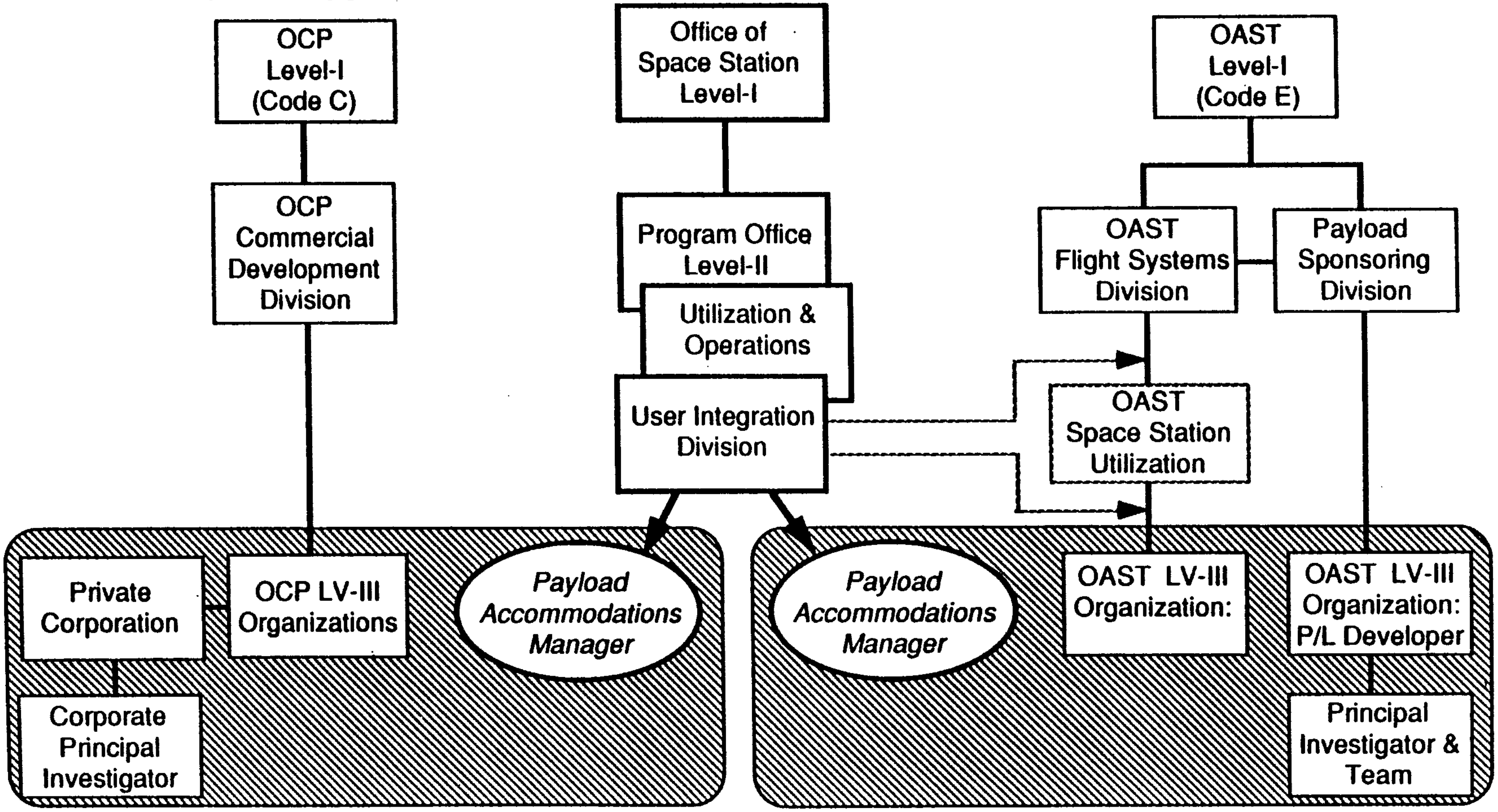
Existing Facilities Use Dominates Mature Operations



——— Traditional "Payload/Mission Integration" for hardware being shipped to/from Orbit

⋯⋯ "Reconfiguration" of on-Orbit Facilities/Payloads to support Multiple User Operations (includes shipment/changeout/use of technology units, specimens, samples and consumables)

Examples of Station-to-User Interface: U.S. Commercial Cooperative vs. U. S. Technology User

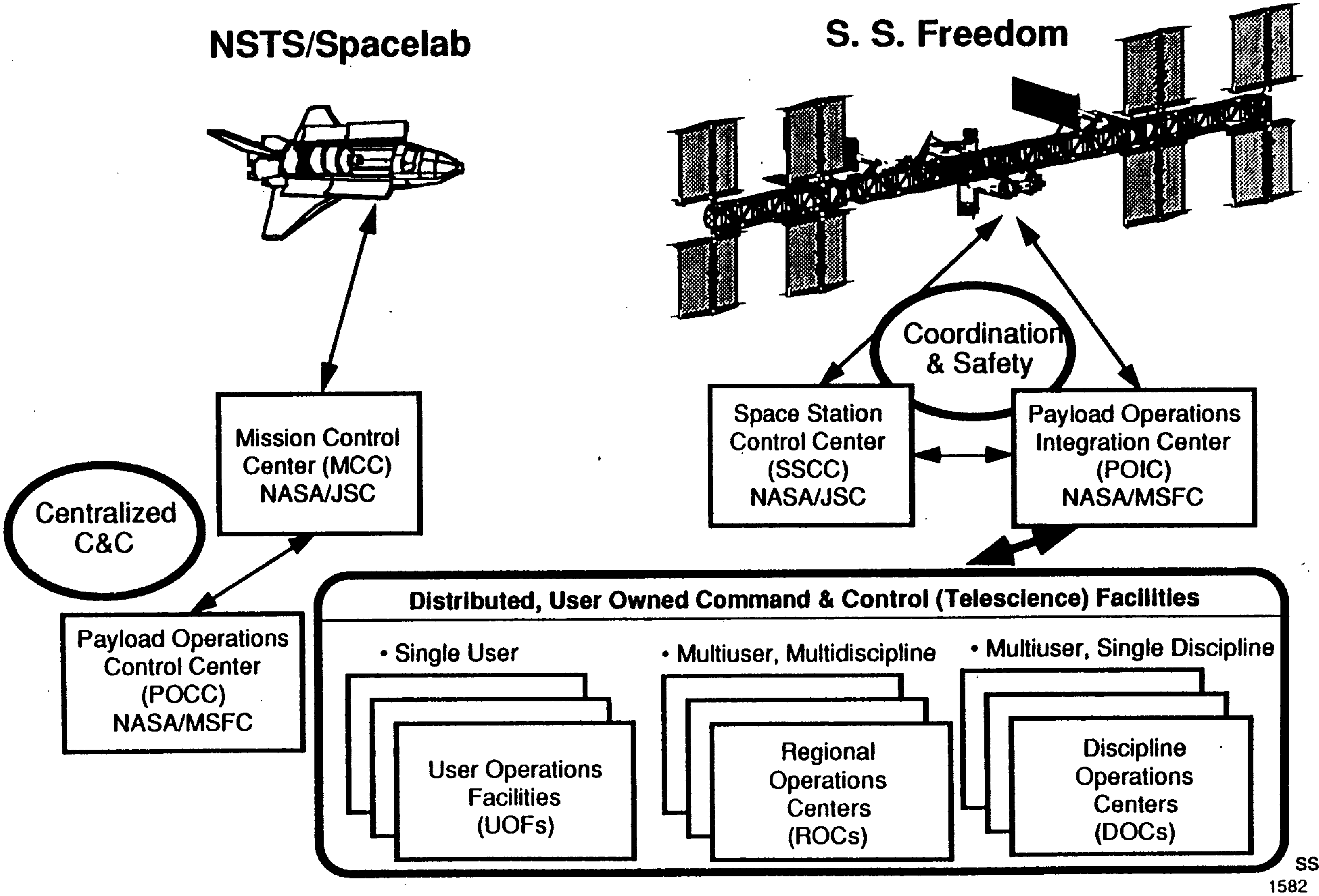


Commercial Cooperative (JEA Type)

Government Technology (NASA OAST Type)

Space Station User Integration Process

User Operations Achitecture



NSTS/Spacelab

S. S. Freedom

Centralized C&C

Mission Control Center (MCC) NASA/JSC

Payload Operations Control Center (POCC) NASA/MSFC

Coordination & Safety

Space Station Control Center (SSCC) NASA/JSC

Payload Operations Integration Center (POIC) NASA/MSFC

Distributed, User Owned Command & Control (Telescience) Facilities

- Single User
- Multiuser, Multidiscipline
- Multiuser, Single Discipline

User Operations Facilities (UOFs)

Regional Operations Centers (ROCs)

Discipline Operations Centers (DOCs)

SSU-8814324
1582 12/04/88 M/JF

SPACE STATION FREEDOM
TECHNOLOGY PAYLOAD ACCOMMODATION

- PROVIDES FOR MULTIPLE TYPES AND SIZES OF TECHNOLOGY R.&D. OPPORTUNITIES
  - QUIET AND ACTIVE ENVIRONMENTAL CONDITION PERIODS CAN BE SCHEDULED
- SPACE STATION FREEDOM, TOGETHER WITH CO-ORBITING PLATFORM TEST FACILITIES, CAN FUNCTION AS A MAJOR TEST BED FACILITY
  - TO SUPPORT INTERPLANETARY SPACECRAFT R.&D.
  - TO SUPPORT LUNAR/MARS BASE TECHNOLOGY AND SYSTEMS R.&D.
- SPACE STATION FREEDOM USER INTEGRATION AND PAYLOAD ACCOMMODATION PROCESSES WILL BE ESTABLISHED
  - TO INSURE RAPID AND SUCCESSFUL INTEGRATION OF TECHNOLOGY PAYLOADS
  - WILL ENABLE "SKUNK WORKS" R.&D. IN SPACE.

SSU-8814298
1582 12/02/88 M/JF

KEYNOTE ADDRESS

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MISSION TO EARTH, MOON, AND MARS

Harrison H. Schmitt

Let us jump ahead to late January, 1990, and try to anticipate what should be the concluding paragraphs of the President's State of the Union Address to the Congress.

> "Now, my fellow Americans, as your representatives assembled in these historic chambers know so well, there has been a rising tide of domestic and international political pressure in support of initiatives for the future. You have made us all increasingly aware that both vulnerabilities and opportunities in America's future and in the future of humankind require our urgent attention. The unfair inequities of the present still do and will always demand our concern and our compassion, however, many issues essential to the future well-being of our children and our country have been too long neglected.
>
> "Therefore, over the next 60 days, I will send to the Congress a number of proposals that address long term structural changes in our approaches to education, the environment, retirement and health security, basic research, and other critical areas.
>
> "Tonight, because of the central roles played by environment and space in the future of our children, I am calling on the Congress to provide the long term commitments necessary to undertake a specific project focused on the turn of the Third Millennium. Although this rare milestone is only 10 years away, the challenge has grown to for a Millennium Project that will match the times and the opportunities.
>
> "Our Millennium Project, in which we invite the family of nations to join, will be the establishment of a permanent human outpost on Mars by 2010 and, by so doing, provide the technology base necessary to preserve the Earth's global environment.
>
> "The creation of a permanent outpost on Mars will have as its primary purposes the eventual settlement of the planet Mars by free human beings and the provision of abundant and environmentally benign electrical power on Earth. The bridge between these two essential achievements is the development of helium-3 fusion

> power plants on Earth fueled by the helium resources of the moon. This bridge of energy also provides, as by-products from the energy resources of the moon, the oxygen, hydrogen, and other consumable materials critical to sustaining the early settlers of Mars.
>
> "Thus, our Millennium Project combines space ventures to the Earth, moon, and Mars into a single great human mission -- a mission to save the atmosphere, waters, and rainforests of Earth, a mission to settle the moon and utilize it resources for the benefit of all, and a mission to establish human civilization and freedom permanently on Mars.
>
> "A draft treaty for international participation in The Millennium Project is being circulated among the nations of Earth. This treaty, tentatively called the INTERMARS Charter, proposes a participant based relationship between nations, users, and investors, modeled after the successful International Telecommunications Satellite or INTELSAT Agreements. It is the intention of the United States Government that an international conference to finalize the INTERMARS Charter will be convened by interested nations before the end of the year.
>
> "Ladies and gentlemen and my fellow Americans, our commitment to the success of The Millennium Project must be unequivocal. It must include an equally unequivocal commitment to carry the sacred institutions of freedom with us as humankind expands into its larger home among the planets and the stars."

The recent return of American astronauts to space, as satisfying as it must be to those of you responsible, constitutes but a very small step in the repair of what can only be called a space policy disaster.

Challenger and the tragedy of its loss did not cause this policy disaster nor was it caused by the dedicated people of NASA and its contractors whatever errors in judgment may have been made. The now so obvious loss of momentum in the United States space program has been the result of a loss of will on the part of national leadership spanning almost two decades.

Humankind's first explorations of the moon and of space near the Earth between 1968 and 1972 were also the species first clear steps of evolution into the solar system and eventually into the galaxy. As the Pueblo Indians tell the lesson of their ancestors, "We walk on the Earth, but we live in the sky."

Early explorers of the sky not only took their eyes and minds into space and became the eyes and minds of billions of other explorers on the starship Earth, but they began the long process of transplanting civilization into space. This fundamental change in the course of history has occurred as humans also have gained new insight into themselves and their first planetary home.

Limitless seas in space exist not only as new frontiers but as new challenges for humankind. The nations on Earth which effectively utilize technology to exploit the economic and military advantages of the new ocean of space will dominate human activities on this planet well into the next century, if not indefinitely. Those nations also will provide the irreversible templates for the social and political evolution of civilization beyond the next century far into the Third Millennium.

The first response to this challenge in space by the United States under President John F. Kennedy's leadership appeared to recognize the historic proportions of the contest. The leading involvement of the United States in space initially insured that the traditions of free institutions would be represented. As a consequence, at the high point of the Apollo Program, the United States verged on the establishment of bases on the moon, research stations in earth orbit, and the statement of a realistic goal of a foothold on Mars by the end of the Century. In the motto of the last Apollo mission to the moon in December 1972, the conclusion of the Apollo Program truly could have been "The End of the Beginning."

The opportunity given to humankind by the Apollo Program and its generation passed by. Consequently, the responsibility to re-ignite Kennedy's torch for space falls to others. The emotional energy to light that torch could be supplied to generations now alive by the vision of the human settlement of Mars and by the necessity of providing vast amounts of environmentally compatible energy for the billions of humans left at home.

The return of Americans and their partners to space must be viewed in the context of the free world's over all perception of the future of humankind. In the United States, unfortunately, little political thought normally is given to that future or to our role with in it. However, in space, we have little choice. The United States will be the free world's principal agent and advocate in space, because there are no other likely alternatives.

One body of opinion in the U.S. today would argue that there is no hurry. "Space will always be there, and meanwhile we have more pressing near term interests here on Earth. What is interesting to do scientifically can be done with robots at much lower cost." Unfortunately for those who hold this opinion, times are changing rapidly, and there is history being made without us. The challenge in space can no longer be viewed as merely a scientific challenge as valuable as the science to be done will be. The challenge now is to both lead the human settlement of space and the environmental preservation of our home planet.

Why the hurry? Why stretch human technological and psychological reach to the limit? First and foremost, the answers are in the minds of young people who will carry us into the Third Millennium. The answers are in the generations now in school, now playing around our homes, now driving us to distraction as they struggle toward adulthood. They will settle the moon and then Mars. They will do this simply because they want to do this. They want to "be there". "Being there" remains the essential human ingredient in life's meaningful experiences.

The desire to "be there" will drive our young people away from the established paths of history on a now too confining Earth. It will take them and their progeny to an infinity of opportunity among the planets and the stars. Video pictures and data streams from robots on Mars, no matter how good or how complete, will never be enough for the parents of the first Martians. Somewhere, those parents are alive today. Whether they now play on the steppes of Russia, on the river banks of China, or on the mountains, plains, and shores of America, or on a combination of all three, constitutes the most critical question of national will we face today.

Thus, an answer to "why the hurry" also lies in the clear determination of the Soviet Union to establish its sovereignty in deep space and on Mars before the forces of freedom do so. The permanently occupied MIR space station, very long duration earth orbital flights by the cosmonauts, heavy lift launch vehicle testing, and their public emphasis of Mars exploration, leading to human visits early in the 21st Century, all tell us what the Soviets expect to do. In spite of all the real and perceived difficulties faced by the Soviet Union in the future, there is now reason to count on their failure in space.

Perhaps the most important answer from the perspective of the physical welfare of the human species lies in the absolute moral and political requirement to provide the ever expanding population of Earth with an ever improving quality of life. We do not currently have the technical means to do this. We do not know how we are going to provide the ten billion human beings expected before the end of the 21st Century with both the hope and the reality that they will have defeated the four horsemen of worldwide disaster: poverty, hunger, disease, and ignorance. The essential ingredient for victory in this very human battle is environmentally compatible energy. Fossil fuels, the rainforests, and conventional nuclear power cannot provide the answer without either unexceptable political conflict or potentially devastating consequences to the biosphere of the Earth.

Fusion power plants fueled by helium-3 from the moon (Wittenberg, 1986) could supply the electrical energy human civilization will require to maintain and expand human quality of life as we enter the Third Millennium. Inherently safe and potentially low cost fusion reactors fueled by lunar helium-3 also could become the basis for producing large quantities of continuously available electrical power in space, for highly efficient space propulsion to and from Mars, and for life giving by-products that insure the self sufficiency of settlements on the moon and Mars (Kulcinski, 1987).

Furthermore, establishment of a permanent settlement on the moon, based on the production of helium-3 for use as an energy source on Earth fully supports the desire to live on Mars as soon as possible.

First of all, most of the technology needed for the creation of a permanent lunar settlement with a resources production economy will support the technological requirements for establishing a Martian settlement. The compatible technologies include heavy lift launch vehicles, long duration surface habitats and mobility systems, resource production facilities, regular and routine capability to work in a hostile and dusty environment, and new concepts in equipment automation, reliability, longevity, and maintainability.

Second, the direct and indirect by-products of helium-3 production from the lunar surface materials will provide a ready source of necessary consumables for Martian inhabitants prior to and possibly even after the creation of their own consumables industry. These lunar produced consumables include hydrogen, oxygen, nitrogen, carbon, and food.

A preliminary extimate of the energy equivalent value of helium-3 today is about two billion dollars per metric tonne if matched against the cost of coal currently used to produce electricity in the United States. This is roughly equivalent to $14 per barrel oil at today's prices. Two billion dollars worth of fuel currently supplies the electrial power needs of the United States for about two weeks or of a city of 10 million for about one year. The foregoing estimates of value do not take into account the additional value of by-products from lunar helium-3 production or the spin-off value of related technologies.

The principle advantages of the helium-3 fusion power cycle on Earth over other nuclear cycles include:

1. About 99 percent of the energy released is in charged particles (protons) that induce no radioactivity in other materials.

2. High efficiency (70-80 percent) in energy conversion due to the potential for direct conversion of protons to electricity.

3. Less waste heat to be rejected due to high efficiency.

4. The energy of each of the few neutrons released (1 percent of total energy) is only one-fourth that released in other fusion cycles and such neutrons create no significant quantities of long lived radioactive waste.

5. A potentially shorter time to licensed commercialization than for other fusion cycles due to the absence of significant radioactivity and waste heat.

Estimates of the ultimate steady-state costs of delivering helium-3 to deuterium/helium-3 power plants on Earth run about one billion dollars per metric tonne. If such cost prove to be correct, such power plants will provide much lower cost electricity as well as much less environmental impact than other competing power sources proposed for the 21st Century.

The only major technical disadvantage of the deuterium/helium-3 fusion cycle is that the ignition temperature and confinement pressure required to initiate fusion is about four times higher that for the competing deuterium/tritium cycle. This disadvantage appears to be becoming less and less significant as new fusion confinement technologies are developed. In fact, a recent test in Great Britain produced a record 60 kilowatts of fusion energy using deuterium and helium-3 (G.L. Kulcinski, personal communication).

Sufficient helium-3 is available on Earth (largely from tritium decay and natural gas) for development and prototype testing of deuterium/helium-3 power plants. Therefore, the primary issues that must be addressed to determine the feasibility of a commercial helium-3 industry are, first, the technical and economic feasibility of deuterium/helium-3 commercial reactors and, second, the technical and economic feasibility of providing lunar helium-3 to fuel such reactors.

Historically, major extensions of the benefits of civilization have built on extensions of the existing foundation of scientific and technical understanding. The creation of the pyramids, the aqueducts and roads of the Roman Empire, the Gothic Cathedrals, the industrial revolution, the airplane, the construction of the Panama Canal, the green revolution in agriculture, and controlled nuclear energy have followed this pattern. No less than these examples, Apollo exploration of the moon and the technological revolution brought about by space flight matched the experience and technology of the past with the imagination and research of the moment.

New explorations at the frontiers of space, that is, in places and for times that are significantly beyond the technical capabilities of Apollo, Skylab, the Space Shuttle, and the space station also will require new technologies to augment those necessary to live and work in near Earth space. New and more rapid interplanetary rockets and new concepts of life support, mobility, and transportation will obviously be necessary. Foresight will be required to invest a reasonable proportion of available resources in these essential new technologies.

In the political climate of the last two decades, however, it is probably appropriate to ask, "do the discussions of future large scale space activities have any actual relevance in the United States today?" This question is particularly topical in view of the very limited commitment to major space activities put forth in the recent congressional and presidential campaigns.

Positive indications of the relevance of discussions related to space are found in the interest and motivation of a core of a few tens of thousands of technical, scientific, and philosophical advocates, in the extraordinary qualitative support of the American people for the space program, and in the historical imperative space imposes on free men and women.

Polls and surveys indicate that 75% or more of the American people support a strong space program. 75% support for anything is almost beyond rational explanation. Space has the potential to excite and motivate almost anyone.

Even if this overwhelming qualitative support did not exist, the question would still have to be asked, "if the Americans do not insure that free institutions are established elsewhere in the solar system, who else will guarantee that they will be?" Further, "if the Americans do not insure the ultimate survival of the Earth's biosphere, who else will guarantee that survival?" These fundamental points have been missed in almost all political and technical debates on the future course of the U.S. space effort.

Unfortunately, the indications of a lack of current political relevance of any discussion about advanced space technology are staggering as any regular reader of Aviation Week and the Wall Street Journal will soon discover.

First, few candidates for political office feel any need to address civilian space activities as a significant philosophical, political, or environmental issue. Nor do they feel the need to address any of the broad spectrum of other critical issues of the future. The short term vested interests dominate their view because that is where elections and re-elections are won or lost.

Second, in spite of tentative commitments to it, the space station may lose its battle for domestic and international legitimacy -- on the one hand, the Administration has failed to make an unequivocal domestic political case for a U.S. managed space infrastructure and, on the other hand, the Soviets have a ten year lead in space station capability with the permanently occupied MIR station already in orbit.

Third, a U.S. heavy lift launch capability, critical to so many aspects of the future in space, does not exist. Again, the Soviets have a ten year lead in such capability which now includes an apparently competitive space shuttle.

Fourth, no significant resources are being allocated to recasting the free world's space agenda toward the settlement of Mars while, once again, the Soviets have at least a ten year lead in planning and developing such a capability.

Fifth, many national leaders are committed to severe limitation on the development of strategic defenses while the Soviets appear to be nearing a strategic defense breakout in ground based systems.

Sixth, our national leaders as well as the armed services have been unable to recognized the values of integrated manned and automated space based systems in tactical and strategic defense doctrines while the Soviets continue to develop and exercise their decades old commitment to an integrated Earth and space military doctrine. As the CINCSPACE, General Piotrowski, has said recently, the Soviets can rapidly and effectively exercise control of space -- the U.S. cannot do so.

Seventh, no workable policy exists that would insure that the U.S. and its allies would have an assured supply of critical energy and materials and the related industrial base necessary to sustain either long term space activities or near term defense and economic activities (Mott Committee, 1988). Indeed, no national leader appears to recognize that this is even an issue, witness the limited factual basis for proposals related to southern Africa.

Even this list does not tell the whole terribly sad story as many of you know better than I.

How did we fall so far from the dizzy heights of Apollo? 1970 was the fateful year history must mark as the year the nation's political leadership began to let our space momentum and maybe our national destiny slip away.

Ironically, the people of Apollo, in spite of their spectacular success in meeting President John Kennedy's challenge, "to put men on the moon and return them safely to Earth," had lost the media and political support necessary to build on their accomplishments.

Once Apollo missions began to be canceled and the industrial base to utilize the Apollo technology base started to be dismantled, the opportunity to lead humankind into space began to slip away. Even the reluctant decision by the Nixon Administration to build the Space Shuttle, and the equally reluctant decision by the Carter Administration to continue, were made out of context relative to any grand design for our future in space. The underfunding of the Shuttle development program, by at least a factor of three less than prudent estimates of the time, was the direct consequence of this hesitant and uncomprehending political environment. The seeds of the Challenger accident were sown by these events. Their tragic harvest sixteen years later is a stark indictment of all who let this drift in space policy begin and continue.

America, like Ebenezer Scrooge, still has time to change this spector of history yet to come. So, rather than conclude on the preceeding pessimistic recital of history and current reality, let me return to the areas of technological challenge before America and the possibilities for progress before the humankind by referring back to the hypothetical State of the Union Address.

> "Our Millennium Project combines space ventures to the Earth, moon, and Mars into a single great human mission -- a mission to save the atmosphere, waters, and rainforests of Earth, a mission to settle the moon and utilize it resources for the benefit of all, and a mission to establish human civilization and freedom permanently on Mars.
>
> "Our commitment to the success of The Millennium Project must be unequivocal. It must include an equally unequivocal commitment to carry the sacred institutions of freedom with us as humankind expands into its larger home among the planets and the stars."

References

Kulcinski, G.L., and Schmitt, H.H. (1987) The moon: An abundant source of clean and safe fusion fuel for the 21st Century, 11th Intl. Sci. Forum on Fueling the 21st Century, Oct. 1987, Moscow, USSR (UWFDM-730).

Mott Committee (1988) National Strategic Materials and Minerals Program Advisory Committee Report, Nov. 1988, Dept. Interior.

Wittenberg, L.J., Santarius, J.F., and Kulcinski, G.L. (1986) Lunar source of He-3 for commercial fusion power, Fusion Technology, v. 10, p. 167 (UWFDM-709).

See also:

Schmitt, H.H (1985) A Millennium Project -- Mars 2000, in W.W. Mendell, ed., Lunar Bases and Space Activities of the 21st Century, LPI, Houston, p. 787-794.

Schmitt, H.H (1986) INTERMARS: User-controlled international management system for missions to Mars, in Manned Mars Missions Working Group Papers, NASA M002, v. 2, June 1986.

Harrison H Schmitt

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BIOGRAPHICAL SKETCH

Harrison "Jack" Schmitt has the varied experience of a geologist, scientist, astronaut, pilot, administrator, educator, writer, and United States Senator.

He trained as a geologist and scientist at the California Institute of Technology, as a Fulbright Scholar at the University of Oslo, and at Harvard University, receiving his PH.D. in geology from Harvard in 1964 based on earlier field studies conducted in Norway.

He was selected for the Apollo Scientist-Astronaut program in 1965 and served as the Lunar Module Pilot for Apollo 17--the last Apollo mission to the Moon.

Schmitt's studies of the Valley of Taurus-Littrow on the Moon in 1972, as well as his earlier scientific work, made Schmitt one of the leading experts on the history of the terrestrial planets. As the only scientist to go to the Moon, he was also the last of twelve men to step on the Moon.

After organizing and directing the activities of the Scientist-Astronaut Office and of the Energy Program Office for NASA in 1973-1975, Schmitt fulfilled a long-standing commitment by entering politics. He was elected to the U.S. Senate from his home state of New Mexico in 1976.

In his last two years in the Senate, Senator Schmitt was Chairman of the Senate Commerce Committee's Subcommittee on Science, Technology, and Space and of the Senate Appropriations Committee's Subcommittee on Labor, Health and Human Services, and Education. He currently serves as a member of the Army Science Board and as consultant to the National Strategic Materials and Minerals Program Advisory Committee.

Harrison Schmitt is consulting, speaking, and writing on a wide range of business, foundation, and government initiatives. His principle activities are in the fields of technology, space, defense, biomedicine, geology, and policy issues of the future. He brings to the consideration of complex public and corporate concerns a unique breadth of experience ranging from the scientific to the practical and from the administrative to the political.

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CRITICAL IN-SPACE TECHNOLOGY NEEDS

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SPACE STRUCTURES
CRITICAL IN-SPACE TECHNOLOGY NEEDS

MARTIN MIKULAS, JR.
LANGLEY RESEARCH CENTER

CRITICAL IN-SPACE TECHNOLOGY NEEDS

SPACE STRUCTURES

THEME ELEMENT #1 : STRUCTURES

1. SYSTEM IDENTIFICATION
    - QUASI-STATIC
    - DYNAMIC
2. VERIFICATION OF PREDICTION METHODS
3. ERECTABLE STRUCTURES CONSTRUCTION
4. PRECISION SENSOR DEVELOPMENT
5. STRUCTURAL INTEGRITY

NOTE: IN PRIORITY ORDER, STARTING WITH 1 AS FIRST PRIORITY

CRITICAL IN-SPACE TECHNOLOGY NEEDS

SPACE STRUCTURES

THEME ELEMENTS #2 & 3 : CONTROL/STRUCTURE INTERACTION & CONTROLS (COMBINED)*

1. FLEXIBLE MULTI-BODY/ARTICULATED CONTROL
2. PRECISION POINTING AND SHAPE DIMENSIONAL CONTROL
3. MULTIPLE INTERACTING CONTROL SYSTEM
4. DAMPING AND VIBRATION SUPPRESSION
5. VIBRATION ISOLATION

*RECOMMENDATIONS: EXPERIMENTS SHOULD BE MULTIDICIPLINARY IN NATURE AND PREFERABLY IN THE FORM OF REUSABLE TEST BEDS..

NOTE: IN PRIORITY ORDER, STARTING WITH 1 AS FIRST PRIORITY

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SPACE ENVIRONMENTAL EFFECTS
CRITICAL IN-SPACE TECHNOLOGY NEEDS

LUBERT J. LEGER
JOHNSON SPACE CENTER

CRITICAL IN-SPACE TECHNOLOGY NEEDS

SPACE ENVIRONMENTAL EFFECTS

THEME ELEMENT #1 : ATMOSPHERIC EFFECTS AND CONTAMINATION

1. ACTIVE MEASUREMENT OF ATMOSPHERIC CONSTITUENTS SUCH AS ATOMIC OXYGEN, TO SUPPORT STUDIES OF ALL ATMOSPHERIC INTERACTION PHENOMENA
2. GLOW PHENOMENA INFORMATION TO SUPPORT SENSOR DESIGN
3. CONTAMINATION EFFECTS AND ATOMIC OXYGEN EROSION DATA FOR MATERIAL DURABILITY ASSESSMENT FUNCTIONAL PERFORMANCE PREDICTION AND MODEL DEVELOPMENT AND VERIFICATION

NOTE: IN PRIORITY ORDER, STARTING WITH 1 AS FIRST PRIORITY

CRITICAL IN-SPACE TECHNOLOGY NEEDS

SPACE ENVIRONMENTAL EFFECTS

THEME ELEMENT #2 : MICROMETEOROID AND DEBRIS

1. CHARACTERIZATION OF THE LOW EARTH ORBIT DEBRIS ENVIRONMENT
   - PARTICLE SIZE DISTRIBUTION
   - MORE INFORMATION ON DEBRIS CHARACTERISTICS - SPECTRAL PROPERTIES, SHAPE, COMPOSITION
2. LONG TERM SURFACE DEGRADATION FROM DEBRIS
3. DEVELOP AND VERIFY COLLISION WARNING SYSTEMS TECHNOLOGY
4. EVALUATE AND VERIFY MITIGATION TECHNIQUES

NOTE: IN PRIORITY ORDER, STARTING WITH 1 AS FIRST PRIORITY

CRITICAL IN-SPACE TECHNOLOGY NEEDS

SPACE ENVIRONMENTAL EFFECTS

THEME ELEMENT #3 : CHARGED PARTICLES & ELECTROMAGNETIC RADIATION EFFECTS

1. BETTER CHARACTERIZATION OF RADIATION ENVIRONMENT IN POLAR REGION AND VAN ALLEN RADIATION BELTS & ASSOCIATED WITH SOLAR FLARE ACTIVITY
2. LONG TERM, CONTINUOUS MEASUREMENTS OF MATERIAL PHYSICAL AND ELECTRICAL PROPERTIES IN CRITICAL ORBITS FOR UNDERSTANDING OF INTERACTION MECHANISM AND VALIDATION OF GROUND BASED TESTING
3. DETERMINE THE EFFECTS OF GAS RELEASES IN LEO ON ELECTROMAGNETIC INTERACTIONS
4. DEVELOPMENT OF SIMPLE SMALL AUTONOMOUS SENSORS FOR MEASUREMENT OF SURFACE CHARGING, RADIATION EXPOSURE AND ELECTRIC FIELDS

NOTE: IN PRIORITY ORDER, STARTING WITH 1 AS FIRST PRIORITY

POWER SYSTEMS AND THERMAL MANAGEMENT CRITICAL IN-SPACE TECHNOLOGY NEEDS

ROY McINTOSH
GODDARD SPACE FLIGHT CENTER

CRITICAL IN-SPACE TECHNOLOGY NEEDS

POWER SYSTEMS & THERMAL MANAGEMENT

THEME ELEMENT #1 : DYNAMIC AND NUCLEAR POWER SYSTEMS

1. GAS COLLECTION AND RETENTION IN LIQ COOLANTS
2. FREEZE/THAW IN LIQ METAL SYSTEMS
3. GAS BUBBLE NUCLEATION/GROWTH IN LIQ METALS
4. TWO COMPONENT (SOLID/LIQUID) PUMPING/SEPARATION
5. TWO PHASE LIQ/GAS SEPARATION IN COOLANTS

NOTE: IN PRIORITY ORDER, STARTING WITH 1 AS FIRST PRIORITY

CRITICAL IN-SPACE TECHNOLOGY NEEDS

POWER SYSTEMS & THERMAL MANAGEMENT

THEME ELEMENT #2 : CONVENTIONAL POWER SYSTEMS

1. ADVANCED ENERGY STORAGE
2. ADVANCED P.V. CELL TECHNOLOGY
3. PRIMARY & REGENERATIVE FUEL CELLS
4. THERMAL ENERGY STORAGE
5. CONTAMINATION, UV & CHARGED PARTICLE PV EFFECTS

NOTE: IN PRIORITY ORDER, STARTING WITH 1 AS FIRST PRIORITY

CRITICAL IN-SPACE TECHNOLOGY NEEDS

POWER SYSTEMS & THERMAL MANAGEMENT

THEME ELEMENT #3 : THERMAL MANAGEMENT

1. TWO-PHASE HEAT TRANSFER
2. HEAT PIPES (LIQUID METAL & CRYO)
3. CAPILLARY LOOPS
4. TWO-PHASE FLOW & STABILITY
5. VOID BEHAVIOR FLIGHT TEST

NOTE: IN PRIORITY ORDER, STARTING WITH 1 AS FIRST PRIORITY

FLUID MANAGEMENT & PROPULSION SYSTEMS
CRITICAL IN-SPACE TECHNOLOGY NEEDS

LYNN ANDERSON
LEWIS RESEARCH CENTER

CRITICAL IN-SPACE TECHNOLOGY NEEDS

FLUID MANAGEMENT & PROPULSION SYSTEMS

THEME ELEMENT #1 : ON-ORBIT FLUID MANAGEMENT

1. FLUID TRANSFER
2. MASS GAUGING
3. THERMODYNAMIC VENT SYSTEM/MIXING
3. LIQUID ACQUISITION DEVICES
3. FLUID DUMPING/TANK INERTING
4. LIQUID DYNAMICS/SLOSH
5. AUTOGENOUS PRESSURIZATION
5. LONG TERM STORAGE

NOTE: IN PRIORITY ORDER, STARTING WITH 1 AS FIRST PRIORITY

CRITICAL IN-SPACE TECHNOLOGY NEEDS

FLUID MANAGEMENT & PROPULSION SYSTEMS

THEME ELEMENT #2 : PROPULSION

1. PLUME IMPACTS & CHARACTERISTICS
2. ELECTRIC PROPULSION SPACE TEST
3. MULTIDISCIPLINE SPACE TEST BED

NOTE: IN PRIORITY ORDER, STARTING WITH 1 AS FIRST PRIORITY

CRITICAL IN-SPACE TECHNOLOGY NEEDS

FLUID MANAGEMENT & PROPULSION SYSTEMS

THEME ELEMENT #3 : FLUID PHYSICS

1. LIQUID-VAPOR INTERFACES
2. POOL/FLOW BOILING
2. CONDENSATION/EVAPORATION
3. ADVANCING LIQUID FRONTS
3. BUBBLE/DROPLET DYNAMICS

NOTE: IN PRIORITY ORDER, STARTING WITH 1 AS FIRST PRIORITY

AUTOMATION AND ROBOTICS CRITICAL IN-SPACE TECHNOLOGY NEEDS

ANTAL K. BEJCZY
JET PROPULSION LABORATORY

CRITICAL IN-SPACE TECHNOLOGY NEEDS

AUTOMATION & ROBOTICS

THEME ELEMENT #1 : ROBTIC SYSTEMS

1. ACTIVE/PASSIVE COMPLIANCE CONTROL AND PRECISION CONTROL IN SMART END EFFECTOR-TOOL-OBJECT INTERACTION
2. DISTURBANCE REJECTION AND STABILIZATION IN ROBOT/PLATFORM COUPLING DYNAMICS
3. SENSOR-CORRECTED PLANNED MOTION EXECUTION, INCLUDING COLLISION DETECTION AND AVOIDANCE
4. ADAPTIVE CONTROL COORDINATION OF MULTIPLE ARM/END EFFECTOR SYSTEMS
5. FAST, HIGH BANDWIDTH AND SMALL-VOLUME CONTROL AND DATA PROCESSING ELECTRONICS

NOTE: IN PRIORITY ORDER, STARTING WITH 1 AS FIRST PRIORITY

CRITICAL IN-SPACE TECHNOLOGY NEEDS

AUTOMATION & ROBOTICS

THEME ELEMENT #2 : TELEOPERATIONS

1. OPERATOR INTERACTION IN MICRO-G WITH FORCE-REFLECTING CONTROL
2. CONTROL TECHNIQUES FOR COMMUNICATION TIME DELAY CONDITIONS
3. OPERATOR MULTI-MODE MANUAL AND SUPERVISORY CONTROL INTERACTION WITH REMOTE MANIPULATORS
4. INTELLIGENT INFORMATION FUSION DISPLAY SYSTEMS
5. OPERATOR PERCEPTIVE/COMMAND INTERACTION WITH HIGH DEGREE-OF-FREEDOM ARM/END EFFECTOR SYSTEMS

NOTE: IN PRIORITY ORDER, STARTING WITH 1 AS FIRST PRIORITY

CRITICAL IN-SPACE TECHNOLOGY NEEDS

AUTOMATION & ROBOTICS

THEME ELEMENT #3 : ARTIFICIAL INTELLIGENCE

1. FAULT DETECTION AND PROCESSING SYSTEMS
2. LARGE INPUT/OUTPUT SENSOR AND SENSOR FUSION SYSTEMS
3. INTEGRATED MODEL AND DATA SENSING INFORMATION SYSTEMS
4. CONTINGENCY MANAGEMENT SYSTEMS
5. PARALLEL, INTEGRATED SYMBOLIC AND NUMERIC DATA PROCESSING AND INTELLIGENT OPERATING SYSTEMS

NOTE: IN PRIORITY ORDER, STARTING WITH 1 AS FIRST PRIORITY

SENSORS AND INFORMATION SYSTEMS CRITICAL IN-SPACE TECHNOLOGY NEEDS

MARTIN M. SOKOLOSKI
NASA HEADQUARTERS
and
JOHN DALTON
GODDARD SPACE FLIGHT CENTER

CRITICAL IN-SPACE TECHNOLOGY NEEDS

SENSORS & INFORMATION SYSTEMS

THEME ELEMENT #1 : SENSORS

1. SPACE QUALIFIED COOLER AND COOLER SYSTEMS
2. IN-SPACE POINTING AND CONTROL

NOTE: IN PRIORITY ORDER, STARTING WITH 1 AS FIRST PRIORITY

CRITICAL IN-SPACE TECHNOLOGY NEEDS

SENSORS & INFORMATION SYSTEMS

THEME ELEMENT #2 : COMMUNICATIONS

1. IN-SPACE LASER COMMUNICATIONS TECHNOLOGY DEMO.

NOTE: IN PRIORITY ORDER, STARTING WITH 1 AS FIRST PRIORITY

CRITICAL IN-SPACE TECHNOLOGY NEEDS

SENSORS & INFORMATION SYSTEMS

THEME ELEMENT #3 : INFORMATION SYSTEMS

1. IN-SPACE TESTING/DEMONSTRATION OF HIGHER PERFORMANCE COMPUTERS FOR AUTOMATED OPERATIONS AND ROBOTICS APPLICATIONS
2. IN-SPACE TESTING/DEMONSTRATION OF SPECIAL PURPOSE PROCESSORS (e.g., FROM THE CSTI HIGH RATE DATA SYSTEMS PROGRAM) FOR IMAGE COMPRESSION/ PROCESSING FOR SCIENCE EXPERIMENTS AND ROBOTICS APPLICATIONS
3. IN-SPACE TESTING OF HIGH RATE/VOLUME STORAGE DEVICES FOR IMAGE DATA PROCESSING AND COMMUNICATION LINK BUFFERING
4. IN-SPACE TESTING AND CHARACTERIZATION OF RADIATION EFFECTS OF NEXT GENERATION COMMERCIAL AND RADIATION HARDENED DEVICES IN VARIOUS ORBTS FOR GENERAL SPACECRAFT AND INSTRUMENT APPLICATIONS

NOTE: IN PRIORITY ORDER, STARTING WITH 1 AS FIRST PRIORITY

IN-SPACE SYSTEMS
CRITICAL IN-SPACE TECHNOLOGY NEEDS

JON B. HAUSSLER
MARSHALL SPACE FLIGHT CENTER

CRITICAL IN-SPACE TECHNOLOGY NEEDS

IN-SPACE SYSTEMS

THEME ELEMENT #1 : MATERIALS PROCESSING

1. UNDERSTANDING OF MATERIALS BEHAVIOR IN SPACE ENVIRONMENT
2. DEMONSTRATION OF INNOVATIVE IN-SPACE SAMPLE ANALYSIS TECHNIQUES
2. CHARACTERIZATION AND MANAGEMENT OF THE MICRO-G ENVIRONMENT
3. DEMONSTRATION OF IMPROVED SENSING AND IMAGING TECHNIQUES IN EXPERIMENTAL SYSTEMS
4. DEMONSTRATION OF AUTOMATION AND ROBOTICS APPLICATIONS TO MATERIAL PROCESSING SYSTEMS

NOTE: IN PRIORITY ORDER, STARTING WITH 1 AS FIRST PRIORITY

CRITICAL IN-SPACE TECHNOLOGY NEEDS

IN-SPACE SYSTEMS

THEME ELEMENT #2 : MAINTENANCE, REPAIR, AND FIRE SAFETY

1. DEMONSTRATION AND VALIDATION OF CAPABILITY TO REPAIR UNEXPECTED EVENTS
1. INVESTIGATION OF LOW-G IGNITION, FLAMMABILITY/FLAME SPREAD AND FLAME CHARACTERISTICS
2. DEMONSTRATION AND VALIDATION OF FLUID REPLENISHMENT TECHNIQUES
2. UNDERSTAND BEHAVIOR OF FLAME EXTINQUISHANTS IN SPACE ENVIRONMENT
3. DEMONSTRATE ROBOTIC MAINTENANCE AND REPAIR CAPABILITY

NOTE: IN PRIORITY ORDER, STARTING WITH 1 AS FIRST PRIORITY

CRITICAL IN-SPACE TECHNOLOGY NEEDS

IN-SPACE SYSTEMS

THEME ELEMENT #3 : PAYLOAD OPERATIONS

1. DEMONSTRATION AND VALIDATION OF TELESCIENCE TECHNIQUES
2. DEMONSTRATION OF AUTONOMOUS CHECKOUT, PLACEMENT AND SPACE CONSTRUCTION

NOTE: IN PRIORITY ORDER, STARTING WITH 1 AS FIRST PRIORITY

HUMANS IN SPACE
CRITICAL IN-SPACE TECHNOLOGY NEEDS

REMUS BRETOI
AMES RESEARCH CENTER

CRITICAL IN-SPACE TECHNOLOGY NEEDS

HUMANS IN SPACE

THEME ELEMENT #1 : EVA / SUIT

1. TECHNOLOGY FOR MEASUREMENT OF EVA FORCES, MOMENTS, DYNAMICS, PHYSIOLOGICAL WORKLOAD, THERMAL LOADS, AND MUSCULAR FATIGUE
2. EVALUATION OF COOPERATIVE ROLES BETWEEN EVA AND TELEROBOTS AND FOR IVA AND ROBOTICS
3. SUIT CONTAMINANTS DETECTION, IDENTIFICATION AND REMOVAL

NOTE: IN PRIORITY ORDER, STARTING WITH 1 AS FIRST PRIORITY

CRITICAL IN-SPACE TECHNOLOGY NEEDS

HUMANS IN SPACE

THEME ELEMENT #2 : HUMAN PERFORMANCE

1. TECHNOLOGY AND MEASUREMENT OF GRAVITY-RELATED ADAPTATION AND RE-ADAPTATION BEHAVIOR
2. TECHNOLOGY FOR IN-SPACE ANTHROPOMETRIC AND PERFORMANCE MEASUREMENT
3. VARIABLE-GRAVITY FACILITY AND APPLICATION TECHNOLOGY

NOTE: IN PRIORITY ORDER, STARTING WITH 1 AS FIRST PRIORITY

CRITICAL IN-SPACE TECHNOLOGY NEEDS

HUMANS IN SPACE

THEME ELEMENT #3 : CLOSED-LOOP LIFE SUPPORT

1. IMPROVED PHASE SEPARATION SYSTEMS
2. GRAVITY-INDEPENDENT SENSOR SYSTEMS
3. WASTE-CONVERSION PROCESSES

NOTE: IN PRIORITY ORDER, STARTING WITH 1 AS FIRST PRIORITY

APPENDICES

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APPENDIX A

FINAL WORKSHOP AGENDA

December 6, 1988

PROGRAM OVERVIEW

• Welcome and Workshop Objectives	NASA OAST
• In-Space Technology Experiments in NASA's Strategic Planning	NASA OAST
• In-Space Technology Experiments Program	NASA OAST
• Space Station Freedom User/Payload Integration and Accommodations	NASA OSS

REVIEW OF CURRENT IN-REACH AND OUT-REACH EXPERIMENTS

SPACE STRUCTURES

• In-Space Structural Dynamics Evaluation of a Skewed Scale Truss	McDonnell Douglas
• Middeck 0-Gravity Dynamics Experiment (MODE)	MIT
• Measurement and Modeling of Joint Damping in Space Structures	Utah State University
• Payload Vibration Isolation in Microgravity Environment	Texas A&M University
• Generic Pointing Mount	Allied/Signal Aerospace
• Space Station Structural Characterization Experiment	NASA Langley
• Inflatable Solar Concentrator Experiment	L'Garde, Inc.

SPACE ENVIRONMENTAL EFFECTS

• Measurement of Surface Reactions in the Space Environment	Globesat, Inc.
• Optical Properties Monitor (OPM) Experiment	John M. Cockerham & Associates
• Experimental Investigation of Spacecraft Glow	Lockheed
• Return Flux Experiment (REFLEX)	NASA Goddard
• Debris Collision Warning Sensors	NASA Johnson
• Thin Foil X-Ray Optics Space Environment Contamination Experiment	NASA Goddard

POWER SYSTEMS AND THERMAL MANAGEMENT

• Sodium-Sulfur Battery Flight Experiment	Ford Aerospace
• Unitized Regenerative Fuel Cell	United Technologies
• Thermal Energy Storage Flight Experiments for Solar Dynamics Power Systems	NASA Lewis/Boeing Aerospace
• Investigation of Micro-Gravity Effects on Heat Pipe Thermal Performance and Working Fluid Behavior	Hughes Aircraft

A High-Efficiency Thermal Interface (Using Condensation Heat Transfer) Between a Two-Phase Fluid Loop and a Heat Pipe Radiator	TRW
Moving Belt Radiator Dynamics	Arthur D. Little
Liquid Droplet Radiator	Grumman

FLUID MANAGEMENT AND PROPULSION SYSTEMS

Tank Pressure Control Experiment	Boeing Aerospace
Integrated Cryogenic Experiment (ICE) Microsphere Insulation Investigation	Lockheed
Liquid Motion in a Rotating Tank	Southwest Research Institute
Thermoacoustic Convection Heat Transfer	University of Tennessee

AUTOMATION AND ROBOTICS

Research and Design of Manipulator Flight Testbeds	Martin Marietta
Control of Flexible Robot Manipulators in Zero Gravity	Utah State University
Jitter Suppression for Precision Space Structures	McDonnell Douglas
Passive Damping Augmentation for Space Applications	Old Dominion University

SENSORS AND INFORMATION SYSTEMS

Development of Emulsion Chamber Technology	University of Alabama in Huntsville
Infrared Focal Plane Performance in the South Atlantic Anomaly	Lockheed
Construction and In-Space Performance Evaluation of High Stability Hydrogen Maser Clocks	Smithsonian Astrophysical Observ.
Acceleration Measurement and Management	University of Alabama in Huntsville
Dynamic Spacecraft Attitude Determination with GPS	Mayflower Communications
Stanford University NASA In-Space Technology Experiment (SUNLITE)	NASA Langley

IN-SPACE SYSTEMS

Definition of Experiments to Investigate Fire Suppressants in Microgravity	Battelle
Risk-Based Fire Safety Experiment Definition	UCLA
Plasma Arc Welding in Space	University of California (Berkeley)
Extra-Vehicular Activity Welding Experiment	Rocketdyne
On-Orbit Electron Beam Welding Experiment	Martin Marietta
Laser Welding in Space	University of Alabama in Huntsville
Liquid Encapsulated Float Zone Refining of Gallium Arsenide	McDonnell Douglas
Vapor Crystal Growth Technology	University of Alabama in Huntsville

HUMANS IN SPACE

• Enhancement of In-Space Operations Using Spatial Perception Auditory Referencing (SPAR)	University of California (Irvine)
• Definition of a Microbiological Monitor for Application in Space Vehicles	University of Alabama in Huntsville
• Design of a Closed Loop Nutrient Solution Delivery System for CELSS (Controlled Ecological Life Support Systems) Application	Lockheed
• Impact of Low Gravity on Water Electrolysis Operation	Life Systems

December 7, 1988

THEME REVIEWS (Government, Industry and University Perspectives)

SPACE STRUCTURES

STRUCTURES

- Air Force Wright Aeronautical Lab
- Boeing Aerospace Company
- University of Colorado

CONTROL/STRUCTURE INTERACTION

- NASA Langley Research Center
- TRW Space & Technology Group
- Massachusetts Institute of Technology

CONTROLS

- NASA Marshall Space Flight Center
- Boeing Aerospace Company
- Purdue University

SPACE ENVIRONMENTAL EFFECTS

ATMOSPHERIC EFFECTS AND CONTAMINATION

- NASA Lewis Research Center
- Martin Marietta Astronautics Group
- University of Alabama in Huntsville

MICROMETEROIDS AND DEBRIS

- NASA Johnson Space Center
- McDonnell Douglas Astronautics Company
- University of Colorado

CHARGED PARTICLES AND ELECTROMAGNETIC RADIATION EFFECTS

- NASA Langley Research Center
- Jet Propulsion Laboratory
- Jet Propulsion Laboratory

POWER SYSTEMS AND THERMAL MANAGEMENT

DYNAMIC AND NUCLEAR POWER SYSTEMS

- NASA Lewis Research Center
- GE Astro Space Division
- University of New Mexico

CONVENTIONAL POWER SYSTEMS

- NASA Lewis Research Center
- GE Astro Space Division
- Auburn University

THERMAL MANAGEMENT

- Air Force Wright Aeronautical Lab
- Boeing Aerospace Company
- University of Houston

FLUID MANAGEMENT AND PROPULSION SYSTEMS

ON-ORBIT FLUID MANAGEMENT

- NASA Lewis Research Center
- General Dynamics Space Systems Division

PROPULSION

- NASA Headquarters
- Jet Propulsion Laboratory
- Pennsylvania State University

FLUID PHYSICS

- NASA Lewis Research Center
- Southwest Research Institute
- University of Houston

AUTOMATION AND ROBOTICS

ROBOTIC SYSTEMS

- NASA Langley Research Center
- Martin Marietta Space Systems Company
- University of Texas at Austin

TELEOPERATIONS

- NASA Johnson Space Center
- GE Aerospace
- Massachusetts Institute of Technology

ARTIFICIAL INTELLIGENCE

- NASA Ames Research Center
- ISX Corporation
- Stanford University

SENSORS AND INFORMATION SYSTEMS

SENSORS

- NASA Headquarters
- Hughes Aircraft Company
- University of South Florida

COMMUNICATIONS

- NASA Headquarters
- Laser Data Technology, Inc.
- Massachusetts Institute of Technology

INFORMATION SYSTEMS
- NASA Goddard Space Flight Center
- IBM
- University of Colorado

IN-SPACE SYSTEMS

MATERIALS PROCESSING
- NASA Headquarters
- Rockwell International Science Center
- University of Arizona

MAINTENANCE, REPAIR, AND FIRE SAFETY
- NASA Goddard Space Flight Center
- Wyle Laboratories
- McDonnell Douglas Space Systems Company

PAYLOAD OPERATIONS
- NASA Johnson Space Center
- Lockheed Missiles and Space Company
- University of Colorado

HUMANS IN SPACE

EVA/SUIT
- NASA Ames Research Center
- Lockheed Missiles and Space Company
- Massachusetts Institute of Technology

HUMAN PERFORMANCE
- NASA Ames Research Center
- NASA Ames Research Center
- University of Arizona

CLOSED LOOP LIFE SUPPORT SYSTEMS
- NASA Ames Research Center
- Boeing Aerospace Company
- University of Colorado

BANQUET

• Keynote Address	Harrison H. Schmitt

December 8, 1988

THEME SUMMARY DISCUSSIONS

• Space Structures	NASA Langley
• Space Environmental Effects	NASA Johnson
• Power Systems and Thermal Management	NASA Goddard
• Fluid Management and Propulsion Systems	NASA Lewis
• Automation and Robotics	Jet Propulsion Lab
• Sensors and Information Systems	NASA Headquarters/ NASA Goddard

In-Space Systems	NASA Marshall
Humans In Space	NASA Ames

EXPERIMENT INTEGRATION PROCESS

Payload Integration Overview	NASA Goddard
Space Shuttle Systems Integration Process	NASA Johnson
Complex Autonomous Payload Carriers	NASA Goddard
Hitchhiker Project Overview	NASA Goddard
Middeck Payload Integration	NASA Johnson
KSC Payload Integration Process	NASA Kennedy

December 9, 1988

CRITICAL TECHNOLOGY REQUIREMENTS

Space Structures	NASA Langley
Space Environmental Effects	NASA Johnson
Power Systems and Thermal Management	NASA Goddard
Fluid Management and Propulsion Systems	NASA Lewis
Automation and Robotics	Jet Propulsion Lab
Sensors and Information Systems	NASA Headquarters/ NASA Goddard
In-Space Systems	NASA Marshall
Humans In Space	NASA Ames

CONCLUDING REMARKS	NASA OAST

APPENDIX B - IN-STEP '88 ATTENDEES

Julio Acevedo
NASA Lewis Research Center

David Akin
Massachusetts Institute of Technology

Thomas Alberts
Old Dominion University

Harold Alsberg
OAO Corporation

Lynn Anderson
NASA Lewis Research Center

Basil Antar
University of Tennessee Space Institute

Foster Anthony
NASA Marshall Space Flight Center

George Apostolakis
University of California, L. A.

J. Armijo
General Electric Astro Space

Raymond Askew
Auburn University Space Power Institute

Frank Austin
NASA Headquarters

Don Avery
NASA Langley Research Center

John Aydelott
NASA Lewis Research Center

Henry Babel
McDonnell Douglas Astronautics Company

Michael Badgley
Teledyne Brown Engineering

Richard Baldwin
NASA Lewis Research Center

Bruce Banks
NASA Lewis Research Center

C. Bankston
Jet Propulsion Laboratory

Mark Banyai
Dynamics Research Corporation

William Baracat
General Research Corporation

Lyle Bareiss
Martin Marietta Astronautics

Edward Barocela
McDonnell Douglas Corporation

Algerd Basiulis
Hughes Aircraft Company

Sherwin Beck
NASA Langley Research Center

Albert Behrend
NASA Johnson Space Center

Antal Bejczy
Jet Propulsion Laboratory

Michael Bentz
Boeing Aerospace Company

Jan Bijvoet
University of Alabama in Huntsville

James Blackmon
McDonnell Douglas Astronautics Company

J. Blair
SCI Systems International

Robert Blakely
Boeing Aerospace Company

Robert Blanks
University of California, Irvine

Cliff Boehmer
McDonnell Douglas Corporation

Robert Bosley
Allied Signal Aerospace Company

Jim Boyd
Harris Corporation

Richard Boykin
NASA Langley Research Center

L. Braun
McDonnell Douglas Corporation

Roger Breckenridge
NASA Langley Research Center

Patrick Brennan
OAO Corporation

Remus Bretoi
NASA Ames Research Center

Jeri Brown
NASA Johnson Space Center

Wayne Bryant
NASA Langley Research Center

Edward Bucher
Massachusetts Institute of Technology Lincoln Labs

John Buckley
NASA Langley Research Center

David Byers
NASA Lewis Research Center

James Cake
NASA Lewis Research Center

Robert Cannon
Stanford University

Paolo Carosso
TS Infosystems, Inc.

Manley Carter
NASA Johnson Space Center

Joseph Casas
SpaceTec Ventures, Inc.

Michael Cassidy
Hughes Aircraft Company

Douglas Chalmers
General Electric Astro Space

Vincent Chan
Massachusetts Institute of Technology Lincoln Labs

Rebecca Chang
Ford Aerospace Corporation

Thomas Charlton
E G & G Idaho, Inc.

C. Chen
NASA Headquarters

Steve Chinn
Science & Engineering Associates, Inc.

Edgar Choueiri
Princeton University

Christopher Chow
Space Research & Applications Laboratory

Louis Chow
University of Kentucky

J. Chung
Washington State University

Lenwood Clark
NASA Langley Research Center

Bernard Cohlan
Consultant in Physics & Engineering

Lisa Collier
Computer Technology Associates, Inc.

Frank Collins
University of Tennessee Space Institute

David Cooper
NASA Ames Research Center

Duncan Cox
Mayflower Communications Company, Inc.

Scott Crocker
University of Tennessee

Robert Crull
Teledyne Brown Engineering

Earle Crum
NASA Johnson Space Center

Ronald Cull
NASA Lewis Research Center

H. Cullingford
NASA Johnson Space Center

Robert Culp
University of Colorado, Boulder

John Dalton
NASA Goddard Space Flight Center

Alan Darby
Rockwell International

Keith Davis
Allied Signal Aerospace Company

Gordon Davison
Boeing Aerospace Company

Dan DeLong
Teledyne Brown Engineering

Michael Dean
Ball Aerospace Systems

Rudolf Decher
NASA Marshall Space Flight Center

Gerard Delaney
McDonnell Douglas Corporation

Robert Dellacamera
McDonnell Douglas Space Systems Company

Lamont Di Biasi
Fairchild Space Company

Jacob Dickinson
McDonnell Douglas Corporation

Tony Docal
Space Studies Institute

Franklin Dodge
Southwest Research Institute

Thomas Dollman
NASA Marshall Space Flight Center

Frank Donivan
Jet Propulsion Laboratory

Steven Donley
The Perkin Elmer Corporation

Joseph Dubel
Sparta Inc.

Joseph Duffy
University of Florida

A. Dukler
University of Houston

Walter Duval
NASA Lewis Research Center

Mohamed El-Genk
University of New Mexico

Stephen Ellis
NASA Ames Research Center

Emily Evans
NASA Langley Research Center

Jack Faber
University of Colorado, Boulder

Edward Falkenhayn
NASA Goddard Space Flight Center

G. Farbman
Westinghouse

Ken Farnell
Teledyne Brown Engineering

Ed Fay
Sverdrup Technology Inc.

Karl Faymon
NASA Lewis Research Center

William Ferrell
University of Arizona

Dale Fester
Martin Marietta Aerospace

H. Fisher
Lockheed Missiles & Space Co., Inc.

Mike Fitzmaurice
NASA Goddard Space Flight Center

Chris Flanigan
SDRC

George Fleischman
Hughes Aircraft Company

Steven Folkman
Utah State University

Anthony Fontana
NASA Langley Research Center

Thomas Foster
Boeing Aerospace Company

James Fox
KMS Fusion, Inc.

Robert Friedman
NASA Lewis Research Center

Edward Gabris
NASA Headquarters

Joe Galliano
Georgia Tech Research Institute

Mukund Gangal
Jet Propulsion Laboratory

Frank Garcia
IBM

William Gardiner
Analytech

Henry Garrett
Jet Propulsion Laboratory

L. Garrett
NASA Langley Research Center

Richard Gates
Boeing Aerospace Company

Carl Gerhold
Texas A&M University

Elzie Gerrels
General Electric Aerospace

Keith Gier
Hughes Aircraft Company

Michael Giesselmann
Texas Tech University

D. Gilluley
AAI Corporation

Rafael Gluck
TRW Space & Technology Group

Linda Godwin
NASA Johnson Space Center

T. Goldsmith
NASA Goddard Space Flight Center

Bruce Goldwater
Mechanical Technology, Inc.

William Grantham
NASA Langley Research Center

John Gregory
University of Alabama in Huntsville

W. Griffiths
Foster-Miller, Inc.

John Haggard
NASA Lewis Research Center

Blake Hannaford
Jet Propulsion Laboratory

Paul Harris
Rocketdyne

Sam Harris
Odetics, Inc.

Leonard Harris
NASA Headquarters

A. Hashemi
Lockheed Missiles & Space Co., Inc.

Leon Hastings
NASA Marshall Space Flight Center

Philip Hattis
C. S. Draper Laboratory

Jonathan Haussler
NASA Marshall Space Flight Center

Chris Hawkins
NASA Johnson Space Center

Robert Hayduk
NASA Langley Research Center

Russell Haynal
Grumman Space Station Program Support

E. Heer
Heer Associates

Barbara Heizer
Boeing Aerospace Company

Keith Henderson
NASA Johnson Space Center

Richard Higgins
U. S. Air Force Space Technology Center

Wayne Hill
Foster-Miller, Inc.

E. Hinkley
Hughes Aircraft Company

Irving Hirsch
Boeing Aerospace Company

Murray Hirschbein
NASA Headquarters

Jeffrey Hoffman
NASA Johnson Space Center

Jaak Holemans
Wyle Laboratories, PSC

Alan Holt
NASA Headquarters

William Hong
W. J. Schafer Associates, Inc.

William Hooper
Martin Marietta

William Howard
Grumman Space Systems

G. Hubbard
NASA Ames Research Center

Leigh Hummer
John M. Cockerham & Associates

J. Hundley
IBM

David Hunt
SDRC

Vinod Jalan
Electrochem, Inc.

Lyle Jenkins
NASA Johnson Space Center

Gary Johnsen
Idaho National Engineering Laboratory

Bradley Johnson
Computer Technology Associates, Inc.

Philip Johnson
Planning Research Corporation

Robert Johnson
Martin Marietta Manned Space Systems

James Johnson
NASA Langley Research Center

Joie Jones
University of California, Irvine

Peggy Jones
Fairchild Space Company

Frank Junga
Lockheed Palo Alto Research Laboratory

Barbara Kanki
NASA Ames Research Center

William Kaukler
University of Alabama in Huntsville

Massoud Kaviany
University of Michigan

James Kelley
Jet Propulsion Laboratory

Gary Ketner
Battelle NW Laboratory

Denney Keys
Ford Aerospace Corporation

Soheil Khajenoori
University of Central Florida

Taras Kiceniuk
Jet Propulsion Laboratory

Melvin Kilgore
University of Alabama in Huntsville

Dennis Killinger
University of South Florida

Richard Knoll
NASA Lewis Research Center

Ted Kramer
Boeing Aerospace Company

Charles Kubokawa
NASA Ames Research Center

C. Land
NASA Johnson Space Center

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