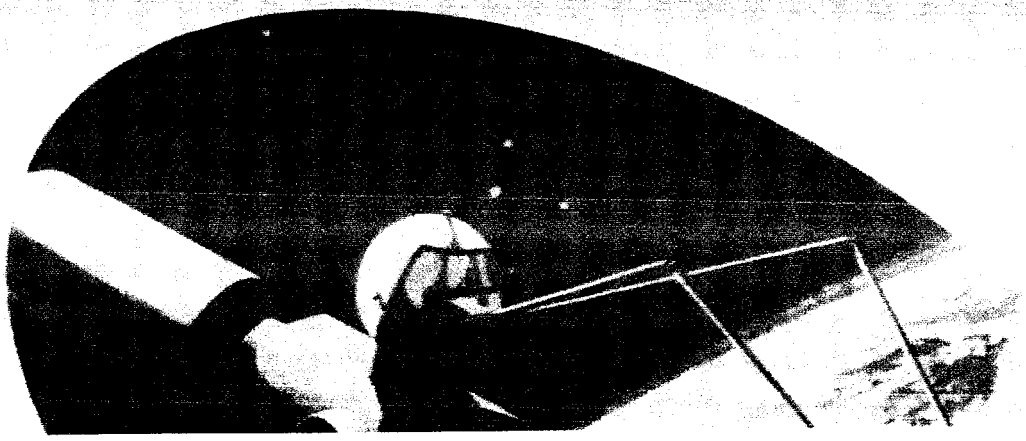
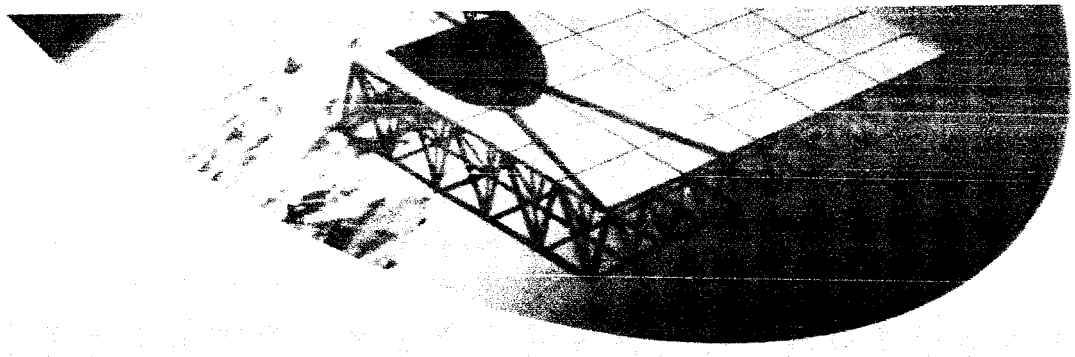
IN-SPACE RESEARCH, TECHNOLOGY AND ENGINEERING (RT&E) WORKSHOP

VOLUME 5 OF 8

ENERGY SYSTEMS AND THERMAL MANAGEMENT





NATIONAL CONFERENCE CENTER
WILLIAMSBURG, VIRGINIA
OCTOBER 8-10, 1985

NASA
National Aeronautics and Space Administration

Langley Research Center
Hampton, Virginia 23665

OAST
Office of Aeronautics and Space Technology
Washington, DC

NOTICE

The results of the OAST Research, Technology, and Engineering Workshop which was held at the National Conference Center, Williamsburg, Virginia, October 8-10, 1985 are contained in the following reports:

VOL 1	Executive Summary
VOL 2	Space Structure (Dynamics and Control)
VOL 3	Fluid Management
VOL 4	Space Environmental Effects
VOL 5	Energy Systems and Thermal Management
VOL 6	Information Systems
VOL 7	Automation and Robotics
VOL 8	In-Space Operations

Copies of these reports may be obtained by contacting:

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ENERGY SYSTEMS AND THERMAL MANAGEMENT

TABLE OF CONTENTS

PAGE

FOREWORD 1

INTRODUCTION 2

WORKSHOP THEME 3

SUMMARY AND CONCLUSIONS 4

PANEL SUMMARY

Energy Systems and Thermal Management 8
Earl VanLandingham

THEME PRESENTATION MATERIAL

Advanced Power System Thermal Energy Storage 17
Ted Mroz (LeRC)

Thermal Management 22
Richard Vernon (LeRC)

Advanced Radiator Concepts 26
Alden Presler (LeRC)

Large Photovoltaic Power System Demonstration 31
Sue Benford (LeRC)

Deploy and Test a Large Solar Concentrator 35
Ed Conway (LaRC)

Test Solar-Pumped Lasers 40
Ed Conway (LaRC)

Laser-to-Electric Energy Conversion 44
Ed Conway (LaRC)

Solar Array/Energy Storage Technology 48
Gordon Bakken (Wyle/MSFC)

Megawatt Power Management 51
Robert Bercaw (LeRC)

Direct Solar Thermal Furnace Technology 56
Sue Benford (LeRC)

PAGE

Solar Dynamic Test Facility 60
Ted Mroz (LeRC)

Radiator Technology 64
Gordon Bakken (Wyle/MSFC)

Thermal Interface Technology 65
Don Waltz (TRW), Robert Middleton (MSFC)

Nuclear Pumped Lasers 66
George H. Miley (University of Illinois)

Solar Array Blanket Zero-G Foldup Experiment 70
Richard V. Elms (LMSC)

Tethered Electrodynamic Power Generation 74
Robert Middleton, Georg von Tiesenhausen (MSFC)

Thermal Energy Storage for Solar Dynamic Power Generation System 75
Timothy J. Bland (Sunstrand)

FOREWORD

Within NASA, the Office of Aeronautics and Space Technology (OAST) has the responsibility for timely development of needed new technologies. Traditionally, the development of new concepts, new materials, designs, and engineering techniques for aeronautics has been accomplished in close cooperation with the aircraft industry and with the great American universities. On the other hand, NASA, as the primary user of space flight, has been its own principal customer for new space technologies.

A new era of permanent presence in space is beginning with the Space Station. This permanent presence will permit and promote commercial ventures and privately funded research in the tradition of university/industry cooperation.

The RT&E workshop in Williamsburg represents a significant milestone for NASA and the space engineering community. It marked the initiation of a long-term program of outreach by NASA to focus the needs of universities, industry, and government for in-space experiments and to begin building a strong national user constituency for space research and engineering.

These proceedings represent a "first-cut" planning activity to involve universities, industry, and other government agencies with NASA to establish structure and content for a national in-space RT&E program. More interactions are needed - more workshops will follow. Program adjustments will be made. A truly national program will evolve, and its beginnings are presented here with the hope and determination needed to make it a program we can all take pride in.

- Raymond Colladay

INTRODUCTION

Among the purposes of the Research, Engineering, and Technology Workshop, an interest in validating the RT&E theme concept has some direct effect on the form of these proceedings. The original five themes, which were themselves a target for validation or recommeded changes, have become seven. During preparations for the workshop, the submitted papers and attendance plans made it evident that the fifth "theme", In-space Operations, was too broad, and would need to be split. As the workshop got underway, a further split occurred, brought about by the different levels of maturity, and needs for technology planning in several sub-disciplines. Thus, these proceedings are presented under seven themes. The volume of presentations, and the quantity of information generated by the individual panel summaries has led to the decision to prepare the proceedings in several volumes.

The first volume is an executive summary and includes the summary presentations made by the panel co-chairmen in the final plenary session. The accompanying seven volumes, of which this is one, each represent a specific "theme", and include the un-edited original presentation material used in that particular panel workshop. Each of these separate "theme" volumes also include the Foreword, the general Summary and Conclusions, and the Chairman's presentation charts and narrative summary. Thus, each should represent a self-standing volume to reflect the proceedings relevant to its respective Panel deliberations and output, as well as the reflection in the general Workshop results.

WORKSHOP THEME

Energy Systems and Thermal Management

--Advanced Photovoltaics

--Solar Dynamics

--Nuclear

--Advanced Thermal Concepts

--Laser Power

SUMMARY AND CONCLUSIONS

NASA's In-Space Research, Technology, and Engineering (RT&E) Workshop brought together representatives of the university community, private sector, and government agencies to discuss future needs for in-space experiments in support of space technology development and the derivative requirements for space station facilities to support in-space RT&E.

The workshop provided an excellent forum for establishing an interactive process for building a national in-space experiments program. It enabled NASA to present to the user community (university and private sector) experiment concepts for NASA's technology development activities in support of future space missions. The meetings also began a process by which industry and university researchers will be able to bring their own TDM requirements to NASA's planning process.

This conference reached three primary goals: first, it expanded and validated NASA's in-space experiment theme areas, including Space Structure (Dynamics and Control), Space Environmental Effects, Fluids Management, Energy Systems and Thermal Management, Automation and Robotics, Information Systems and In-Space Operations; second, it began the development of a user community network which will interface with NASA throughout the lifetime of the in-space experiment program; and third, it formed the basis for the establishment of on-going working groups which will continue to interest and coordinate requirements for in-space RT&E activities.

As an adjunct to the conference, NASA/OAST announced plans to initiate a long-term program to encourage and support industry and university experiments. NASA's modest investment in this program is initially targeted for generating experiment

ideas and concepts. It is anticipated that this base of concepts will lead to cooperatively funded experiments between NASA, industry, and academia and thereby, begin to build an active in-space RT&E program.

Several key points emerged from this conference regarding the adequacy of the TDM data base that should be addressed in future planning activities. First, many of the experiments could be performed on the ground, i.e., they do not justify a space experiment. Secondly, many of the experiments address near-term or current applications and do not take into account advanced system requirements. The TDM data base must look beyond extensions of current programs to reflect future needs and trends to have an effective and useful impact on space station planning and design. This will require increased input from industry and university researchers and engineers.

In order to address these concerns, it is imperative that a long-range planning view be taken in which industry and university researchers help NASA derive the technology development program. The following recommendations have been developed on the basis of the workshop:

1. Development of an on-going RT&E university and industry advisory group;
2. Continuation of in-space RT&E symposia to act both as outreach mechanisms and as working sessions to refine the TDM data base;
3. Development of an RT&E information clearinghouse;
4. Development and continuation of the new experiments outreach activity announced at the RT&E workshop;
5. Development of an "impacts assessment group" which will focus its energy on identifying experiment accommodation requirements to impact the design of in-space facilities, i.e., space station and others.

If carried out, these recommendations constitute movement toward development of an effective NASA/industry/university partnership in a National In-Space RT&E Program. This will also enable NASA/OAST to have an effective voice in space station planning, which is essential toward the success of a future in-space activities. The workshop, by promoting the process of NASA/industry/university interactions and by pointing out concerns with the developing TDM data base has provided an important first step towards a successful long-term space technology development effort.

IN-SPACE RESEARCH, TECHNOLOGY, AND ENGINEERING WORKSHOP

ENERGY SYSTEMS & THERMAL MANAGEMENT

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ENERGY SYSTEMS AND THERMAL MANAGEMENT

Summary

Earl VanLandingham

To date, the largest space power systems in use have been in the range of 10 kilowatts. Technology is now being developed for the I.O.C. space station at 75 KW, with growth versions being planned at 300 KW and higher. In D.O.D., spacecraft requiring power levels above a MW are being considered. This move to vastly increase power levels has resulted in a technology need for power systems capable of efficiently producing these high power levels with long life and low cost. Solar dynamic and nuclear power systems offer promise to initially meet these increased power requirements. In the longer term, innovative technologies such as laser power transmission may enhance the ability to provide substantial power. With the higher power levels, and the advent of extended space science missions and space manufacturing comes the requirement to both use and reject heat in quantities that are orders of magnitude higher than that of present systems. Many of the new designs being considered and the long term nature of the energy and thermal systems raise the question of the need for in-space experiments.

The Energy Systems and Thermal Management Panel reviewed the proposed experiments. Recognizing that most of the experiments were at the ideal level and minimal technical detail was available, the following general observations were made: much of the proposed experimental effort could be conducted on the ground; many of the proposed experiments were more appropriate for shuttle flights; some experiments because of size or other factors such as safety could not reasonably be conducted on the shuttle or station. In the opinion of the committee, the flight experiments fell into four categories.

(1) Confidence - generally system level tests.

(2) Unique Technology Issues - component level tests to answer a question of how a particular subsystem might operate in zero g.

(3) Development of Fundamental Understanding - Laboratory-type experiments to establish fundamental data needed design or perhaps more likely optimize the design of space power systems. An example of this is the cyclic heat transfer characteristics of two phase materials (particularly solid/liquid) in zero g.

(4) Long-Term Exposure - Atomic Oxygen, Space Plasma, etc.

The panel suggested that consideration be given to the development of a space station based general purpose power/thermal test facility, that would provide power, heat source, instrumentations and controls, data storage, etc. and the characteristics of which would be both known to and suitable for use by the power community. Experiments to address confidence, and unique technology issues need to be further defined and addressed on a case by case basis.

In addition to defining a need for a general purpose test facility, the panel recommended that greater participation by industry, universities and DOD in the definition of experiments is needed. Also, consideration should be given to combining experiments across themes and finally the space station should be instrumented for data purposes.

ENERGY SYSTEMS AND THERMAL MANAGEMENT

GENERAL OBSERVATIONS

- MUCH OF PROPOSED EXPERIMENTAL EFFORT COULD BE CONDUCTED ON THE GROUND
- MANY PROPOSED EXPERIMENTS WERE APPROPRIATE FOR PRECURSOR SHUTTLE FLIGHT
- SOME EXPERIMENTS WERE NOT SUITED FOR SHUTTLE OR SPACE STATION
- MOST EXPERIMENTS WERE AT THE "IDEA" LEVEL -- MINIMAL TECHNICAL DETAIL
- TWO FUNDAMENTAL RESEARCH AREAS WERE IDENTIFIED AS REQUIRING SPACE FLIGHT
  - PHASE CHANGE/HEAT TRANSFER PHENOMENA IN ZERO-G
  - ENVIRONMENTAL EFFECTS
- ADVANCED POWER AND THERMAL SYSTEMS WILL REQUIRE IN-SPACE EXPERIMENTAL SUPPORT

ENERGY SYSTEMS AND THERMAL MANAGEMENT

DRIVERS FOR IN-SPACE EXPERIMENT

- o CONFIDENCE
  - SYSTEM LEVEL TESTS
- o UNIQUE TECHNOLOGY ISSUE
  - COMPONENT TESTS
- o DEVELOPMENT OF FUNDAMENTAL UNDERSTANDING
  - LAB EXPERIMENTS
- o LONG-TERM EXPOSURE

ENERGY SYSTEMS AND THERMAL MANAGEMENT

MISSING INPUTS

- COMPLETE REQUIREMENTS FROM INDUSTRY, UNIVERSITIES AND GOVERNMENT AGENCIES
- COMPREHENSIVE EXPERIMENT PLANS
- ADVANCED SYSTEM CONSIDERATIONS

ENERGY SYSTEMS AND THERMAL MANAGEMENT

KEY TECHNOLOGY ISSUES

PERFORMANCE TESTING

- o COMPONENTS/SUBSYSTEM
- o SYSTEMS

ENVIRONMENTAL FACTORS

- o ATOMIC OXYGEN
- o SPACE PLASMA
- o MICROMETEOROIDS

FUNDAMENTAL PHENOMENA

- o THERMAL TRANSPORT
  - PHASE CHANGE SYSTEMS
- o THERMAL STORAGE
  - SOLID/LIQUID CONTAINMENT
  - HEAT FLOW MANAGEMENT

ENERGY SYSTEMS AND THERMAL MANAGEMENT

REQUIREMENTS FOR ADVANCED POWER/THERMAL SYSTEMS EXPERIMENT FACILITY

- GENERAL PURPOSE
  - EXPLORE FUNDAMENTAL RESEARCH PHENOMENA
  - INVESTIGATE ADVANCED TECHNOLOGY
  - PERFORM ENGINEERING EXPERIMENTS
- USER FRIENDLY
  - VERSATILE
  - FLEXIBLE
  - READILY AVAILABLE
- CAPABILITIES (STRAWMAN UP TO 5 KW)
  - POWER
  - HEAT SOURCE
  - HEAT SINK
  - LOAD BANK
  - INSTRUMENTATION/CONTROLS
  - DATA STORAGE & PROCESSING
  - ATTACHMENT POINTS (INTERNAL & EXTERNAL)
  - ISOLATED AREA(S)
  - IVA
  - EVA

ENERGY SYSTEMS AND THERMAL MANAGEMENT

RECOMMENDATIONS

- o OBTAIN ADDITIONAL INPUT TO COMPLETE SPACE STATION EXPERIMENTS DEFINITION
  - INDUSTRY
  - UNIVERSITIES
  - GOVERNMENT
- o COMBINE EXPERIMENTS WITHIN/ACROSS THEMES -- INTEGRATE TEST FACILITIES
- o DEFINE CAPABILITIES REQUIRED FOR GENERAL PURPOSE ADVANCED POWER/THERMAL SYSTEMS TEST CAPABILITY
- o INSTRUMENT SPACE STATION FOR DATA PURPOSES

THEME

PRESENTATION

MATERIAL

ADVANCED POWER SYSTEM
THERMAL ENERGY STORAGE

TED MROZ

NUCLEAR & THERMAL SYSTEMS OFFICE

SOLAR DYNAMIC PROJECT

LEWIS RESEARCH CENTER

ADVANCED POWER SYSTEM
THERMAL ENERGY STORAGE EXPERIMENT

EXPERIMENT OBJECTIVES

THE OVERALL OBJECTIVE IS TO EVALUATE THE PERFORMANCE OF SELECTED AND GROUND TESTED COMBINATIONS OF THERMAL ENERGY STORAGE (TES) AND CONTAINMENT MATERIALS UNDER SIMULATED THERMAL OPERATING CONDITIONS IN CONTINUOUS MICRO-GRAVITY. EXPERIMENTAL RESULTS ARE TO VERIFY GROUND TESTS AND IDENTIFY THE MOST PROMISING TES/CONTAINMENT MATERIALS AND CONFIGURATIONS FOR THE CYCLE TEMPERATURES REQUIRED FOR ADVANCED SOLAR DYNAMIC POWER SYSTEMS (STIRLING/H-T BRAYTON ETC.)

EXPERIMENT DESCRIPTION

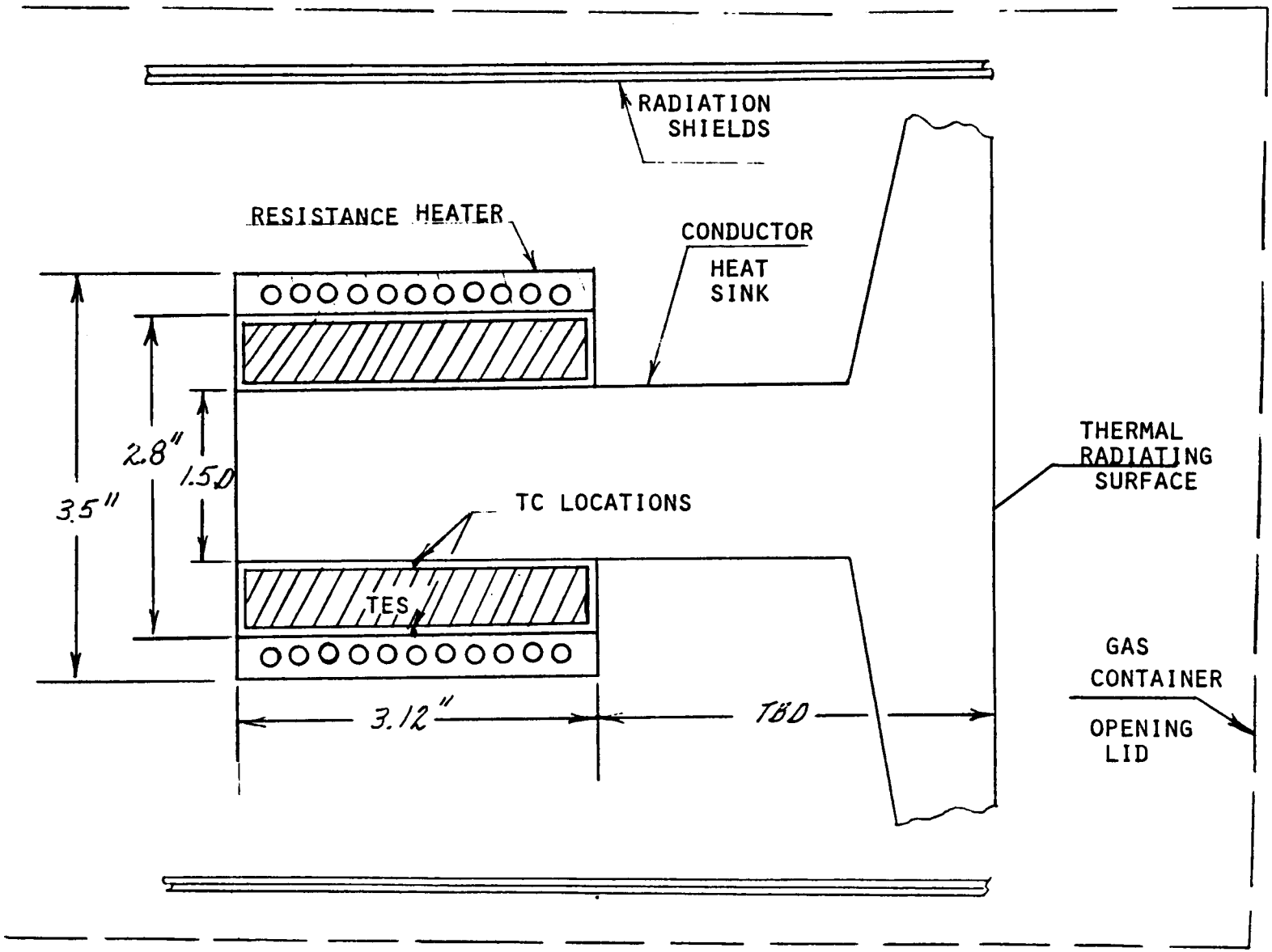
THE ZERO-G, THERMAL ENERGY STORAGE (TES) EXPERIMENTS ARE PLANNED FOR THE GET AWAY SPECIAL (GAS) CONTAINER LOCATED IN THE CARGO BAY OF THE SHUTTLE. EACH EXPERIMENT WILL BE COMPLETELY INDEPENDENT OF SHUTTLE, HAVING ITS OWN BATTERY POWER SUPPLY, CONTROLS, INSTRUMENTATION, DATA RECORDING, ETC. INTERACTION WITH THE SHUTTLE CREW WILL ONLY INVOLVE A START AND STOP SWITCH.

THE TEST ARTICLE WILL CONSIST OF APPROXIMATELY 300 GRAMS OF THE TES MATERIAL IN AN ANNULAR CONTAINER. THE MELT CYCLE SIMULATING THE SUN PORTON OF A LEO ORBIT WILL BE ACCOMPLISHED VIA RESISTANCE HEATERS WRAPPED AROUND THE OUTER DIAMETER OF THE ANNULUS AND SUPPORTED ON CERAMIC. HEAT ADDITION WILL BE RADIALLY INWARD FROM THE OUTSIDE DIAMETER. THE FREEZE CYCLE SIMULATING THE SHADE PROTION OF A LEO ORBIT WILL OCCUR WHEN THE POWER IS TURNED OFF AND HEAT RADIATED TO THE EXTERIOR OF THE SHUTTLE. HEAT WILL BE REMOVED FROM THE TES MATERIAL AT THE INNER DIAMETER OF THE ANNULAR SPECIMEN AND CONDUCTED OR RADIATED TO THE GAS CONTAINER FOR FINAL HEAT REJECTION.

THE MINIMUM OF 10 MELT/FREEZE CYCLES IS PLANNED FOR EACH EXPERIMENT. PRIOR GROUND TESTING WILL EVALUATE AND SELECT TES/CONTAINMENT MATERIAL COMBINATIONS AND WILL ESTABLISH THE MAJOR PARAMETERS WHICH CAN AFFECT OPERATION IN MICRO-GRAVITY.

EXTENSIVE ANALYSES AND TESTS WILL ESTABLISH HEAT TRANSFER AND VOID FORMATION CHARACTERISTICS. TESTING WILL DEMONSTRATE THE UNDERSTANDING AND BEHAVIOR OF SPECIFIC TES AND CONTAINMENT MATERIALS IN OPERATION IN THE MICRO-GRAVITY ENVIRONMENT. THE EXPERIMENT WILL CONSIDER NEW TES SALT AND EUTECTIC MIXTURES FOR SPECIFIC OPERATING TEMPERATURES, EFFECTS OF WETTING, MELT AND FREEZE PATTERNS, AND SURFACE TENSION ON CONTACT HEAT TRANSFER AREA. CONTROL OF VOID DISTRIBUTION THROUGH DESIGN WILL BE EVALUATED.

THERMAL ENERGY STORAGE EXPERIMENT FOR ADVANCED TECHNOLOGY POWER SYSTEMS



EXPERIMENT TITLE: ADVANCED POWER SYSTEM THERMAL ENERGY STORAGE

PROPOSED FLIGHT DATE - TBD YEAR

OPERATIONAL DAYS REQUIRED - 1-2

MASS - * KG

VOLUME: *

STORED: W ____ x L ____ x H ____ = ____ M^3

DEPLOYED: W ____ x L ____ x H ____ = ____ M^3

INTERNALLY ATTACHED ____ ~~(YES/NO)~~
EXTERNALLY ATTACHED ____ ~~(YES/NO)~~
FORMATION FLYING ____ ~~(YES/NO)~~

ORIENTATION (inertial, solar, earth, other) SPACE

EXTRA-VEHICULAR ACTIVITY REQUIRED:

SET-UP: ____ Hrs/Day ____ No. of days

OPERATIONS: ____ Hrs/Day ____ No. of days ____ Interval

SERVICING: ____ Hrs/Day ____ No. of days ____ Interval

INTRA-VEHICULAR ACTIVITY REQUIRED:

SET-UP: ____ Hrs/Day ____ No. of days

OPERATIONS: ____ Hrs/Day ____ No. of days ____ Interval

SERVICING: ____ Hrs/Day ____ No. of days ____ Interval

POWER REQUIRED:

____ KW AC or DC (circle one)

____ Hrs/Day ____ No. of days

DATA RATE: ____ Megabits/second

DATA STORAGE: ____ Gigabits

* GET-AWAY SPECIAL EXPERIMENT

THERMAL MANAGEMENT

R. VERNON

PROGRAM OBJECTIVE

ESTABLISH A TECHNOLOGY DATA BASE FOR TWO-PHASE FLOW AND HEAT TRANSFER IN MICROGRAVITY TO ENABLE ADVANCED DYNAMIC POWER, ENVIRONMENTAL CONTROL, HEAT REJECTION, AND LIQUID STORAGE SYSTEMS

- DEFINE PROGRESSIVE SERIES OF COORDINATED INVESTIGATIONS
  - THEORETICAL MODELS
  - GROUND BASED MICROGRAVITY TESTS
  - SHUTTLE EXPERIMENTS
  - SPACE STATION EXPERIMENTS
- ACQUIRE UNDERSTANDING OF PROCESSES AND ASSEMBLE GENERIC DATA BASES
  - TWO PHASE FLOW REGIMES
  - EVAPORATION/CONDENSATION
  - POOL BOILING
  - FLOW BOILING/CONDENSATION
  - MELTING/FREEZING
- DEVELOP COMPONENT TECHNOLOGY BASES
  - BOILERS/CONDENSERS
  - COLD PLATES
  - STORAGE TANKS
  - RADIATORS

THERMAL MANAGEMENT

R. VERNON

DESCRIPTION

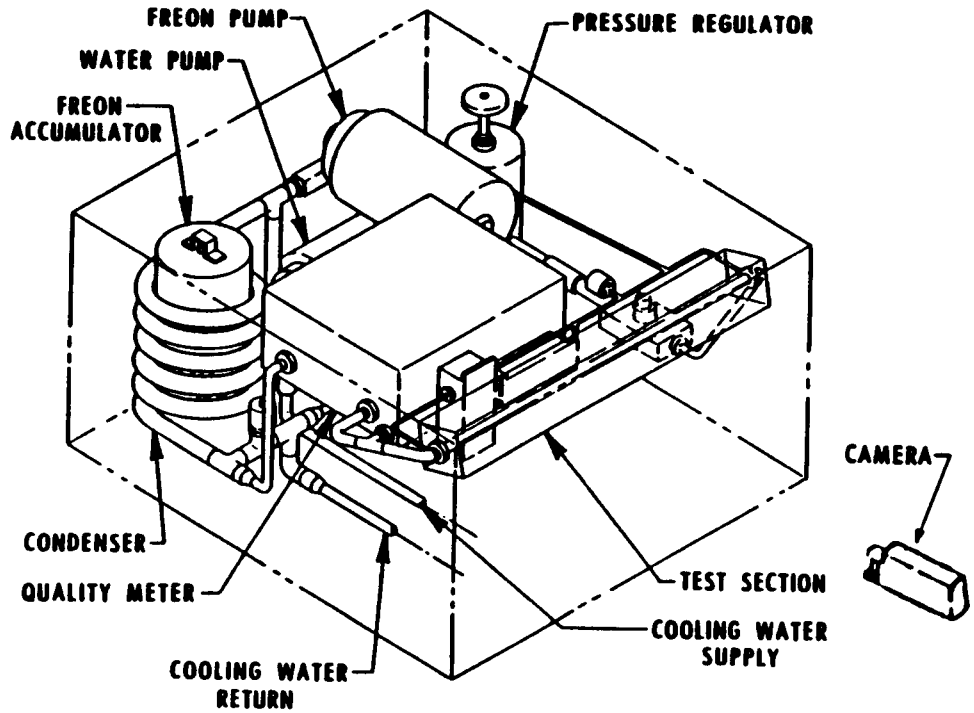
EXPERIMENTS DESIGNED AND PHASED TO PROGRESSIVELY UTILIZE THE UNIQUE CAPABILITIES OF REDUCED GRAVITY FACILITIES

- o PRECURSOR TESTS - DROP TOWER, AIRCRAFT, SHUTTLE
  - FLOW REGIME DEFINITION
  - POOL BOILING
  - FLOW BOILING/CONDENSATION
  - MELTING/FREEZING
- o TECHNOLOGY EXPERIMENTS - SHUTTLE, SPACE STATION
  - BOILERS/CONDENSERS
  - COLD PLATES
  - STORAGE TANKS
  - RADIATORS

COOPERATIVE FLIGHT EXPERIMENTS WITH NASA, DOD, AND DOE

THERMAL MANAGEMENT

R. VERNON



FLOW BOILING EXPERIMENT

Beech Aircraft Corporation

Contract NAS 3-23160

National Aeronautics and Space Administration
Lewis Research Center

SPACE EXPERIMENTS OFFICE

NASA

EXPERIMENT TITLE: TYPICAL ACCOMODATION REQUIREMENTS FOR THERMAL MANAGEMENT EXPERIMENTS

THERMAL MANAGEMENT
R. Vernon

PROPOSED FLIGHT DATE - 1988 - 1995 YEAR

OPERATIONAL DAYS REQUIRED - 1 - 5

MASS - 50 - 200 KG

VOLUME:

STORED: W 1M x L 1 - 2M x H 1M = 1 - 2M M^3

DEPLOYED: W _____ x L _____ x H _____ = _____ M^3

INTERNALLY ATTACHED YES (YES/NO)
EXTERNALLY ATTACHED NO (YES/NO)
FORMATION FLYING NO (YES/NO)

ORIENTATION (inertial, solar, earth, other)_____

EXTRA-VEHICULAR ACTIVITY REQUIRED:

SET-UP: _____ Hrs/Day _____ No. of days

OPERATIONS: _____ Hrs/Day _____ No. of days _____ Interval

SERVICING: _____ Hrs/Day _____ No. of days _____ Interval

INTRA-VEHICULAR ACTIVITY REQUIRED:

SET-UP: 1 Hrs/Day 1 - 5 No. of days

OPERATIONS: 2 - 4 Hrs/Day 1 - 5 No. of days _____ Interval

SERVICING: _____ Hrs/Day _____ No. of days _____ Interval

POWER REQUIRED:

1 - 3 KW AC or DC (circle one)
3 - 5 Hrs/Day 1 - 5 No. of days

DATA RATE: 0.1 - 1 Megabits/second

DATA STORAGE: 0.5 - 2 Gigabits

ADVANCED RADIATOR CONCEPTS

TEST BED DEMONSTRATION TDMX 2132

FOR LIQUID DROPLET RADIATOR

ALDEN PRESLER
THERMAL MANAGEMENT PROJECT
LEWIS RESEARCH CENTER

LIQUID DROPLET RADIATOR TEST BED EXPERIMENTAL OBJECTIVE

TEST AND EVALUATE AN EXPERIMENTAL SUBSCALE LIQUID DROPLET RADIATOR OVER AN EXTENDED OPERATING PERIOD IN SPACE.

SPECIFIC MISSION GOALS INCLUDE: DETERMINE WORKING FLUID MASS COLLECTION EFFICIENCY, VALIDATE PROJECTED HEAT REJECTION PERFORMANCE, EVALUATE SPACE ENVIRONMENTAL IMPACT ON SYSTEM OPERATION, EVALUATE SYSTEM CONTROLABILITY, RELIABILITY, PART LOAD PERFORMANCE, TRANSIENT BEHAVIOR, AND MAINTENANCE.

TDMX-2132 TEST BED DESCRIPTION

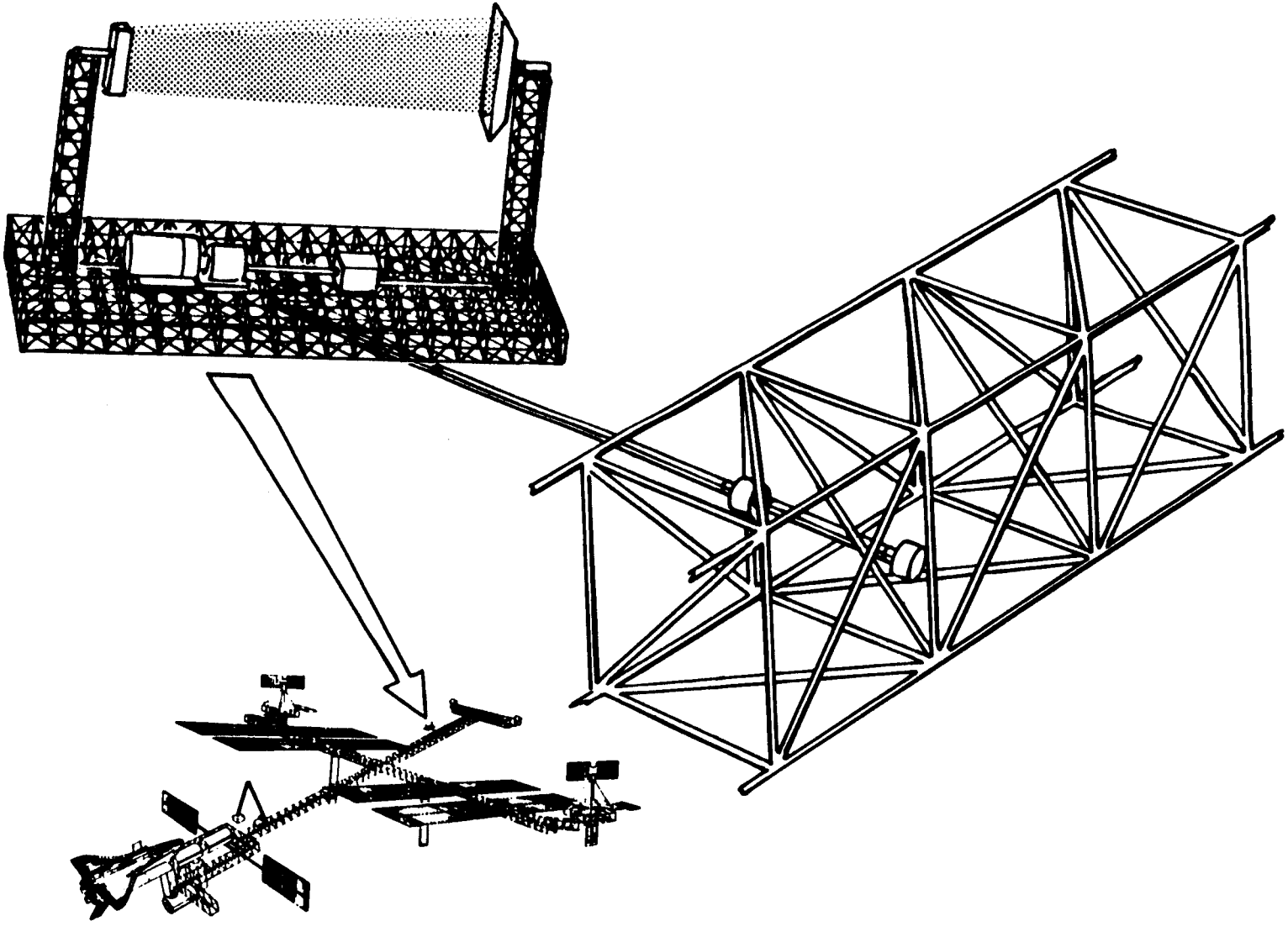
THIS SUB-SCALE EXPERIMENT WILL TEST THE TOTAL PERFORMANCE CAPABILITY OF THE LIQUID DROPLET RADIATOR SYSTEM IN SPACE ENVIRONMENT. THE RADIATING SURFACE IS A SHEET OF FINE DROPLETS OF A SPECIAL WORKING FLUID THAT ARE EJECTED DIRECTLY INTO SPACE ALONG A STRAIGHT PATH INTO A COLLECTOR/SUMP FOR RECYCLING THROUGH THE THERMAL MANAGEMENT LOOP. THE DROPLETS ARE PRODUCED BY PUMPING THE FLUID THROUGH AN ORIFICE PLATE WITH SEVERAL THOUSAND MACHINED HOLES OF ABOUT 100 MICRONS DIAMETER.

ALL THE COMPONENTS INCLUDING THE DROPLET GENERATOR, COLLECTOR, PUMPS, HEAT EXCHANGER, VALVES, PIPING INSTRUMENTATION AND ELECTRONICS ARE MOUNTED ON A LIGHT WEIGHT TEST BED ATTACHED EXTERNALLY TO THE SPACE STATION STRUCTURE. A POINTING SYSTEM IS REQUIRED TO POSITION THE DROPLET SHEET EDGEWISE TO THE SUN.

ELECTRIC POWER WILL BE NEEDED FOR RESISTANCE HEATERS, PUMPS, ACTIVATORS, AND ELECTRONICS. THE WORKING FLUID WILL BE VERY LOW VAPOR PRESSURE ORGANIC LIQUID.

THE EXPERIMENT IS DESIGNED TO OPERATE ONLY INTERMITTENTLY AT FULL POWER, AND TO UNDERGO A NUMBER OF STARTUPS AND SHUTDOWNS TO TEST SYSTEM RESPONSDE. THE SPACE STATION IS NECESSARY TO PROVIDE LONG DURATION OPERATION AT ADEQUATE POWER LEVELS IN SPACE ENVIRONMENT TO ESTABLISH CONCEPT RELIABILITY.

LIQUID DROPLET RADIATOR TDMX2132



CD-85 17216

EXPERIMENT TITLE: LIQUID DROPLET RADIATOR TEST BED TDMX 2132

PROPOSED FLIGHT DATE - 1994 YEAR

OPERATIONAL DAYS REQUIRED - 150

MASS - 180 KG

VOLUME:

STORED: W 2.0 x L 5.0 x H 1.0 = 10.0 M^3

DEPLOYED: W 2.0 x L 5.0 x H 2.0 = 20.0 M^3

INTERNALLY ATTACHED NO (YES/NO)
EXTERNALLY ATTACHED YES (YES/NO)
FORMATION FLYING NO (YES/NO)

ORIENTATION (inertial, solar, earth, other) SOLAR

EXTRA-VEHICULAR ACTIVITY REQUIRED:

SET-UP: 8 Hrs/Day 1 No. of days

OPERATIONS: - Hrs/Day - No. of days - Interval

SERVICING: - Hrs/Day - No. of days - Interval

INTRA-VEHICULAR ACTIVITY REQUIRED:

SET-UP: 4-6 Hrs/Day 1 No. of days

OPERATIONS: 0.5 Hrs/Day 150 No. of days - Interval

SERVICING: 1 Hrs/Day - No. of days A.R. Interval

POWER REQUIRED:

3 (PEAK) KW AC or DC (circle one)

18 Hrs/Day _____ No. of days

DATA RATE: 0.1 Megabits/second

DATA STORAGE: .001 Gigabits

SPACE STATION SYSTEMS
ADVANCED PROGRAMS & PLANNING OFFICE

NASA

PROPOSED SPACE STATION EXPERIMENT
LARGE PHOTOVOLTAIC POWER SYSTEM DEMONSTRATION

OBJECTIVE:

TO TEST AND ASSESS ADVANCED PHOTOVOLTAIC (PV) POWER SYSTEM COMPONENTS AND TOTAL PV SYSTEMS IN THE SPACE STATION ENVIRONMENT, INCLUDING PLANAR AND CONCENTRATOR PV ARRAYS, ADVANCED POWER MANAGEMENT AND DISTRIBUTION (PMAD) COMPONENTS AND ENERGY STORAGE CONCEPTS; PRIMARY EMPHASIS ON INTERACTION OF COMPONENTS WITH THE SPACE PLASMA IN LEO.

PHOTOVOLTAIC SYSTEMS
ADVANCED CONCEPTS ⟶ IMPROVED EFFICIENCY

PV ARRAYS	PMAD	ENERGY STORAGE
• PLANAR	• COMPONENTS	• CHEMICAL
• CONCENTRATOR	• DISTRIBUTION	• MECHANICAL
• ADVANCED MATERIALS		
• DEPLOYABLE/ERECTABLE		

PROPOSED SPACE STATION EXPERIMENT
LARGE PHOTOVOLTAIC POWER SYSTEM DEMONSTRATION

DESCRIPTION:

THE LARGE PHOTOVOLTAIC POWER SYSTEM DEMONSTRATION CONSISTS OF A PV ARRAY, PMAD SYSTEM, ENERGY STORAGE UNIT, INSTRUMENTATION (ESPECIALLY FOR PLASMA MONITORING), AND AUTOMATED CONTROLS AND DATA COLLECTION. THE TEST BED WOULD BE COMPLETELY MODULAR FOR SCHEDULED CHANGE OUTS IN THE COLLECTION, DISTRIBUTION, AND STORAGE SYSTEMS, AND MIGHT BE ATTACHED OR FREE FLYER. DEPENDENCE ON AND INTERACTION WITH THE MAIN STATION POWER SYSTEM WOULD BE MINIMIZED FOR PROTECTION OF BOTH SYSTEMS. IT IS DESIRABLE TO LOCATE THE TEST BED DISTANT FROM CONTAMINATION SOURCES, PERHAPS ON THE UPPER BOOM OR ON THE TRANSVERSE (POWER) BOOMS OUTBOARD OF THE ALPHA JOINTS. THE SKETCH SHOWS A NOMINAL 12.5 KW PEAK POWER TEST BED (7.5 X 9M) CONSISTING OF TWO PLANAR SILICON ARRAY UNITS WITH INDIVIDUAL STORAGE AND CONTROLS. ADVANCED ARRAYS MAY GENERATE 25-35 KW PEAK POWER IF CELL EFFICIENCIES ARE 20-30%. STORAGE WOULD BE REMOTE FROM THE ARRAYS, BUT CONDITIONING MIGHT BE BUILT INTO THE ARRAYS. PMAD MUST BE COMPLETELY DECOUPLED FROM THE MAIN POWER SYSTEM PMAD IF A TRANSVERSE BOOM LOCATION IS SELECTED.

SPACE STATION SYSTEMS
ADVANCED PROGRAMS & PLANNING OFFICE

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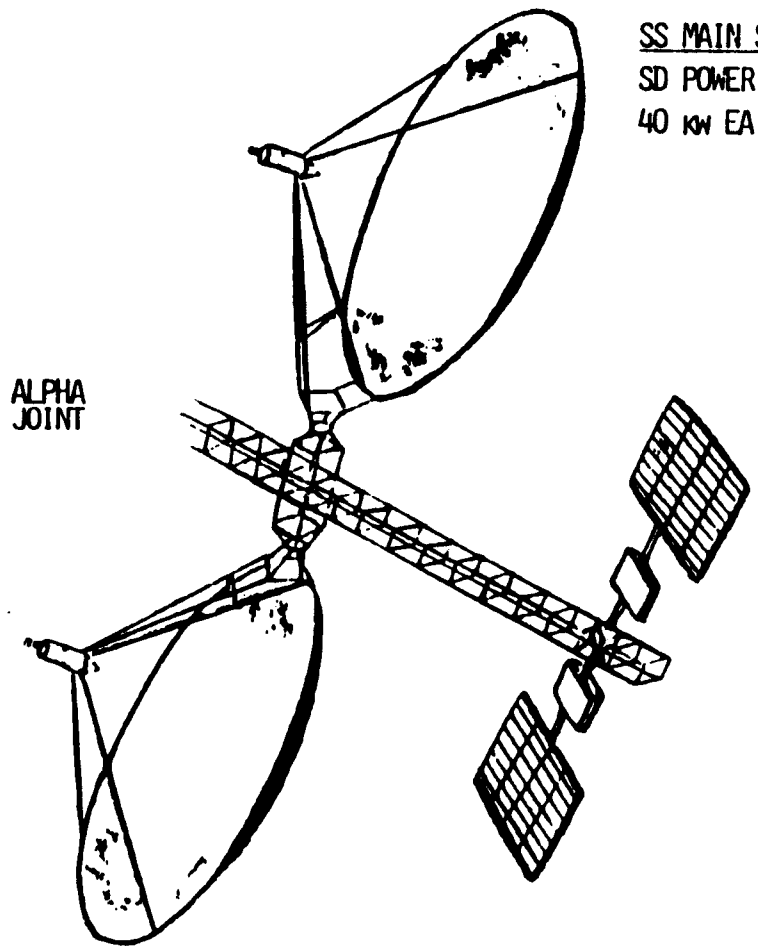
LARGE PHOTOVOLTAIC POWER SYSTEM DEMONSTRATION 2152



SS MAIN SYSTEM
SD POWER UNITS
40 KW EA. (AVG)

POWER TEST BED
PV TEST UNITS
- o 12.5 KW EA. (PEAK)
- o 5.0 KW EA. (AVG) FOR SILICON/BATTERIES
- o HIGHER FOR ADVANCED ARRAYS AND STORAGE

(RADIATORS NOT SHOWN)

EXPERIMENT TITLE: Large Photovoltaic Power System Demo.

PROPOSED FLIGHT DATE - 1993 YEAR

OPERATIONAL DAYS REQUIRED - 360

MASS - 2,000 KG

VOLUME:

STORED: W TBD x L TBD x H _____ = TBD M^3

DEPLOYED: W 10 x L 15 x H _____ = 150 M^3

INTERNALLY ATTACHED _____ (YES/NO)
EXTERNALLY ATTACHED Yes (YES/NO)
FORMATION FLYING Yes (YES/NO)

ORIENTATION (inertial, solar, earth, other) Solar

EXTRA-VEHICULAR ACTIVITY REQUIRED:

SET-UP: TBD Hrs/Day TBD No. of days

OPERATIONS: _____ Hrs/Day _____ No. of days _____ Interval

SERVICING: _____ Hrs/Day _____ No. of days _____ Interval

INTRA-VEHICULAR ACTIVITY REQUIRED:

SET-UP: _____ Hrs/Day _____ No. of days

OPERATIONS: 1 Hrs/Day 360 No. of days _____ Interval

SERVICING: _____ Hrs/Day _____ No. of days _____ Interval

POWER REQUIRED: (Own Power)

N/A KW AC or DC (circle one)

N/A Hrs/Day N/A No. of days

DATA RATE: TBD Megabits/second

DATA STORAGE: TBD Gigabits

DEPLOY AND TEST A LARGE SOLAR CONCENTRATOR (TDMX 2111) ED COMMX

EXPERIMENT OBJECTIVE - TO DEPLOY A LARGE STABLE, SPECIAL PURPOSE SOLAR CONCENTRATOR FOR FOLLOW-ON EXPERIMENTS

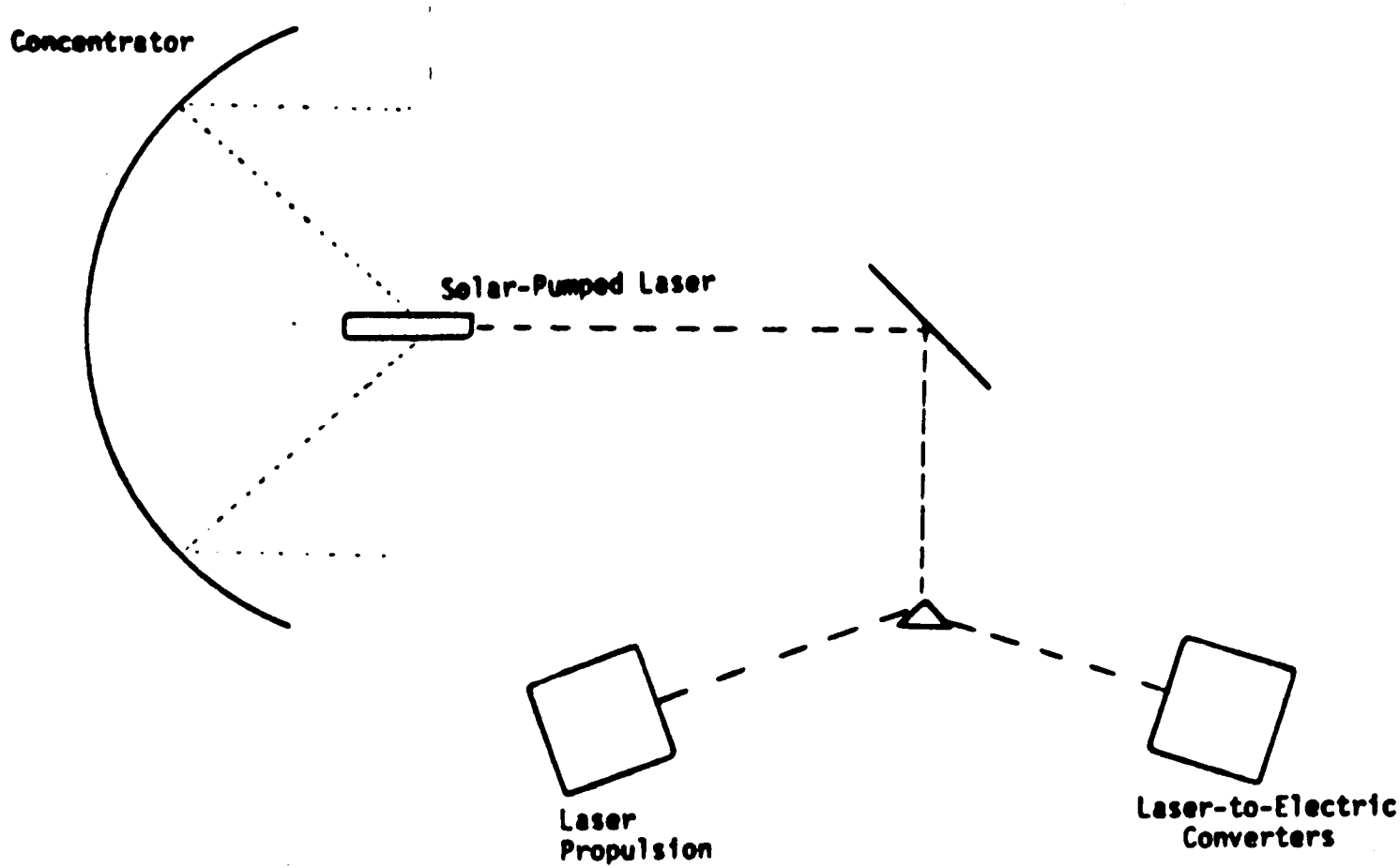
THIS IS THE FIRST OF FOUR INTERRELATED EXPERIMENTS TO TEST KW-LEVEL SOLAR-PUMPED LASERS, AND LASER CONVERTERS FOR POWER AND PROPULSION

A LARGE, HIGH-CONCENTRATION, MECHANICALLY, THERMALLY AND OPTICALLY STABLE SPECIAL PURPOSE SOLAR CONCENTRATOR IS REQUIRED TO POWER SOLAR LASERS

THE EXPERIMENT IS A TEST BED FOR ASSESSING THE PERFORMANCE OF AN ADVANCED-DESIGN CONCENTRATOR WHICH APPEARS (FROM TERRESTRIAL EXPERIMENTS) TO MEET THE REQUIREMENTS IMPOSED BY SOLAR-PUMPED LASERS

THIS EXPERIMENT WILL TEST THE DESIGN PHILOSOPHY, MATERIALS, DEPLOYMENT STRATEGY AND INTENSITY PATTERN FOR CONCENTRATOR TECHNOLOGY IN SUPPORT OF POSSIBLE FUTURE SPACE SOLAR POWER STATIONS AND OTHER ADVANCED APPLICATIONS

Four Interrelated TDM Experiments



DEPLOY AND TEST A LARGE SOLAR CONCENTRATOR (TDMX 2111)

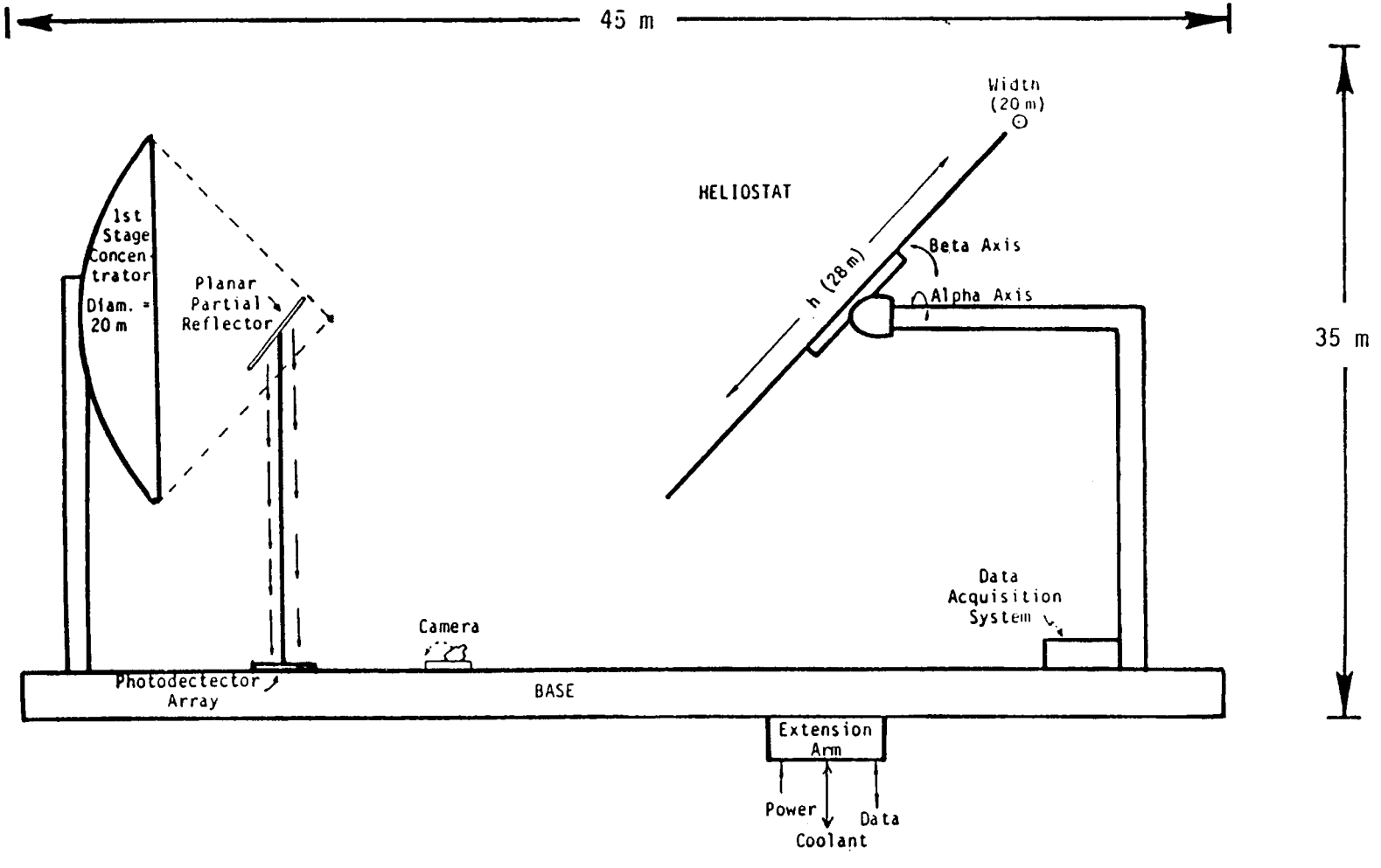
EXPERIMENT DESCRIPTION

THE PURPOSE OF THIS EXPERIMENT IS TO DEPLOY, TEST AND CALIBRATE THE OPERATION OF ONE OR MORE CONCENTRATOR DESIGNS.

THE EQUIPMENT INCLUDES A SUN-TRACKING HELIOSTAT (A PLANE MIRROR) AND A FIXED (RE SPACE STATION) CONCAVE CONCENTRATOR OF NEAR-PARABOLIC SHAPE.

THE EXPERIMENT WILL CONSIST OF MEASURING THE INTENSITY PATTERN IN THE FOCAL VOLUME AND MONITORING THE SHAPE, REFLECTIVITY AND TEMPERATURE OF THE CONCENTRATING SURFACE AS A FUNCTION OF ORBITAL PHASE AND TIME-IN-ORBIT

A SECONDARY ASPECT WILL BE ASSESSMENT OF SCALABILITY OF DEPLOYMENT MODE TO LARGER CONCENTRATION.



Physical Layout of Solar Concentrator System.

EXPERIMENT TITLE: TDMX 2111 Deploy and Test a Large Solar Concentrator

All Data Approximate

PROPOSED FLIGHT DATE - 1992 YEAR

OPERATIONAL DAYS REQUIRED - 500

MASS - 5700 KG

VOLUME: 250 m^3

STORED W - x L 16 m x 4.5 m dia = 250 M^3

DEPLOYED W - x L 45 m x 40 m dia = 56000 M^3

INTERNALLY ATTACHED ____ (YES/NO)
EXTERNALLY ATTACHED yes (YES/NO)
FORMATION FLYING no (YES/NO)

ORIENTATION (inertial, solar, earth, other) Solar

EXTRA-VEHICULAR ACTIVITY REQUIRED:

SET-UP:	8 *	Hrs/Day	5.5	No. of days		
OPERATIONS:	2	Hrs/Day	1	No. of days	week	Interval
SERVICING	8	Hrs/Day	1	No. of days	6 month	Interval

INTRA-VEHICULAR ACTIVITY REQUIRED:

SET-UP:	4	Hrs/Day	6	No. of days		
OPERATIONS:	.5	Hrs/Day	1	No. of days	week	Interval
SERVICING	.5	Hrs/Day	1	No. of days	week	Interval

POWER REQUIRED:

.25 KW AC or (DC) (circle one)

12 Hrs/Day 500 No. of days

DATA RATE: .005 Megabits/second

DATA STORAGE: .004 Gigabits

*Three men working

TEST SOLAR-PUMPED LASERS (TDMX 2121)

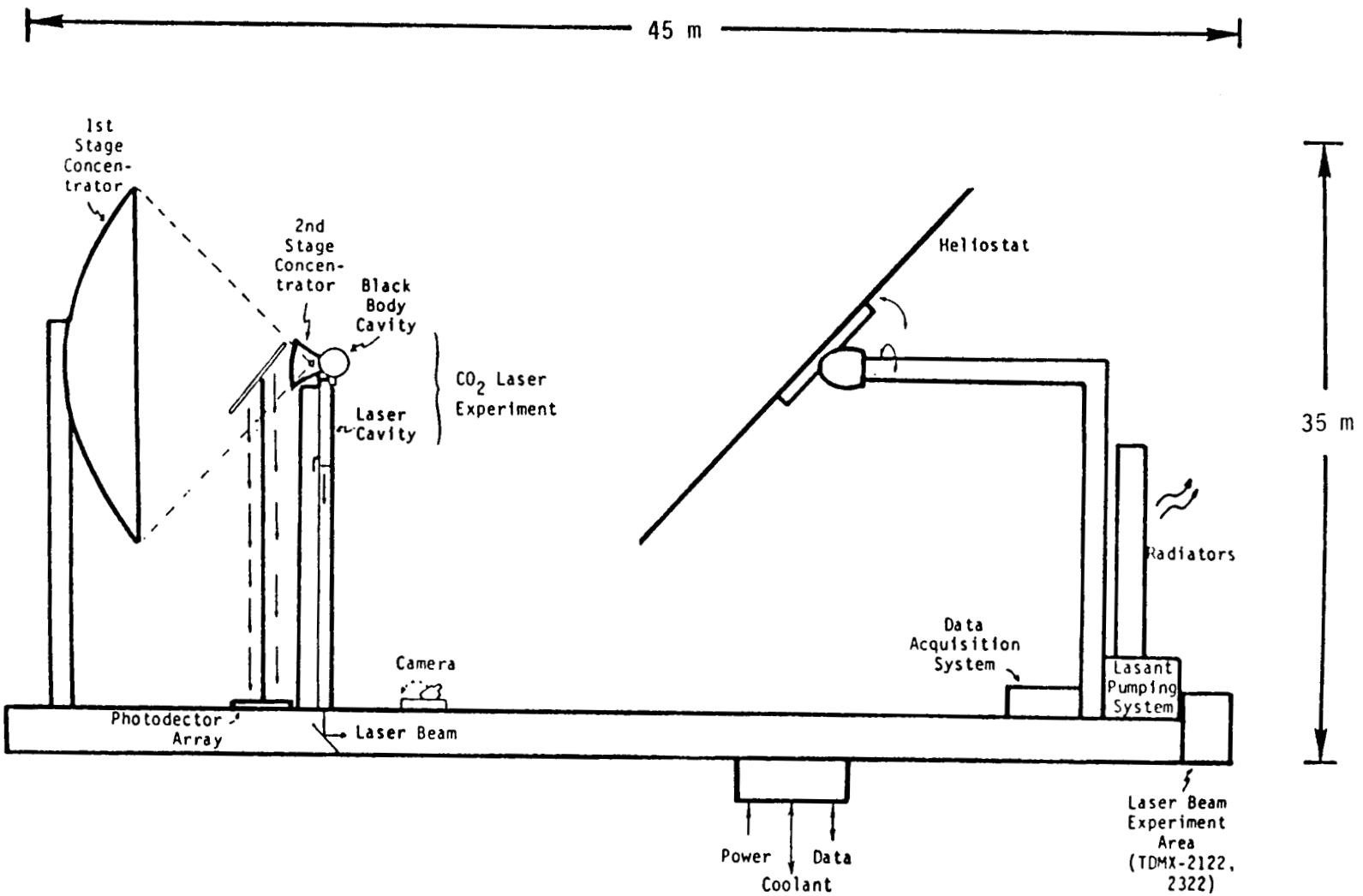
EXPERIMENT OBJECTIVE - TO EVALUATE THE SPACE OPERATION OF CANDIDATE SOLAR-PUMPED LASERS

THE EXPERIMENT IS A TEST-BED FOR ASSESSING THE PERFORMANCE OF AND SPACE QUALIFYING SOLAR-PUMPED FLUID AND SOLID HIGH AVERAGE POWER (~1 KW) LASERS. THIS IS THE SECOND OF FOUR INTERRELATED EXPERIMENTS TO TEST KW-LEVEL SOLAR-PUMPED LASERS, AND LASER CONVERTERS FOR POWER AND PROPULSION. IT EMPLOYS A LARGE EXISTING SOLAR CONCENTRATOR (TDMX 2111) TO POWER THE LASERS. THIS EXPERIMENT ASSESSES THE OPERATION (EFFICIENCY, OPTICAL MODE, MECHANICAL, THERMAL-, OPTICAL-, POWER STABILITY, CLOSED-CYCLE FLOW) IN AMO SUNLIGHT AND 0-G OF TWO OR MORE SOLAR-PUMPED LASERS, AND TESTS THE VALIDITY OF COMPUTATIONAL AND LABORATORY RESULTS.

TEST SOLAR-PUMPED LASERS (TDMX 2121)

EXPERIMENT DESCRIPTION

THE EXPERIMENT EMPLOYS AN EXISTING, SOLAR CONCENTRATOR (TDMX 2111) TO PROVIDE A TAILORED REGION OF HIGH SOLAR INTENSITY. INSTRUMENTED, TEMPERATURE CONTROLLED, FLUID AND SOLID LASERS ARE PLACED IN THE CONCENTRATOR'S FOCAL VOLUME. THE LASERS INTERCEPT NEARLY ALL THE FOCUSED SOLAR ENERGY. THE MAXIMUM LASER POWER IS LESS THAN 2 KW CW. EMISSION WAVELENGTHS RANGE FROM THE INFRARED TO THE VISIBLE. MEASUREMENTS OF SOLAR INTENSITY, LASER POWER (EFFICIENCY, OPTICAL MODE, DYNAMICS), TEMPERATURES (LASANT, LASER WALLS AND SUPPORT STRUCTURE), AND CLOSED-CYCLE FLOW OPERATION ARE PERFORMED TO TEST AND AUGMENT THEORY AND LABORATORY DATA. EXPERIMENT TESTS (1) SHUT-DOWN OR RE-START OF LASING WHEN ENTERING OR EMERGING FROM EARTH'S SHADOW, (2) OPTICAL MODE DETERMINED BY DETAILS OF PUMPING, QUENCHING AND RELAXATION IN O-G WITH TRUE AMO SPECTRUM AND CONCENTRATED IRRADIANCE.



The CO_2 Laser System As Seen Integrated With The Solar Concentrator Experiment (TDMX 2111).

EXPERIMENT TITLE: TDMX 2121 - Test Solar Pumped Laser

All Data Approximate

PROPOSED FLIGHT DATE - 1992 YEAR

OPERATIONAL DAYS REQUIRED - 60

MASS - 800 KG

VOLUME: 18 m^3

STORED	W	3 m / 1	x L	3 m / 17	x H	2 m / 1	=	18	M^3
DEPLOYED	W	3 / .5	x L	4 / 36	x H	1 / .5	=	38	M^3

INTERNALLY ATTACHED no (YES/NO)
EXTERNALLY ATTACHED yes (YES/NO)
FORMATION FLYING no (YES/NO)

ORIENTATION (inertial, solar, earth, other) (Solar - see TDMX 2111)

EXTRA-VEHICULAR ACTIVITY REQUIRED:

SET-UP:	8	*Hrs/Day	1	No. of days	for each of three lasers
OPERATIONS:	2	Hrs/Day	1	No. of days	month Interval
SERVICING	2	Hrs/Day	1	No. of days	week Interval

INTRA-VEHICULAR ACTIVITY REQUIRED:

SET-UP:	0	Hrs/Day		No. of days	
OPERATIONS:	0	Hrs/Day		No. of days	Interval
SERVICING	0	Hrs/Day		No. of days	Interval

POWER REQUIRED:

0.1 KW AC or (DC) (circle one)

12 Hrs/Day 60 No. of days

DATA RATE: .010 Megabits/second

DATA STORAGE: .020 Gigabits

*Two men working

LASER-TO-ELECTRIC ENERGY CONVERSION (TDMX 2122)

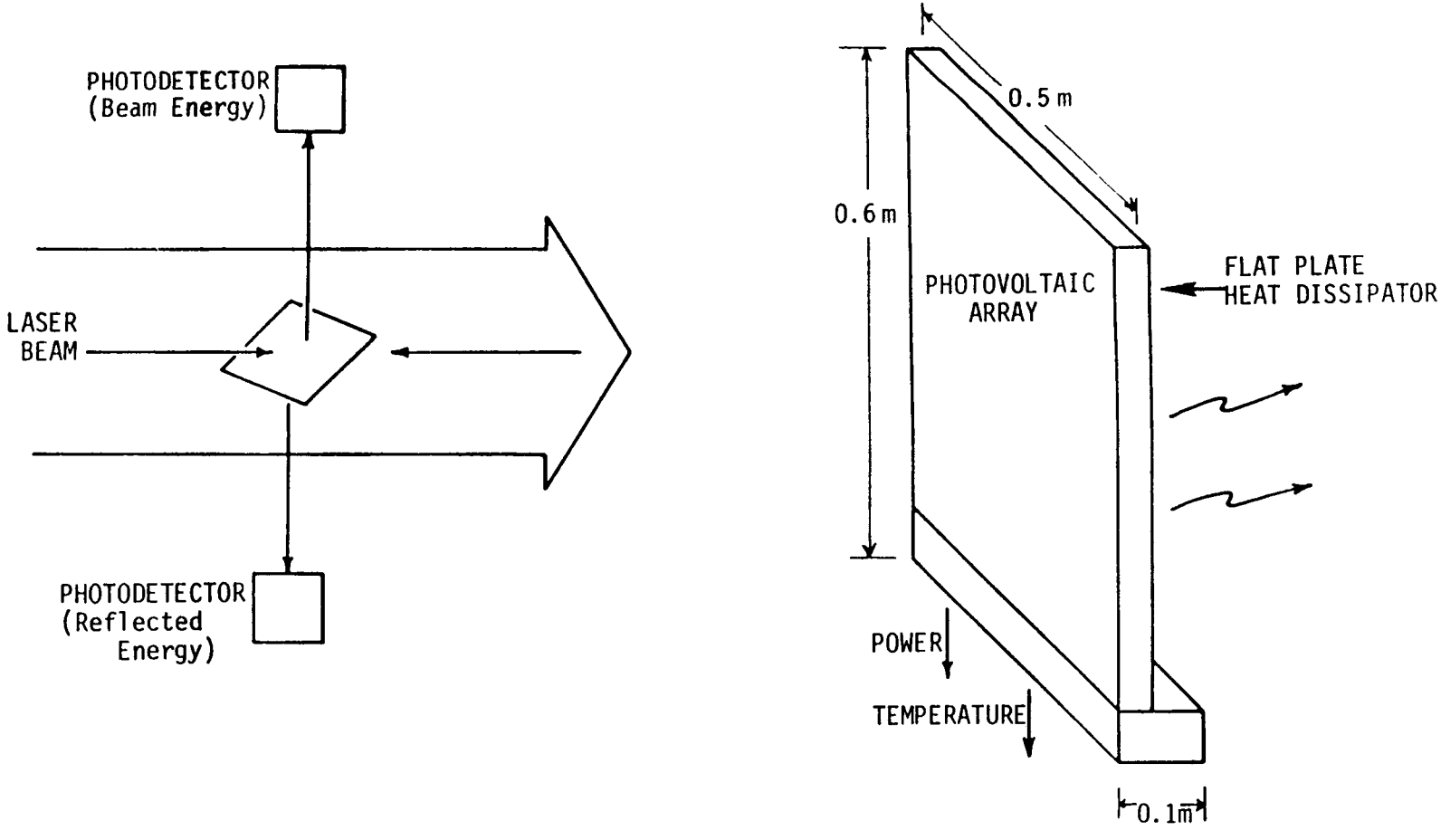
<u>EXPERIMENT OBJECTIVE</u> - TO ASSESS THE IN-SPACE OPERATION OF LASER-TO-ELECTRIC CONVERSION DEVICES

THIS IS THE THIRD OF FOUR INTERRELATED EXPERIMENTS TO TEST KW-LEVEL SOLAR-PUMPED LASERS, AND LASER CONVERTERS FOR POWER AND PROPULSION. THIS EXPERIMENT EMPLOYS AN EXISTING SOLAR CONCENTRATOR (TDMX 2111) AND AN OPERATING SOLAR-PUMPED LASER (TDMX 2121) AS THE POWER SOURCE FOR LASER-TO-ELECTRIC CONVERSION DEVICES WHICH FORM THE RECEIVING PORTION OF A POTENTIAL SPACE LASER POWER TRANSMISSION SYSTEM. ASSESSMENT OF TWO DEVICES, A LASER PHOTOVOLTAIC CONVERTER AND A LASER MAGNETOHYDRODYNAMIC (MHD) CONVERTER, IS PLANNED. THE INITIAL EXPERIMENT EMPLOYS THE PHOTOVOLTAIC DEVICE. THE OBJECTIVES ARE (1) TO ASSESS CONVERSION EFFICIENCY UNDER SPACE OPERATING CONDITIONS (2) TO MEASURE 0-G WASTE-HEAT REMOVAL EFFICIENCY, (3) TO EVALUATE THE COMBINED EFFECTS OF INTENSE LASER POWER AND REACTIVE SPACE ATMOSPHERE ON FRONT SURFACE AR COATINGS OF THE DEVICE.

TEST LASER-TO-ELECTRIC ENERGY CONVERSION (TDMX 2122)

EXPERIMENT DESCRIPTION

THIS EXPERIMENT EMPLOYS AN EXISTING SOLAR CONCENTRATOR AND OPERATING, CHARACTERIZED SOLAR-PUMPED LASER TO POWER LASER CONVERTERS. THE INSTRUMENTED CONVERTERS (EITHER LASER PHOTOVOLTAIC OR LASER MHD DEVICES) ARE PLACED IN THE FAR-FIELD POSITION OF THE LASER BEAM. THE INITIAL EXPERIMENT IS THE PHOTOVOLTAIC DEVICE. SEVERAL DIFFERENT MATERIALS AND DEVICE GEOMETRIES ARE UNDER CONSIDERATION. POWER IS INCIDENT ON THE CONVERTER AT APPROXIMATELY 1 KW/CM^2 LEADING TO HIGH CURRENT DENSITIES AND REQUIRING THE REMOVAL OF HUNDREDS OF WATTS OF HEAT PER SQUARE CENTIMETER. THE CHALLENGE IS TO CONDUCT THIS HEAT FROM THE SEMICONDUCTOR, THROUGH AN ELECTRICALLY INSULATING HEAT TRANSFER FLUID, TO A ROOM TEMPERATURE HEAT SINK WITH ONLY A SMALL TEMPERATURE GRADIENT. DUE TO THE FLUID, THERMAL CONDUCTANCE IS EXPECTED TO BE INFLUENCED BY GRAVITY. IN ADDITION, ANTIREFLECTION (AR) COATINGS, REQUIRED TO MINIMIZE REFLECTION LOSSES, ARE SENSITIVE TO TEMPERATURE, THE SPACE ENVIRONMENT (ATOMIC OXYGEN, LOW PRESS, AND SOLAR UV LIGHT) AND TO INTENSE ILLUMINATION. THIS EXPERIMENT IS THE FIRST OPPORTUNITY TO ASSESS THE COMBINED LASER-POWER AND SPACE-ENVIRONMENT INTERACTION WITH THE AR COATING. THE DEVICE WILL BE INSTRUMENTED TO (1) MEASURE AND DISSIPATE THE LASER POWER, (2) MEASURE AND DISSIPATE THE CONVERTED ELECTRICAL POWER, (3) DETERMINE THE HEAT TRANSFER COEFFICIENT ACROSS THE SEMICONDUCTOR-FLUID-METAL INTERFACE AND (4) ASSESS THE OPTICAL SCATTERING AND ADSORPTION CHANGES OF THE AR COATING WITH TIME.



Layout of the Photovoltaic Laser-to-Energy Conversion Experiment TDMX 2122.

EXPERIMENT TITLE: TDMX 2122 Laser-to-Electric Energy Conversion

PROPOSED FLIGHT DATE - 1992 YEAR

OPERATIONAL DAYS REQUIRED - 30

MASS - 20 KG

VOLUME: 1 m^3

STORED W 1 m x L 1 m x H 1 m = 1 M^3

DEPLOYED W 1 m x L 1 m x H 1 m = 1 M^3

INTERNALLY ATTACHED no (YES/NO)
EXTERNALLY ATTACHED yes (YES/NO)
FORMATION FLYING no (YES/NO)

ORIENTATION (inertial, solar, earth, other) (Solar - see TDMX 2111)

EXTRA-VEHICULAR ACTIVITY REQUIRED:

SET-UP: 2 Hrs/Day 1 No. of days for each device

OPERATIONS: 0 Hrs/Day ____ No. of days ____ Interval

SERVICING 0 Hrs/Day ____ No. of days ____ Interval

INTRA-VEHICULAR ACTIVITY REQUIRED:

SET-UP: 0 Hrs/Day ____ No. of days

OPERATIONS: 0 Hrs/Day ____ No. of days ____ Interval

SERVICING 0 Hrs/Day ____ No. of days ____ Interval

POWER REQUIRED:

0 KW AC or DC (circle one)

0 Hrs/Day ____ No. of days

DATA RATE: 10^{-3} Megabits/second

DATA STORAGE: 10^{-3} Gigabits

NASA/MSFC

TDM 2151

G. BAKKEN

SOLAR ARRAY/ENERGY STORAGE TECHNOLOGY

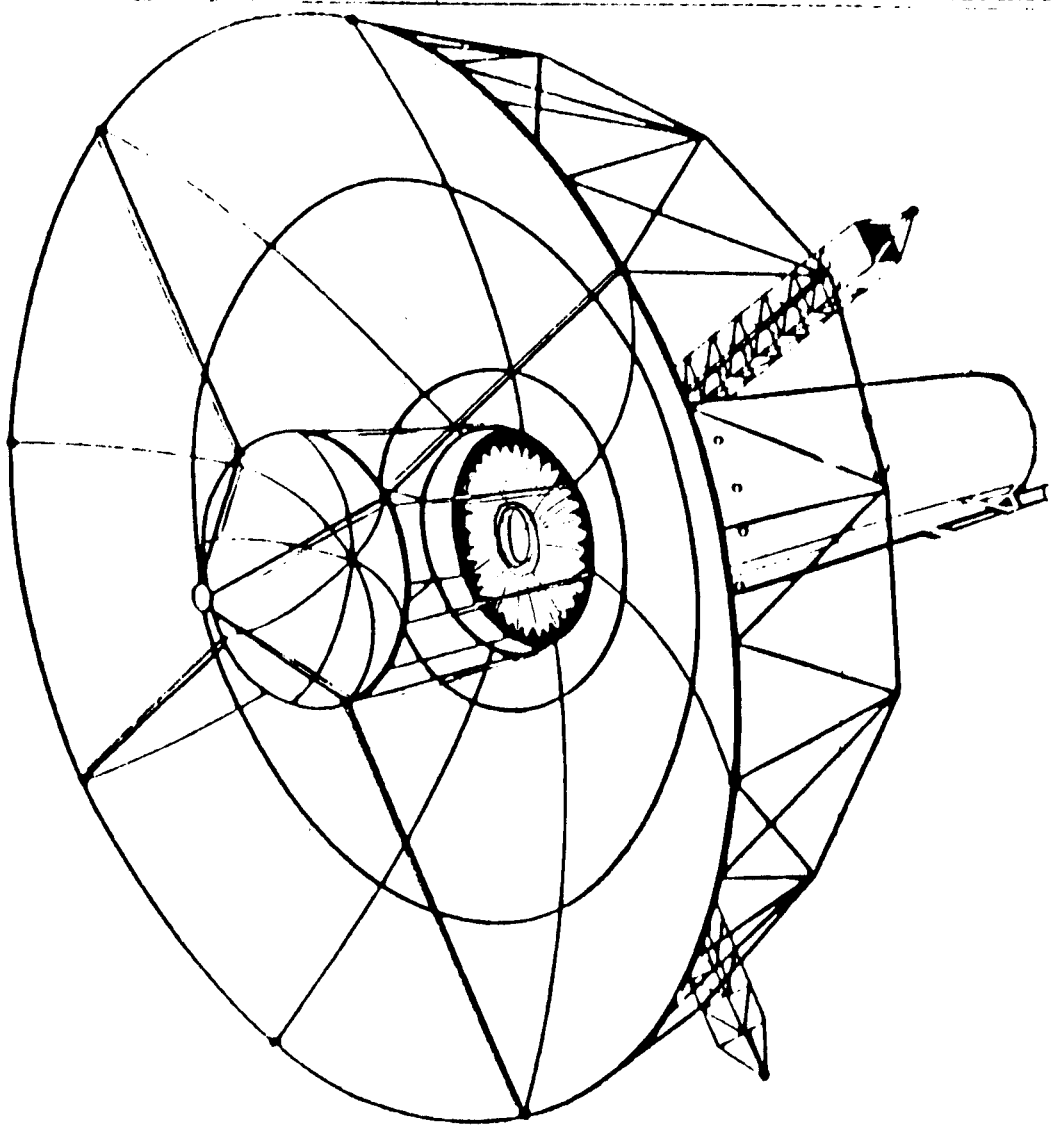
EXPERIMENT OBJECTIVE

TO DEMONSTRATE POWER SYSTEM TECHNOLOGY SUCH AS SOLAR ARRAY/ELECTROLYSIS OR INERTIAL ENERGY STORAGE REQUIRING AN ENGINEERING MODEL TO BE TESTED IN SPACE PRIOR TO OPERATIONAL APPLICATIONS.

EXPERIMENT DESCRIPTION

A PHASED PROGRAM WILL ALLOW ORBITAL TEST AND EVALUATION OF ENERGY STORAGE UNITS WHICH COULD BE USED FOR VARIOUS SPACE MISSIONS. INITIAL EMPHASIS WILL BE PLACED ON THE USE OF ELECTROLYSIS WHICH COULD UTILIZE POWER FROM SOLAR ARRAYS TO GENERATE OXYGEN AND HYDROGEN FROM WATER. APPLICATION TO REGENERATING FUEL CELLS AND/OR PROPULSION SYSTEMS COULD BE MADE FROM THE STORED OXYGEN AND HYDROGEN. ADDITIONAL TESTS OF INERTIAL ENERGY STORAGE DEVICES ARE ALSO ANTICIPATED.

CONCEPT FOR SOLAR ARRAY/ENERGY STORAGE EXPERIMENT



WYLE

EXPERIMENT TITLE: TDM 2151 SOLAR ARRAY/ENERGY STORAGE TECHNOLOGY

PROPOSED FLIGHT DATE - 1993 YEAR

OPERATIONAL DAYS REQUIRED - 700

MASS - 280 KG

VOLUME:

STORED: W 1.0 x L .65 x H .6 = .39 M^3

DEPLOYED: W _____ x L _____ x H _____ = _____ M^3

INTERNALLY ATTACHED YES (YES/NO)
EXTERNALLY ATTACHED NO (YES/NO)
FORMATION FLYING NO (YES/NO)

ORIENTATION (inertial, solar, earth, other) NONE

EXTRA-VEHICULAR ACTIVITY REQUIRED: NONE

SET-UP: _____ Hrs/Day _____ No. of days

OPERATIONS: _____ Hrs/Day _____ No. of days _____ Interval

SERVICING: _____ Hrs/Day _____ No. of days _____ Interval

INTRA-VEHICULAR ACTIVITY REQUIRED:

SET-UP: 5 Hrs/Day 2 No. of days

OPERATIONS: 0 Hrs/Day _____ No. of days _____ Interval

SERVICING: .1 Hrs/Day 24 No. of days 2YR Interval

POWER REQUIRED:

2 KW AC or DC (circle one)

24 Hrs/Day 700 No. of days

DATA RATE: LOW Megabits/second

DATA STORAGE: LOW Gigabits

MEGAWATT POWER MANAGEMENT
EXPERIMENT OBJECTIVE

TO DEMONSTRATE BOTH AC AND DC MEGAWATT POWER MANAGEMENT IN SPACE AND ASSESS THE IMPACTS OF THE SPACE ENVIRONMENT AND SPACECRAFT DESIGN CONSTRAINTS ON PMAD COMPONENTS AND CIRCUITS INCLUDING:

- INVERTERS
- TRANSMISSION LINES
- BREAKERS
- TRANSFORMERS
- RECTIFIERS

MEGAWATT POWER MANAGEMENT
EXPERIMENT DESCRIPTION

COMPONENTS AND CIRCUITS RATED AT 1 MW

- o FACTOR OF 10-20 INCREASE OVER IOC SPACE STATION
- o APPLICABLE TO MODULAR SYSTEMS OF 10-20 MW
- o UNIQUE COMPONENT DESIGNS (LOW MASS, ADVANCED COOLING, ELECTRONIC, ETC.)

TEST REQUIREMENTS

- o OPERATE ON AVAILABLE POWER (70 KW MAX)
- o RESOLVE ISSUES ON SPACE ENVIRONMENT & SPACECRAFT DESIGN
  - HEAT TRANSPORT (INTERNAL & EXTERNAL)
  - TRANSIENTS
  - EMI & GROUNDING
  - PLASMA INTERACTIONS
- o TEST BOTH AC AND DC SYSTEMS AT QUASI-STEADY STATE
- o MINIMIZE USE OF STS AND SS RESOURCES

EXPERIMENT DESCRIPTION - (CONTINUED)

APPROACH

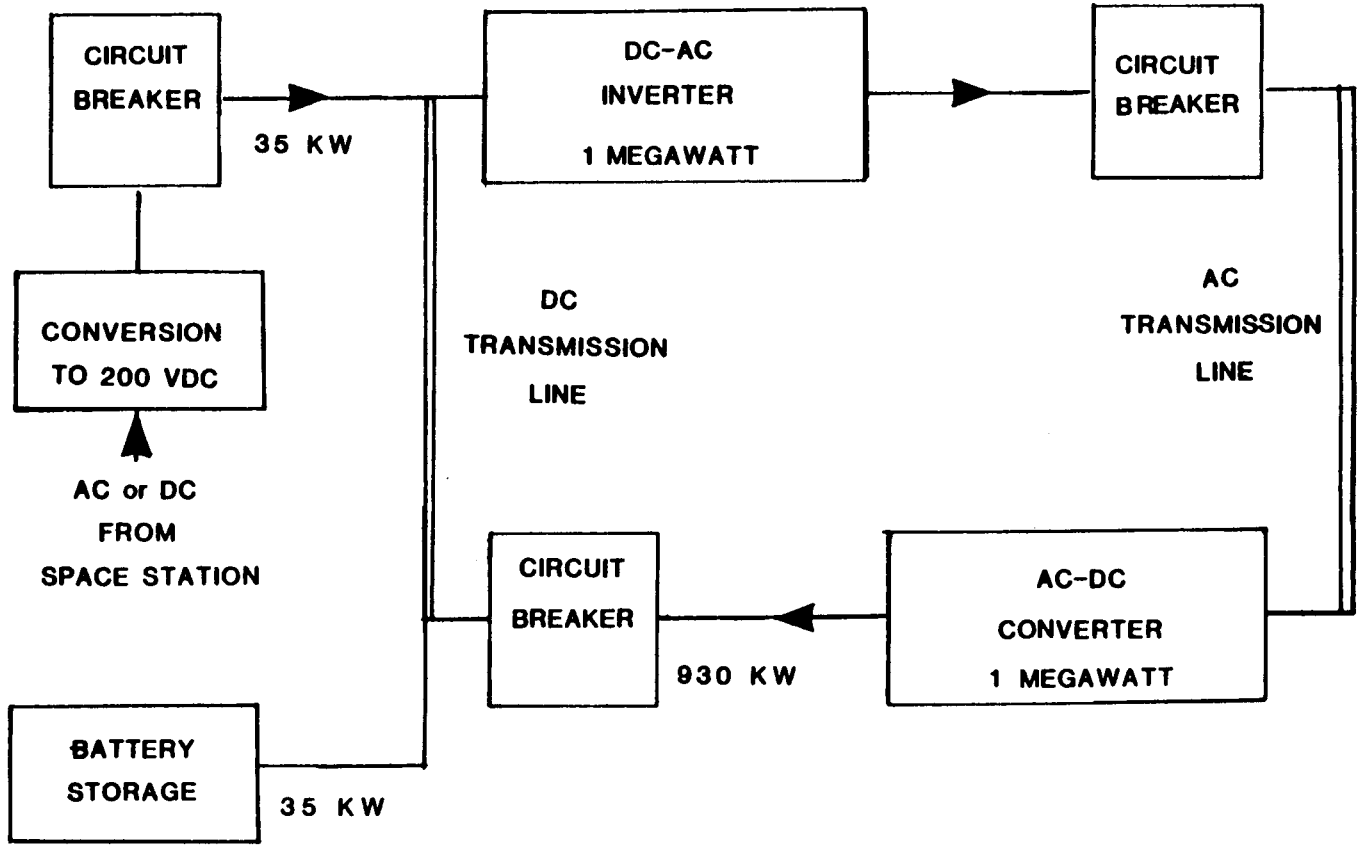
- o CIRCUIT ELEMENTS ARE CONNECTED IN CLOSED LOOP WITH 35-70 KW AC OR DC FEED FROM SS POWER SYSTEM
  - DC : RECTIFIER → FILTER/STORAGE → BREAKER → TRANSMISSION LINE → INVERTER
  - AC : INVERTER → BREAKER → TRANSMISSION LINE → RECTIFIER
- o STORAGE, FILTERS AND LOADS ADDED AS NEEDED
  - STARTUP
  - STABILITY
  - TRANSIENT SIMULATION

National Aeronautics and Space Administration
Lewis Research Center

POWER TECHNOLOGY DIVISION

NASA

MEGAWATT POWER MANAGEMENT IN-SPACE EXPERIMENT



EXPERIMENT TITLE: MEGAWATT POWER MANAGEMENT SPACE STATION EXPERIMENT

PROPOSED FLIGHT DATE - 1995 YEAR

OPERATIONAL DAYS REQUIRED - 2

MASS - 20,000 KG

VOLUME:

STORED: W 2.5 x L 10M x H 2.5 = 62.5 M^3

DEPLOYED: W 2.5 x L 50M x H 2.5 = 300 M^3

INTERNALLY ATTACHED NO (YES/NO)
EXTERNALLY ATTACHED YES (YES/NO)
FORMATION FLYING NO (YES/NO)

ORIENTATION (inertial, solar, earth, other) FIXED WITH RESPECT TO SPACE STATION

EXTRA-VEHICULAR ACTIVITY REQUIRED:

SET-UP: 4 Hrs/Day 2 No. of days

OPERATIONS: 4 Hrs/Day 2 No. of days - Interval

SERVICING: - Hrs/Day - No. of days - Interval

INTRA-VEHICULAR ACTIVITY REQUIRED:

SET-UP: - Hrs/Day - No. of days

OPERATIONS: - Hrs/Day - No. of days - Interval

SERVICING: - Hrs/Day - No. of days - Interval

POWER REQUIRED:

35 KW AC or DC (circle one) EITHER

4 Hrs/Day 2 No. of days

DATA RATE: N/A Megabits/second

DATA STORAGE: N/A Gigabits

SPACE STATION SYSTEMS
ADVANCED PROGRAMS & PLANNING OFFICE

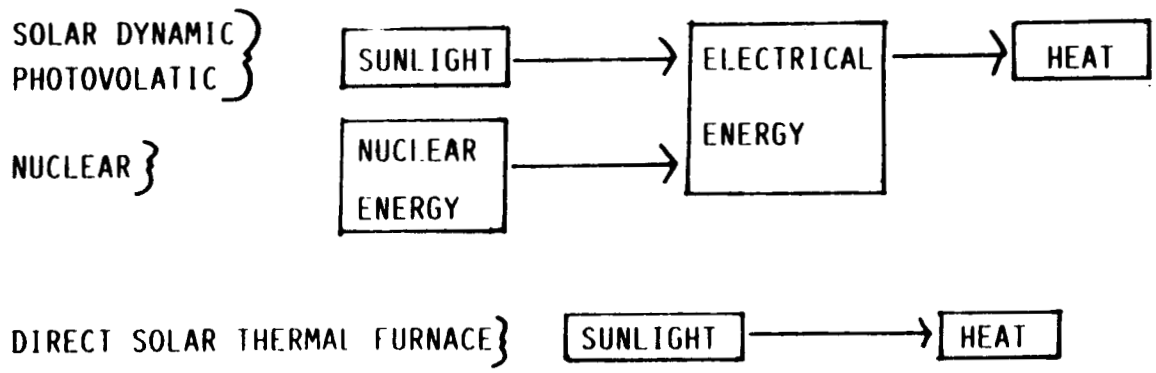
SUE BENFORD
Lewis Research Center

NASA

PROPOSED SPACE STATION EXPERIMENT
DIRECT SOLAR THERMAL FURNACE TECHNOLOGY

OBJECTIVE:

TO IMPROVE THE EFFICIENCY OF POWER DELIVERY TO MATERIALS PROCESSING EXPERIMENTS WHICH REQUIRE LARGE AMOUNTS OF HEAT ENERGY BY TRANSMITTING SUNLIGHT DIRECTLY TO SPECIALLY DESIGNED FURNACES (PYROSTATS); AVOIDS LOSSES ASSOCIATED WITH CONVERSION INTO ELECTRICAL ENERGY, REQUIRES UNIQUE COLLECTION/TRANSMISSION/FURNACE DESIGN.



PROPOSED SPACE STATION EXPERIMENT

DIRECT SOLAR THERMAL FURNACE TECHNOLOGY

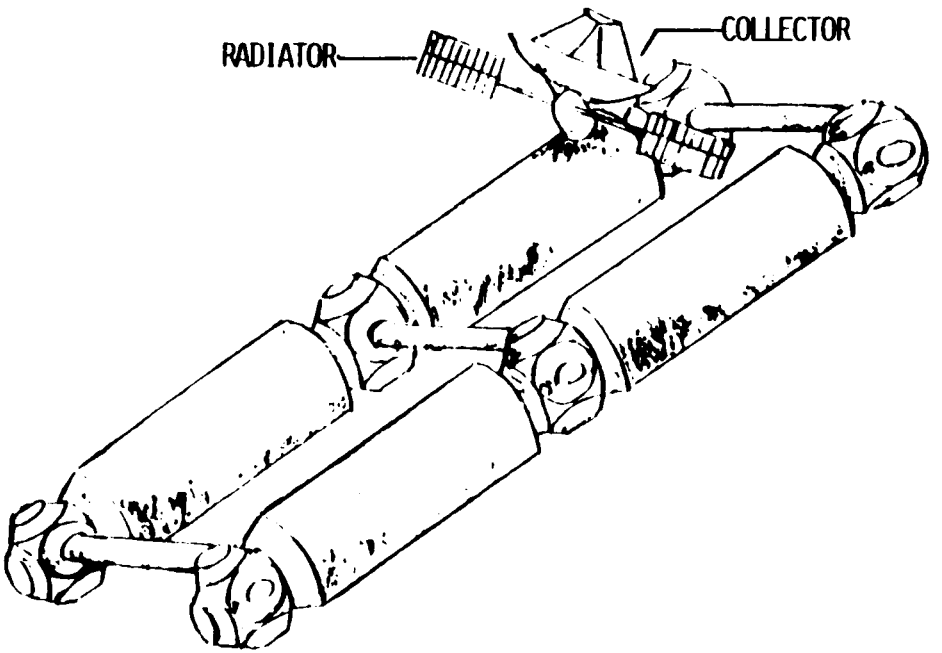
DESCRIPTION:

THE DIRECT SOLAR THERMAL TEST FACILITY CONSISTS OF A COLLECTOR, TRANSMISSION PATH, THERMAL STORAGE AND DELIVERY SYSTEM, COOLANT STORAGE AND DELIVERY SYSTEM, AND A SPECIALLY DESIGNED FURNACE (PYROSTAT). SUNLIGHT IS GATHERED BY A PARABOLIC MIRROR COLLECTOR AND TRANSMITTED TO A FOCUSING ELEMENT WHICH DELIVERS THE BEAM TO A SMALL SAMPLE LOCATED IN AN EVACUATED FURNACE AND/OR A THERMAL STORAGE UNIT. THE BEAM MAY IMPINGE DIRECTLY ON A SAMPLE FOR RAPID MELTING OR IMPINGE UPON A CIRCULATING FLUID WHICH WOULD HEAT THE SAMPLE SLOWLY BY RADIATION. "ZONES" MAY BE ESTABLISHED BY A COMBINATION OF BEAM FOCUSING AND RADIATION HEATING. THE FACILITY WOULD INCLUDE BOTH ACTIVE AND PASSIVE COOLING. THE SKETCH SHOWS A NOMINALLY 20KW PEAK POWER UNIT WHICH WOULD MELT A 2CM. DIA. x 7.5CM. LENGTH ROD OF COPPER IN THREE SECONDS. THE COLLECTOR DIAMETER FOR THIS UNIT, MOUNTED DIRECTLY ON A SPACE STATION MODULE, IS 5.0 M ATTACHED OR FREE FLYER.

SPACE STATION SYSTEMS
ADVANCED PROGRAMS & PLANNING OFFICE

DIRECT SOLAR THERMAL FURNACE FACILITY

20kw PEAK POWER



EXPERIMENT TITLE: Direct Solar Thermal Furnace Technology

PROPOSED FLIGHT DATE - 1995 YEAR

OPERATIONAL DAYS REQUIRED - 90

MASS - 2,000 KG

VOLUME:

STORED: W _____ x L _____ x H _____ = _____ M^3

DEPLOYED: W TBD x L N/A x H Dia. 5m = 20 M^3

INTERNALLY ATTACHED _____ (YES/NO)
EXTERNALLY ATTACHED Yes (YES/NO)
FORMATION FLYING Yes (YES/NO)

ORIENTATION (inertial, solar, earth, other) Solar

EXTRA-VEHICULAR ACTIVITY REQUIRED:

SET-UP: TBD Hrs/Day TBD No. of days

OPERATIONS: _____ Hrs/Day _____ No. of days _____ Interval

SERVICING: _____ Hrs/Day _____ No. of days _____ Interval

INTRA-VEHICULAR ACTIVITY REQUIRED:

SET-UP: _____ Hrs/Day _____ No. of days

OPERATIONS: 5 Hrs/Day 90 No. of days _____ Interval

SERVICING: _____ Hrs/Day _____ No. of days _____ Interval

POWER REQUIRED: (Own Power)

N/A KW AC or DC (circle one)

N/A Hrs/Day N/A No. of days

DATA RATE: TBD Megabits/second

DATA STORAGE: TBD Gigabits

SOLAR DYNAMIC TEST FACILITY

TDMX 2153

EXPERIMENT OBJECTIVES

0 PROVIDE DEDICATED AREA/LOCATION ON THE IOC SPACE STATION FOR TEST AND EVALUATION OF ADVANCED CANDIDATE SOLAR DYNAMIC POWER SYSTEMS, SUBSYSTEMS AND COMPONENTS. THE FACILITY IS TO PROVIDE THE CAPABILITY FOR LONG TERM EVALUATION OF ADVANCED TECHNOLOGY HARDWARE UNDER ACTUAL SPACE ENVIRONMENTAL CONDITIONS AND DYNAMIC SPACE STATION INTERFACES.

EXPERIMENT DESCRIPTION

INDEPENDENT OF THE SELECTION OF THE SPACE STATION IOC POWER SYSTEM DEVELOPMENT OF ADVANCED SOLAR DYNAMIC POWER SYSTEM TECHNOLOGY AT THE COMPONENT, SUBSYSTEM AND SYSTEM LEVEL WILL UTILIZE THE TECHNOLOGY BASE DEVELOPED FOR THE IOC SPACE STATION WILL IDENTIFY FUTURE TECHNOLOGY NEEDED TO IMPROVE PERFORMANCE, EFFICIENCY, WEIGHT, SIZE, RELIABILITY ETC.

RESEARCH AND TECHNOLOGY DEVELOPMENT WILL BE INITIATED AND CONDUCTED IN GROUND PROGRAMS AT THE COMPONENT, SUBSYSTEM AND SYSTEM LEVEL FOR ADVANCED POWER SYSTEMS (STIRLING, HIGH TEMP. BRAYTON ETC.). THE PROGRAM INVOLVES HIGH EFFICIENCY SOLAR CONCENTRATORS, RECEIVERS, RADIATORS & POWER CONVERSION SYSTEMS. SPACE ENVIRONMENT WILL BE SIMULATED TO THE MAXIMUM PRACTICAL EXTENT.

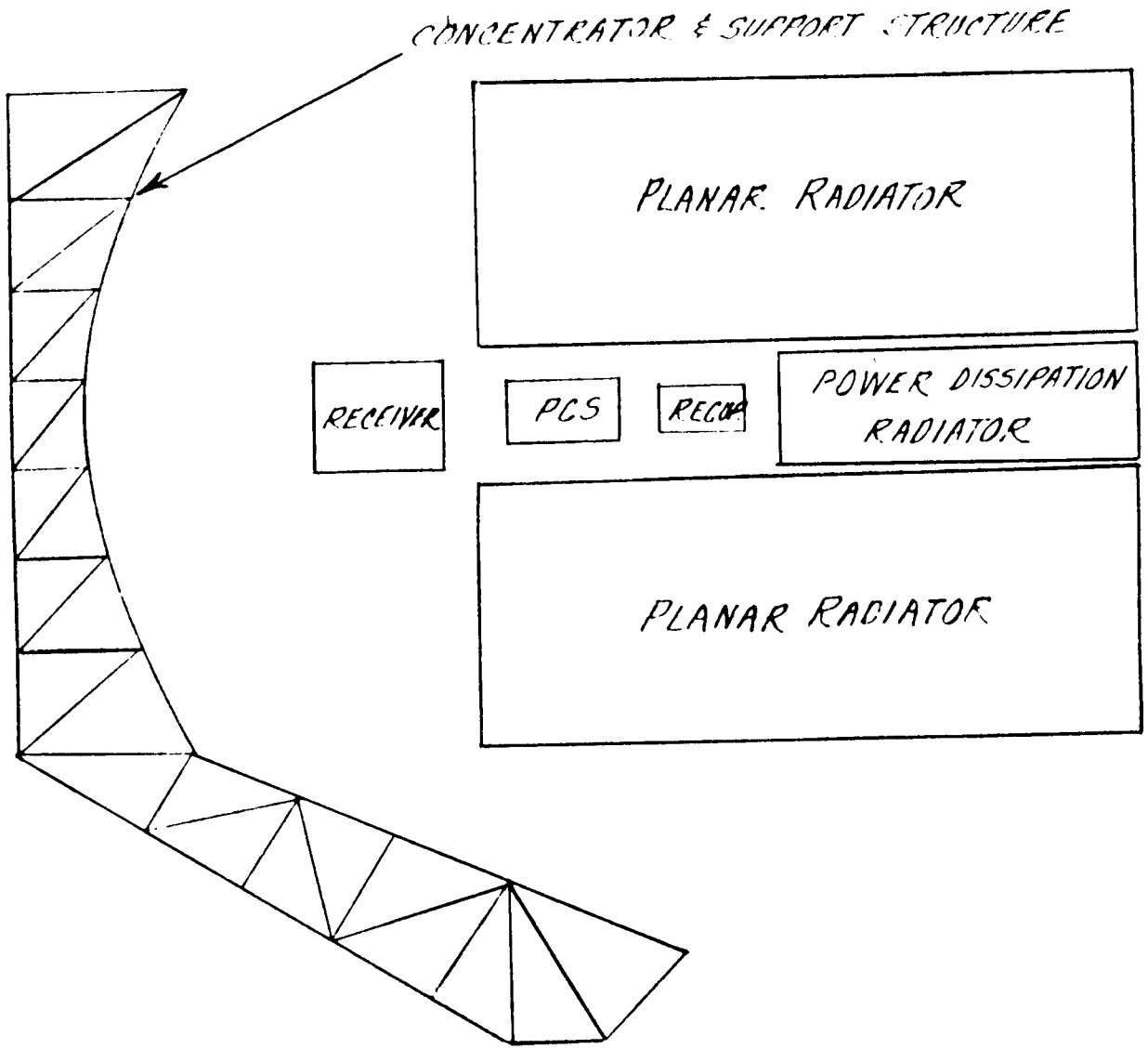
AVAILABILITY OF A TEST BED FOR LONG TERM EVALUATION UNDER THE ACTUAL SPACE ENVIRONMENT AND DYNAMIC SPACE STATION INTERFACE WILL PROVIDE A REALISTIC TECHNICAL ASSESSMENT. UTILIZATION OF THE SPACE POTENTIAL PROVIDES AN EFFECTIVE "R & T" TOOL WHICH CAN'T BE DUPLICATED ON EARTH.

LOCATION AND SIZE OF THE TEST BED WILL BE DETERMINED BY SITE AVAILABILITY, IOC CONFIGURATION AND INTEGRATION REQUIREMENTS.

ELECTRIC POWER AND DATA ACQUISITION CAPABILITY WILL BE REQUIRED FOR THE TEST BED. INSTRUMENTATION REQUIREMENTS ARE EXPERIMENT DEPENDENT. GROUND CONTROL OF THE EXPERIMENT WILL BE USED. A CONTROL AND POINTING SYSTEM WILL BE REQUIRED FOR THE SOLAR CONCENTRATOR.

SOLAR DYNAMIC TEST FACILITY

TDMX - 2153



EXPERIMENT TITLE: SOLAR DYNAMIC TEST FACILITY

PROPOSED FLIGHT DATE - TBD YEAR

OPERATIONAL DAYS REQUIRED - TBD

MASS - TBD KG

VOLUME: TBD

STORED: W ____ x L ____ x H ____ = ____ M^3

DEPLOYED: W ____ x L ____ x H ____ = ____ M^3

INTERNALLY ATTACHED ____ (YES/NO)
EXTERNALLY ATTACHED ____ (YES/~~NO~~)
FORMATION FLYING ____ ~~(YES/NO)~~

ORIENTATION (inertial, solar, earth, other) SOLAR

EXTRA-VEHICULAR ACTIVITY REQUIRED:

SET-UP: TBD Hrs/Day TBD No. of days

OPERATIONS: TBD Hrs/Day TBD No. of days ____ Interval

SERVICING: TBD Hrs/Day TBD No. of days ____ Interval

INTRA-VEHICULAR ACTIVITY REQUIRED:

SET-UP: TBD Hrs/Day TBD No. of days

OPERATIONS: TBD Hrs/Day TBD No. of days ____ Interval

SERVICING: TBD Hrs/Day TBD No. of days ____ Interval

POWER REQUIRED:

TBD KW AC or DC (circle one)

TBD Hrs/Day TBD No. of days

DATA RATE: TBD Megabits/second

DATA STORAGE: TBD Gigabits

RADIATOR TECHNOLOGY

G. BAKKEN

EXPERIMENT OBJECTIVE

TO DEVELOP TECHNOLOGY FOR HIGH PERFORMANCE, LONG-LIFE, LIGHT-WEIGHT, REPAIRABLE/REFURBISHABLE RADIATOR ELEMENTS.

EXPERIMENT DESCRIPTION

THE PROPOSED MISSION WILL INVESTIGATE THERMAL PERFORMANCE AND STRUCTURAL DYNAMIC CHARACTERISTICS OF ADVANCED RADIATOR CONCEPTS, IN DEPLOYED, PARTIALLY DEPLOYED, AND RETRACTED NODES AND UNDER SIMULATED FAILURE/DEGRADATION CONDITIONS, AND WILL DEVELOP TECHNOLOGY FOR ON-ORBIT REPAIR/REFURBISHMENT. RADIATOR TYPES MAY INCLUDE FIXED AND ORIENTABLE VERSIONS OF ACTIVE AND PASSIVE CONCEPTS. EFFECTS OF LONG-DURATION EXPOSURE TO NOMINAL AND EXTREME ENVIRONMENTS AND TO THERMAL AND MECHANICAL CYCLING WILL BE MEASURED.

TDM 2565 Thermal Interface Technology

PI: MSFC/Robert Middleton

Objective

To develop and demonstrate techniques to remove components from a cold plate heat sink in orbit via EVA and replace them. restoring adequate thermal conductivity by proper replacement of the fill material between component cold plate.

Description

Simulated components (black boxes) representing various sizes and fastening methods will be mounted to a cold plate. Various fill material will be incorporated between the component and cold plate. The simulated components will incorporate controllable heaters to represent heat dissipation of the component. Instrumentation will measure cold plate and component temperatures so that conductivity from component to cold plate can be determined. An astronaut in EVA will remove the components and replace them after restoring the fill material. The interface thermal conductivity will be measured to determine the effectiveness of the procedure. Several trials using different methods and fill materials will be made.

NUCLEAR PUMPED LASERS

by

GEORGE H. MILEY
UNIVERSITY OF ILLINOIS

EXPERIMENTAL OBJECTIVE:

NUCLEAR PUMPED LASERS ARE PARTICULARLY SUITABLE FOR SPACE APPLICATIONS DUE TO THE ENORMOUS ENERGY TO MASS RATIO OF THE NUCLEAR FUEL. A METHOD FOR COUPLING NUCLEAR ENERGY TO A LASER MEDIA BY CONVERTING CHARGED-PARTICLE ENERGY TO PHOTON ENERGY WHICH CAN THEN BE USED FOR PHOTOLYTIC LASER PUMPING IS DESIRABLE DUE TO THE ATTAINABLE ENERGY FOCUSSING. UTILIZATION OF URANIUM MICROSPHERES FOR PUMPING A NUCLEAR "FLASHLAMP" WAS PREVIOUSLY PROPOSED AT THE UNIVERSITY OF ILLINOIS. EXPERIMENTAL TESTING OF THE PERFORMANCE OF SUCH MICROSPHERES SUSPENDED IN SPACE IS PROPOSED.

NUCLEAR PUMPED LASERS

by

GEORGE H. MILEY
UNIVERSITY OF ILLINOIS

EXPERIMENT DESCRIPTION:

THE PROPOSED EXPERIMENT IS BUILT AROUND A URANIUM PELLET SUSPENSION SPHERE. URANIUM PELLETS WILL BE INJECTED INTO THE SPHERE FROM A STORAGE COMPARTMENT. A NEUTRON SOURCE IS CONNECTED TO THE SPHERE THROUGH SEVERAL LAYERS OF CADMIUM AND POLYTHYLINE SHIELDING ALLOWING FOR VARIATION OF NEUTRON FLUX AND SPECTRUM. THE WHOLE SPHERE IS SHIELDED BEHIND SEVERAL CENTIMETERS OF CADMIUM.

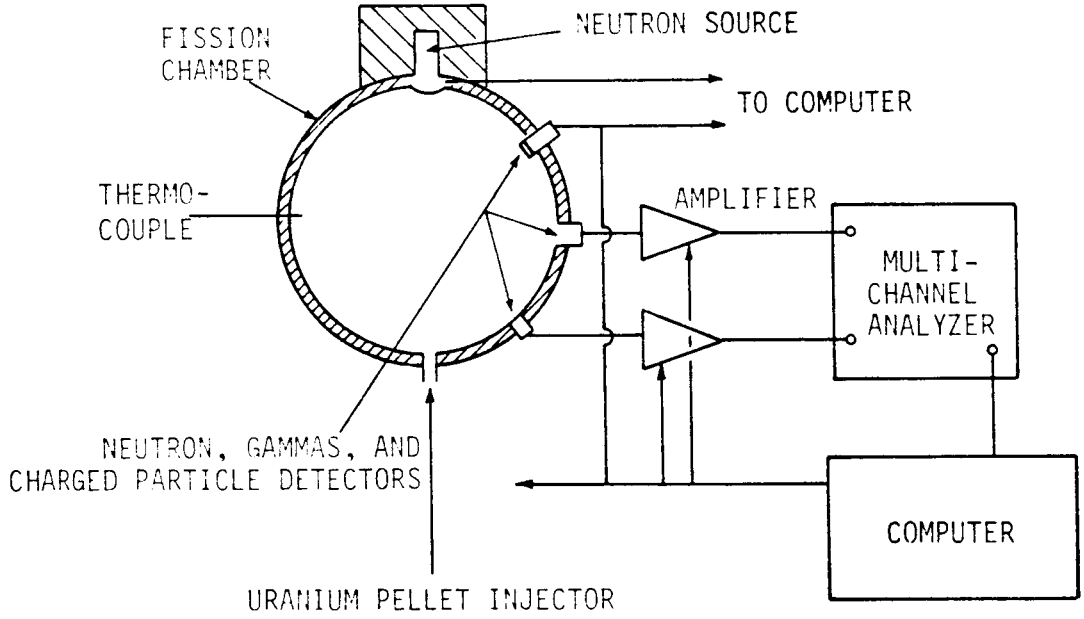
A LARGE SET OF DIAGNOSTIC TOOLS WILL BE CONNECTED TO THE SPHERE. THESE INCLUDE NEUTRON, CHARGED PARTICLE, AND GAMMA DETECTORS AND A THERMOCOUPLE. NEUTRONS WILL BE DETECTED BY A ^{10}B IONIZATION CHAMBER SURROUNDED BY A VARIABLE THICKNESS OF POLYTHYLINE TO ALLOW FOR NEUTRON SPECTRA ANALYSIS. THE SPECTRA OF CHARGED PARTICLES IS MONITORED BY A SURFACE BARRIER DETECTOR CONNECTED TO A MULTICHANNEL ANALYZER. THE GAMMA RAY SPECTRA IS MONITORED BY A SCINTILLATION DETECTOR.

THE EXPERIMENTAL PLAN MAINLY CONSISTS OF THE STUDY OF THE POWER DEPOSITION AND RADIATION SPECTRA FROM A MICROPELLET DRIVEN FISSION SYSTEM. THE QUESTION OF STABILITY OF SUCH A DEVICE (THE POTENTIAL FUEL BUNCHING PROBLEM) WILL BE ADDRESSED. INITIALLY OPERATION AT VERY LOW POWERS WILL BE CONDUCTED. IF SUITABILITY IS DEMONSTRATED, HIGH POWER OPERATIONS WILL BE PLANNED FOR LATER MISSIONS.

NUCLEAR PUMPED LASERS

by

GEORGE H. MILEY
UNIVERSITY OF ILLINOIS



SET-UP FOR SPACE SUSPENDED URANIUM MICROSPHERE STUDIES

GEORGE H. MILEY
UNIVERSITY OF ILLINOIS

EXPERIMENT TITLE: NUCLEAR PUMPED LASERS

PROPOSED FLIGHT DATE - 1986 YEAR

OPERATIONAL DAYS REQUIRED - ~ 2

MASS - < 400 KG

VOLUME:

STORED: W 3 x L 3 x H 3 = 27 M^3 (max.)

DEPLOYED: W 3 x L 3 x H 3 = 27 M^3 (max.)

INTERNALLY ATTACHED YES (YES/NO)
EXTERNALLY ATTACHED NO (YES/NO)
FORMATION FLYING NO (YES/NO)

ORIENTATION (inertial, solar, earth, other) N/A

EXTRA-VEHICULAR ACTIVITY REQUIRED: N/A

SET-UP: _____ Hrs/Day _____ No. of days

OPERATIONS: _____ Hrs/Day _____ No. of days _____ Interval

SERVICING: _____ Hrs/Day _____ No. of days _____ Interval

INTRA-VEHICULAR ACTIVITY REQUIRED:

SET-UP: 12 Hrs/Day 3 No. of days

OPERATIONS: 8 Hrs/Day 2 No. of days _____ Interval

SERVICING: - Hrs/Day - No. of days _____ Interval

POWER REQUIRED:

< 12 KW AC or DC (circle one)

8 Hrs/Day ~ 2 No. of days

DATA RATE: - Megabits/second

DATA STORAGE: - Gigabits

ARRAY BLANKET ZERO-G FOLDUP EXPERIMENT

OBJECTIVE

The objective of this proposed Space Station experiment is to reduce the mass of the system that provides zero-g foldup of a deployed solar array and to improve zero-g testing methods.

The specific objective of this experiment are:

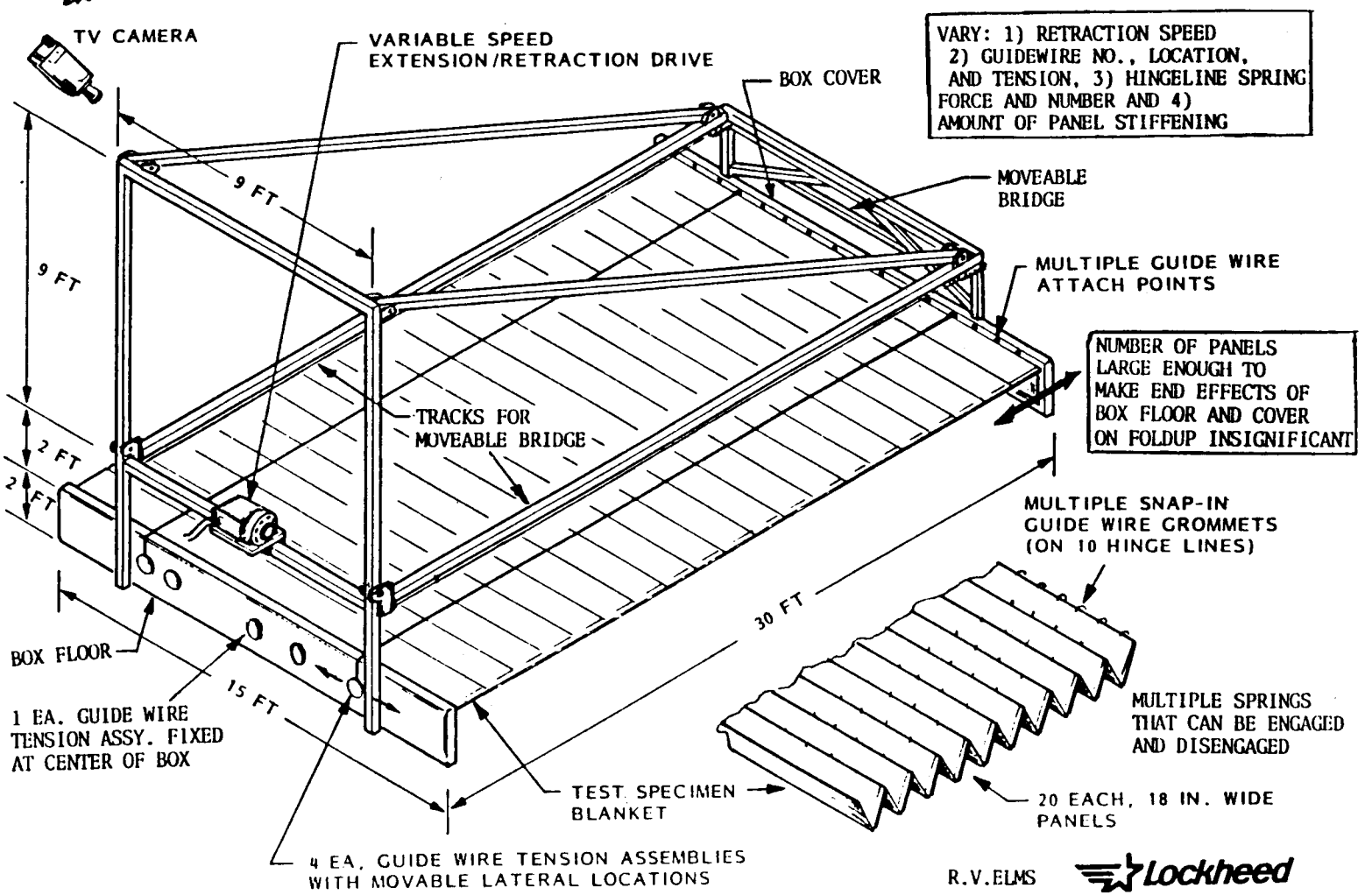
- o DEVELOP TOOLS FOR MINIMUM WEIGHT ZERO-G FOLDUP DESIGN
- o DESIGN TEST SPECIMEN AND TEST FIXTURE WITH CAPABILITY TO VARY DESIGN PARAMETER VALUES AND TEST SPECIMEN CONFIGURATION ON-ORBIT
- o SIMULATE NON-NOMINAL COMPONENT PERFORMANCE & COMPONENT TOTAL FAILURE (PROVIDE BACKUP/RECOVERY DESIGN IN EXPERIMENT FOR RETRACTION FAILURES)
- o OBTAIN TEST DATA TO CORRELATE TEST SPECIMEN PERFORMANCE WITH PERFORMANCE PREDICTIONS
- o IMPROVE ZERO-G TEST METHODS & RESULTS OVER GROUND AND AIRCRAFT TESTING.

EXPERIMENT DESCRIPTION

The experiment consists of a test fixture, a data acquisition system, and a test specimen. The test specimen is a simulation of a foldup solar array blanket that is stored for STS launch between a containment box floor and a containment box cover. A test fixture is launched and attached to the Space Station. The fixture allows attachment of the test specimen containment box floor in a fixed position and attachment of the box cover to a movable bridge structure which rides on a dual track. An electric motor on the test fixture drives the movable bridge through a cable/pulley system. The bridge takes the box cover out away from the box floor and extends the test blanket which has its outboard edge attached to the box cover. A blanket bottom tension system tensions the extended blanket. The motor drive system retracts the array blanket. The retraction rate (which is selectable and variable) is recorded. Two Television cameras and TV tape recorders on the Station record the blanket foldup design operation. The location, number, and tension in the blanket guide wires is variable. The maximum panel stiffening design initially on the blanket panels is removable in steps to reduce the panel stiffening Springs on the blanket hinges may be deactivated or activated to vary the spring force and locations.

It is estimated that five 6-hr. EVA periods would set up the experiment, run the test series, make configuration changes, and break down the experiment.

BLANKET FOLDUP ZERO-G EXPERIMENT



R.V.ELMS

• EXPERIMENT TITLE: SOLAR ARRAY BLANKET ZERO-G FOLDUP

PROPOSED FLIGHT DATE - 1993 YEAR

OPERATIONAL DAYS REQUIRED - 5

MASS - 200 KG

VOLUME:

STORED: W 3.4 x L 12 x H 1.1 = 44.9 M^3

DEPLOYED: W 5.7 x L 11.4 x H 5.0 = 325 M^3

INTERNALLY ATTACHED NO (YES/NO)
EXTERNALLY ATTACHED YES (YES/NO)
FORMATION FLYING NO (YES/NO)

ORIENTATION (inertial, solar, earth, other) 1/2 OPERATIONS WITH SOLAR ILLUMINATION

EXTRA-VEHICULAR ACTIVITY REQUIRED:

SET-UP 3 Hrs/Day 2 No. of days (INCLUDES BREAKDOWN)

OPERATIONS: 6 Hrs/Day 5 No. of days b No Interval required.

SERVICING: None Hrs/Day — No. of days — Interval

INTRA-VEHICULAR ACTIVITY REQUIRED:

SET-UP: 3 Hrs/Day 2 No. of days

OPERATIONS: 6 Hrs/Day 5 No. of days No Interval required.

SERVICING: None Hrs/Day — No. of days — Interval

POWER REQUIRED:

0.2 KW AC or DC (circle one)

4 Hrs/Day 5 No. of days

DATA RATE: .005 Megabits/second

DATA STORAGE: 0.5 Gigabits

R.V.ELMS

TDM 2541 Tethered Electrodynamic Power Generation

PI: MSFC/Georg von Tiesenhausen

Objective

To utilize an electrodynamic tether to supply either electrical energy to the Space Station or to provide a means to reboost the Space Station to its nominal altitude.

Description

A 100 Km electrodynamic tether deployed vertically from the Space Station to generate DC power levels in the 100 Kw range at the expense of orbital altitude. Conversely, use of the tether to function as thruster by injecting in the tether a reverse current to boost back the orbital altitude to the nominal value. The power phase would occur during the dark period, the boost phase during the daylight period.

OBJECTIVE OF EXPERIMENT

- PERFORM A FLIGHT TEST OF A REPRESENTATIVE ELEMENT OF A SOLAR DYNAMIC POWER GENERATION SYSTEM RECEIVER

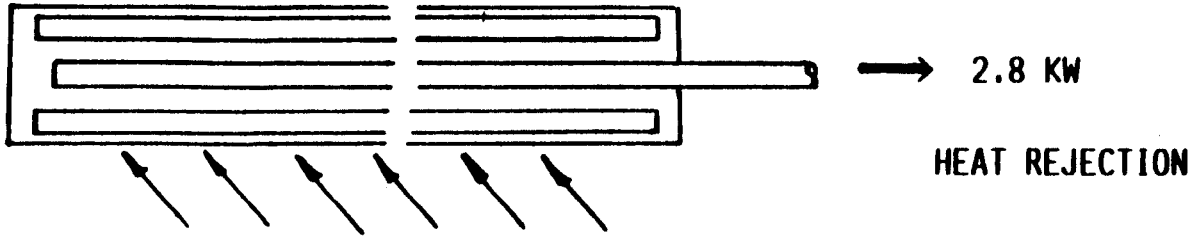
- DEMONSTRATE THAT CYCLIC OPERATION OF A HEAT PIPE WITH INTEGRAL SALT STORAGE IS NOT ADVERSELY AFFECTED BY ZERO-G OPERATION

DESCRIPTION OF EXPERIMENT

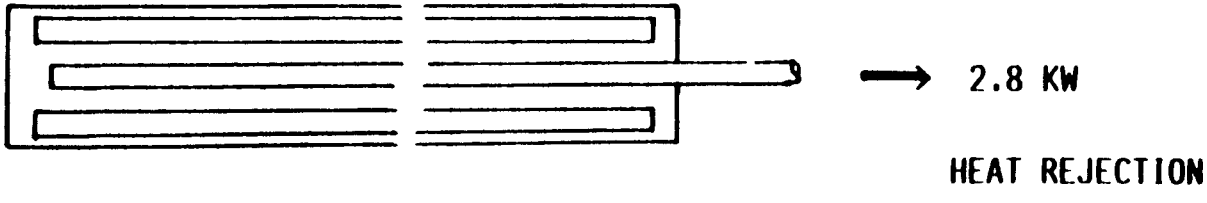
- PERFORM A FLIGHT TEST IN THE STS
- EMPLOY ELECTRICAL RESISTIVE HEATING TO SIMULATE SOLAR FLUXES ALONG THE LENGTH OF A POTASSIUM HEAT PIPE WHICH CONTAINS SALT THERMAL STORAGE CANISTERS
- HEATING AND COOLING RATES WILL SIMULATE THE SPACE STATION ORBIT
- A CLOSED-LOOP COOLANT SUPPLY WILL BE PROVIDED TO EXTRACT THERMAL POWER FROM THE HEAT PIPE DURING BOTH CHARGE AND DISCHARGE CYCLES. THE COOLANT LOOP WOULD INTERFACE WITH THE STS HEAT REJECTION SYSTEM
- THERMOCOUPLE INSTRUMENTATION WILL BE USED TO DETERMINE THERMAL OPERATION AND LOCATE HOT SPOTS

FULL SCALE HEAT-PIPE TEST

CHARGE CYCLE



DISCHARGE CYCLE



EXPERIMENT TITLE: THERMAL ENERGY STORAGE FOR SOLAR DYNAMIC PGS

PROPOSED FLIGHT DATE - 1990 YEAR

OPERATIONAL DAYS REQUIRED - 3

MASS - APPROX 40 KG

VOLUME:

STORED W _____ x L _____ x H _____ = 0.02 M^3

DEPLOYED W _____ x L _____ x H _____ = 0.02 M^3

INTERNALLY ATTACHED YES (YES/NO)
EXTERNALLY ATTACHED _____ (YES/NO)
FORMATION FLYING _____ (YES/NO)

ORIENTATION (inertial, solar, earth, other) ANY

EXTRA-VEHICULAR ACTIVITY REQUIRED: NONE

SET-UP: _____ Hrs/Day _____ No. of days

OPERATIONS: _____ Hrs/Day _____ No. of days ____ Interval

SERVICING _____ Hrs/Day _____ No. of days ____ Interval

INTRA-VEHICULAR ACTIVITY REQUIRED: NONE

SET-UP: _____ Hrs/Day _____ No. of days

OPERATIONS: _____ Hrs/Day _____ No. of days ____ Interval

SERVICING _____ Hrs/Day _____ No. of days ____ Interval

POWER REQUIRED:

5 KW AC or DC (circle one) INTERMITTENT
+0.2 KW AC CONTINUOUS
_____ Hrs/Day 3 No. of days

DATA RATE: TBD Megabits/second

DATA STORAGE: TBD Gigabits