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SPACE POWER TECHNOLOGIES

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BY

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AIAA/OAST CONFERENCE ON
CSTI AND PATHFINDER
9/13/88

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WHAT WILL BE DISCUSSED

- OAST BASE RESEARCH AND TECHNOLOGY POWER PROGRAM

- PATHFINDER
  - ROVER POWER
  - SURFACE POWER
  - SPACE NUCLEAR POWER (SP-100)

- CSTI
  - HIGH CAPACITY POWER

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BASE R & T
POWER PROGRAM

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SPACE ENERGY CONVERSION R&T BASE PROJECT ELEMENTS

- **PHOTOVOLTAICS** — LeRC, JPL
  - CELLS, BLANKETS, MODULES — D. FLOOD P. STELLA
- **ELECTROCHEMISTRY** — LeRC, JPL
  - BATTERIES, FUEL CELLS — L. THALLER G. HALPRIN
- **THERMAL ENERGY CONVERSION** — LeRC, JPL
  - ADVANCED SOLAR DYNAMICS, AMTEC — M. WARSHAY P. BANKSTON
- **POWER MANAGEMENT** — LeRC, JPL
  - FAULT TOLERANT, 20 kHz, SPACE ENVIRON. ELECTROPHYSICS — R. BERCAW J. KLEIN
- **THERMAL MANAGEMENT** — LeRC, GSFC, JSC
  - ADVANCED RADIATORS, LOW TEMP. HEAT PUMPS, 0-G — M. WARSHAY T. SWANSON W. ELLIS

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PATHFINDER POWER SYSTEMS - MISSIONS

- **ROVER POWER**
  - LUNAR/MARS EXPLORATION
  - ROBOTIC EXPLORATION AND SAMPLE RETURN
  - LUNAR/MARS BASES
- **SURFACE POWER**
  - LUNAR/MARS OUTPOSTS
  - PILOTED MARS EXPEDITION
  - SPACECRAFT POWER
    - **EARTH ORBIT**
    - **OBSERVERS**
    - **TRANSFER**
    - **OTHERS**
- **SPACE NUCLEAR POWER (SP-100)**
  - LUNAR/MARS BASES
  - MANNED MARS EXPEDITION
  - ADVANCED EARTH ORBIT OPERATIONS
  - OUTER PLANETARY EXPLORATION

ROLE OF NUCLEAR POWER IN SPACE

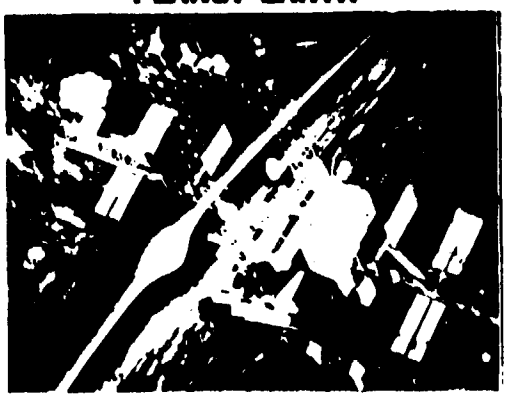
LUNAR BASE

BASE CENTRAL UTILITY POWER
NUCLEAR SPACE TRANSPORT (NST)
COMMUNICATIONS SATELLITE POWER

MANNED MARS MISSION

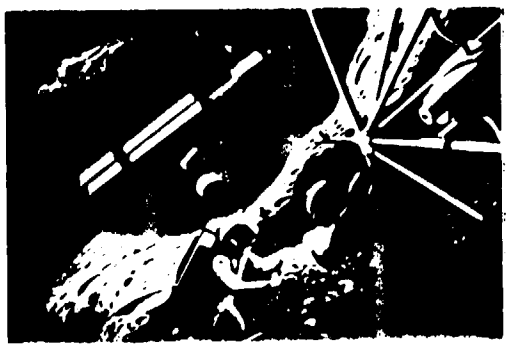
BASE CENTRAL UTILITY POWER
NST CARGO VEHICLE
MANNED VEHICLE APU
COMMUNICATIONS SATELLITE POWER

PLANET EARTH



CO-ORBITING PLATFORM UTILITY POWER

PLANETARY EXPLORATION



NST CARGO/EXPLORATION VEHICLE

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EVOLUTIONARY POWER REQUIREMENTS FOR SURFACE BASE OPERATIONS

UNMANNED PRECURSOR	MANNED OUTPOST/CAMP	INTERIM BASE	SUSTAINED BASE
2 kWe	~ 25-100 kWe	500 kWe	2000 kWe
• ORBITER	• HABITAT (6 CREW)	• HABITAT (15 CREW)	. HABITAT (24 CREW)
• ROVER	• LABORATORY	• ADD'L LABS	. RESEARCH FACILITIES
• SAMPLE RETURN	• SCIENCE EXPTS	• EXTENDED SCIENCE	. SUSTAINED SCIENCE
• FARSIDE COMSAT	• LOX PILOT PLANT	• IN-SITU RESOURCES PLANT	. INCREASED LOX PRODUCTION
	• SITE PREP	• CELSS RESEARCH	. METALS PRODUCTION
	• ROVERS/TRAILERS	• SURFACE SURVEYS	. MANUFACTURING
	• LANDER/ASCENT VEHICLE	• MINING	. CERAMICS PRODUCTION
		• LOX PRODUCTION	. FOOD PRODUCTION
		• MATL'S PILOT PLANT	. PRODUCT EXPORT
		• REUSABLE LEM CARGO VEHICLE	. MASS DRIVER

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LUNAR POWER SYSTEM MASS AND MARS BASES

	SOA SOLAR	ADV SOLAR	NUCLEAR 4Π	NUCLEAR SURFACE
100 kWe				
LUNAR	3,300,000	33,000	11,900	4000
MARS	120,000	12,500	11,900	4000
500 kWe				
LUNAR	—	165,000	20,700	12,000
MARS	—	62,500	20,700	12,000

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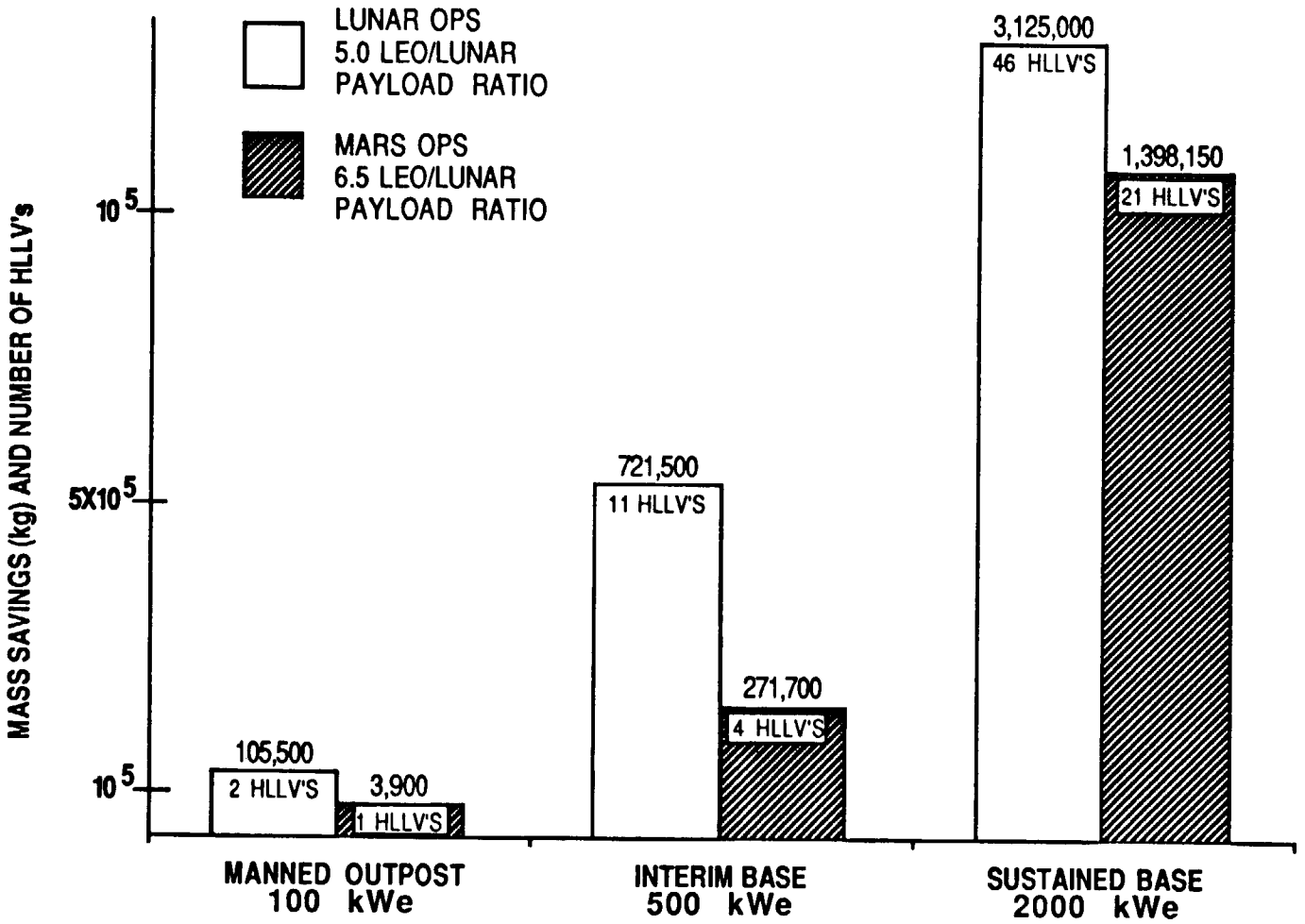
MASS SAVINGS IN LEO FOR LUNAR AND MARS OPERATIONS

NUCLEAR (4 PI SHIELD TRANSPORTED FROM EARTH) VERSUS ADVANCED SOLAR



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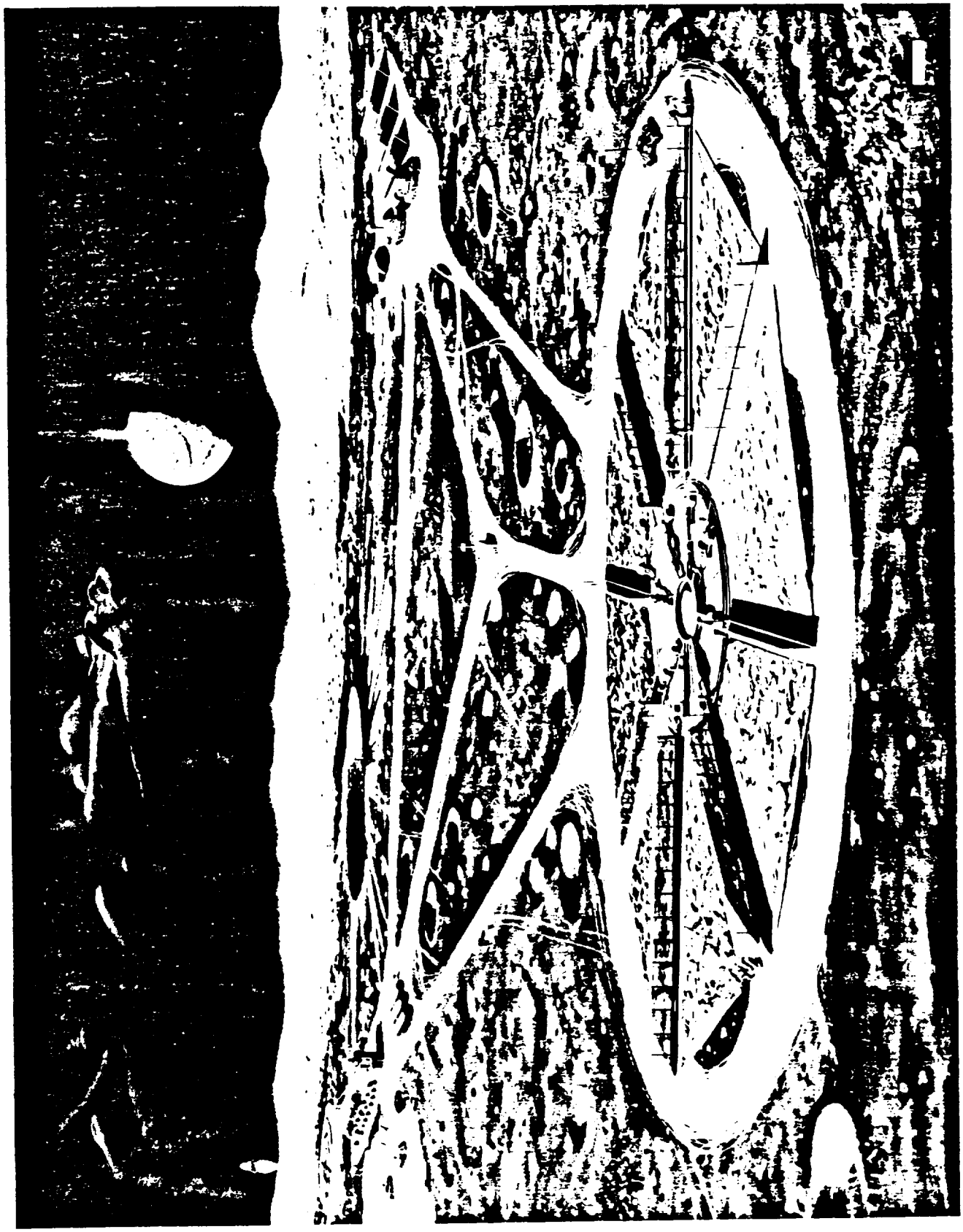
MARS/LUNAR BASE
POWER SYSTEM PHILOSOPHY

- SPACECRAFT, INITIAL CAMP BASED ON ADVANCED SOLAR POWER SYSTEMS (10 - 25 kWe MODULES)
- SURFACE PREPARATION FOR NUCLEAR POWER
- EVOLUTION TO NUCLEAR POWER PROVIDES HUNDREDS TO THOUSANDS OF kWe
- PATHFINDER - SOLAR POWER
  - SP-100 GES SUPPORT
- CSTI - HIGH CAPACITY POWER (NUCLEAR)



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TECHNOLOGY GOALS

- EARTH ORBITAL, SPACECRAFT, OTHER APPLICATIONS

	SOA	
SOLAR	3-6 W/kg	16-20 W/kg
NUCLEAR		15-40 W/kg

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PATHFINDER

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SURFACE POWER SYSTEMS

GOAL: DEMONSTRATE FEASIBILITY OF CRITICAL COMPONENT TECHNOLOGIES NECESSARY FOR INITIAL LUNAR/MARS CAMPS, SPACECRAFT POWER SYSTEMS

REQUIREMENTS:			
	~ 3 We/kg - LUNAR CAMP	14 DAYS	D/N CYCLE
	~ 8 We/kg - MARS CAMP	12 HR	D/N CYCLE

ENERGY CONVERSION 40 → 300 W/kg

ENERGY STORAGE 40 → 500-1000 Whr/kg
- MISSION DEPENDENT

POTENTIAL FOR SUCCESSFUL OPERATION ON MARS, LUNAR SURFACES

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SURFACE POWER SYSTEMS
PROJECT ELEMENTS

- **MISSIONS AND SYSTEMS ANALYSIS**
- **H_2 -O_2 REGENERATIVE FUEL CELL**
- **PHOTOVOLTAIC POWER**
  - AMORPHOUS SILICON CELLS/BLANKETS
  - ADVANCED ARRAY STRUCTURES
- **ADVANCED SOLAR DYNAMICS**
  - CONCEPTUAL DESIGN STUDY
- **POWER CONDITIONING/CONTROL**
- **ENVIRONMENTAL COMPATIBILITY**

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SURFACE POWER SYSTEMS

MAJOR DELIVERABLES

FY'93

- **DEMONSTRATE 2000 HR OPERATION ON 65% REGENERATIVE FUEL CELL**
  - 300F, 200 PSI
  - HIGH PRESSURE ELECTROLYZER (3000 PSI)
  - BUILDING BLOCK STACK
- **1 kWe DEMONSTRATION AMORPHOUS SILICON ON KAPTON**
  - 2000 W/kg
- **CONCEPTUAL DESIGN REDUCED-G ARRAY STRUCTURE**
  - .46 kg/m^2

300 W/kg

- **CONCEPTUAL DESIGN OF SOLAR DYNAMIC LUNAR/MARS POWER SYSTEMS**
  - ELECTRICAL, THERMAL 3 - 8 W/kg
- **POWER CONDITIONING CONTROL DESIGN/ENVIRONMENTAL COMPATIBILITY**

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SURFACE POWER SYSTEMS

- **MAJOR LABORATORIES**
  - LeRC - LEAD CENTER
  - TECHNICAL SUPPORT FROM JPL, LANL
- **CONTACT - J. BOZEK, LeRC**

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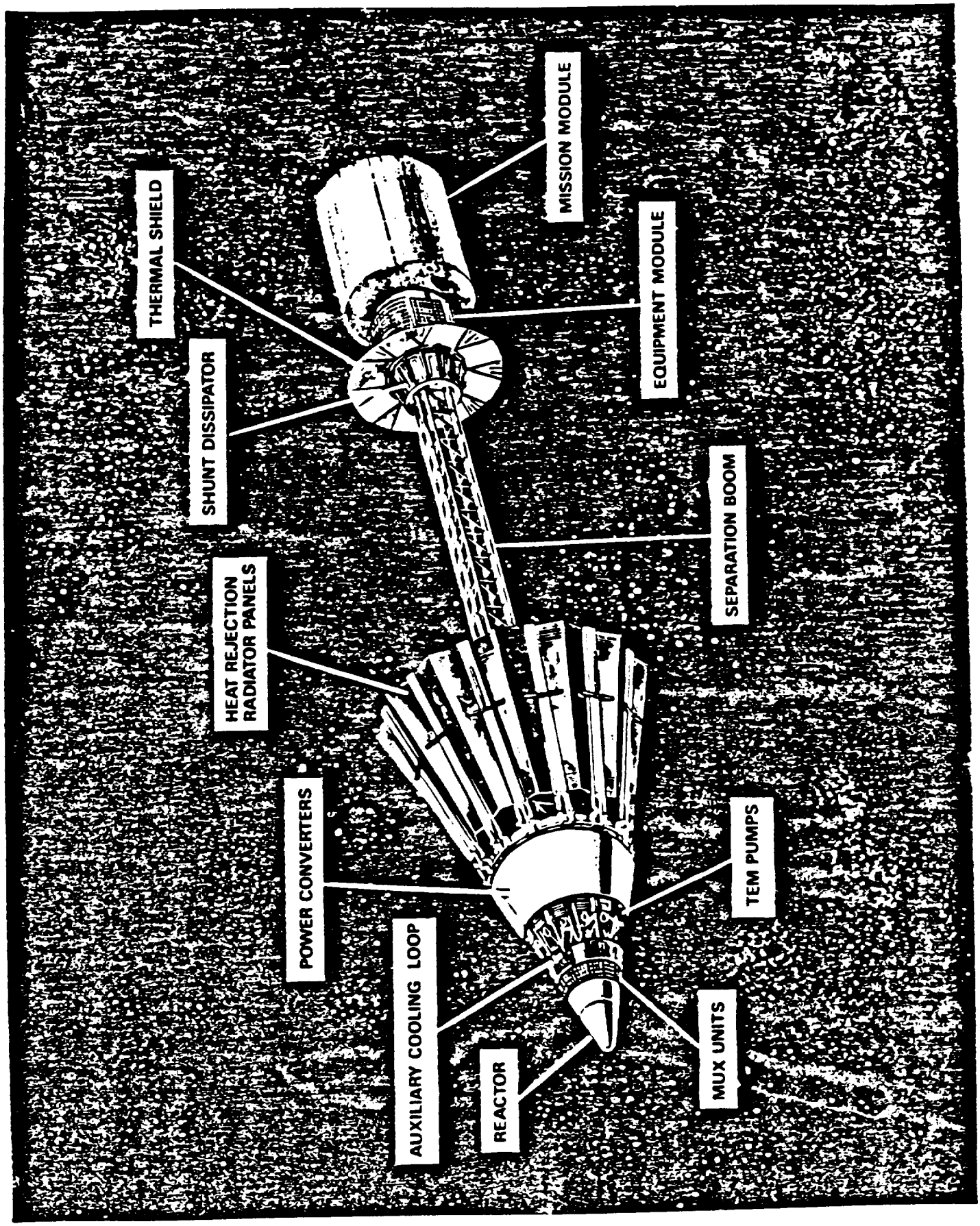
SPACE NUCLEAR POWER SP-100

- **PROVIDES NASA SUPPORT TO TRI-AGENCY, DOE/NASA/DOD, SP-100 GROUND ENGINEERING SYSTEM (GES) DEVELOPMENT PROGRAM**
  - ENSURES REACTOR AVAILABLE FOR NASA APPLICATIONS
- **REQUIREMENTS**
  - 100 kWe
  - 7 - 10 YEARS LIFE
  - > .95 RELIABILITY
  - 30 W/kg
  - 1/3 SHUTTLE BAY



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SPACE NUCLEAR POWER SP-100
MAJOR DELIVERABLES

- 2.5 MW_T REACTOR TEST - FY'92
- SPACE SUBSYSTEM TEST - 15 kWe - FY'94

MAJOR LABORATORIES

DOE - PGM. DIR. - E. WAHLQUIST
JPL - PROJECT MGMT. - V. TRUSCELLO
LeRC - NASA GES SUPPORT - H. BLOOMFIELD

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CSTI
HIGH CAPACITY
POWER

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CSTI HIGH CAPACITY POWER

- PROVIDES FOR INCREASED POWER, RELIABILITY AND LIFETIME FOR NUCLEAR SPACE POWER SYSTEMS USING THE SP-100 REACTOR WITH EITHER DYNAMIC OR STATIC CONVERSION SYSTEMS.

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CSTI

HIGH CAPACITY NUCLEAR POWER

- FOCUSED TECHNOLOGY DEVELOPMENT TO ENHANCE CAPABILITY OF SPACE POWER SYSTEMS USING GES REACTOR

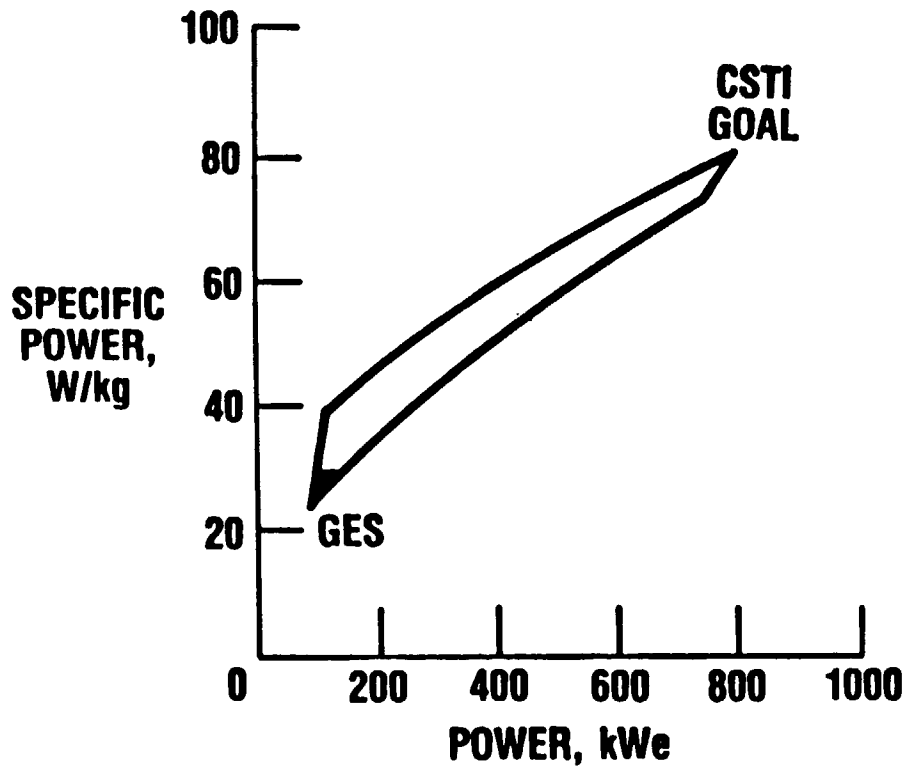
  25 → 80 W/kg
  100 → 800 kWe

- ADVANCED ENERGY CONVERSION
  - FREE PISTON STIRLING ENGINES
  - ADVANCED THERMOELECTRICS

- ADVANCED RADIATORS

- POWER CONDITIONING & CONTROL

- REFRACTORY & COMPOSITE MATERIALS



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CSTI HIGH CAPACITY POWER MAJOR MILESTONES FY92

- **DEMONSTRATE TECH. READINESS ⇒ 1300 k FPSE**
  - 1050 k (25%, <6kg/kWe, 25kWe/pl, T_R= 2.0)
  - 1 YEAR ENDURANCE
  - COMPONENT PERF. W/REFRACTORY METALS
- **Z = 1.2 Si Ge GaP "n" LEG TECH. AVAIL. FOR GES**
  - OA Z = 0.85
  - DEMONSTRATE POT. FOR Z = 1.2 COUPLE
- **850k, 550k HT PIPE DEMO., ε >0.85, <5kg/m^2**
  - ADV. RADIATOR DEMO. ~ 5kg/m^2
- **10^8 RAD. HARD, 400C INVERTER DEMO.**
- **COMPLETE REFRACTORY COMPOSITE CHARACTERIZATIONS**
- **POTENTIAL FOR 10 YEAR LIFE**

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CSTI
HIGH CAPACITY POWER

- **NASA CENTERS**

  LeRC - PROJECT MANAGEMENT - J. WINTER
  - ALL PROGRAM ELEMENTS

  JPL - ADVANCED THERMOELECTRICS - C. WOOD

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CONCLUDING REMARKS

- **COMPREHENSIVE SPACE POWER PROGRAM**
  - BASE R&T, CSTI, PATHFINDER
  - SIGNIFICANT ACCOMPLISHMENTS
- **WELL CO-ORDINATED**
  - SDIO, USAF, DOE
  - LEVERAGE AT NATIONAL LEVEL
- **POWER SYSTEM CAPABILITY**
  - ENABLE BOLD NEW MISSIONS
  - RESTORE NATIONAL TECHNICAL LEADERSHIP
- **WE HOPE YOU CAN PARTICIPATE**