OAST SPACE POWER TECHNOLOGY PROGRAM

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The NASA Space Power Technology Program is aimed at providing a sound technological basis for future space electrical power systems. While future needs for electrical energy in space cannot be known with certainty, an analysis of programmatic trends and opportunities now under study identify two classes of need. The first is for very high performance systems to support electric propulsion and ambitious geosynchronous missions. The second is for very high power levels at low cost to support the Shuttle-based habitation and use of near-Earth space. In this paper the current R&T base program is first described, then special attention is directed toward outlining a new system technology initiative specifically oriented toward providing the utility power plant technology base for semi-permanent Earth orbital facilities expected to be needed in the middle to late 1980's.

The R&T base program involves five areas of research: Photovoltaic Energy Conversion, Chemical Energy Conversion and Storage, Thermal-to-Electric Conversion, Environmental Interactions, and Power Systems Management and Distribution. The general objectives and planned direction of efforts in each of these areas is summarized below and in Figures 1 through 15.

In the area of Photovoltaic Energy Conversion, the aim is to improve conversion efficiency, reduce mass, reduce cost, and increase operating life of photovoltaic converters and arrays. Emphasis is being placed on very efficient thin solar cells, lightweight blankets, radiation resistance, low cost and advanced cells, and both planar and concentrator array designs.

In Chemical Energy Conversion and Storage, the objective is to achieve improved energy density, life, operational capability, and cost of space battery and fuel cell systems. Research is being done to increase energy density and life of nickel cadmium batteries and to increase their capacity; to achieve high energy density probe and lander batteries; and to evaluate new electrochemical concepts for very high energy density. In addition, effort is being initiated to evolve the fuel cell-electrolyzer concept for high capacity low-Earth-orbit energy storage applications.

Thermal-to-Electric Conversion efforts aim at technologies which can be used with either nuclear or solar heat sources and focus on achieving acceptable efficiencies in thermoelectric and thermionic converters and on evaluating Brayton systems for low and high power application. In addition, some work on ancillary equipment necessary for system feasibility is carried out.

Research is also undertaken to insure that future power systems can adequately cope with the space environment. This work includes both ground and flight efforts on spacecraft charging and on high voltage - space plasma interactions.

Finally, work aimed at providing the power system management and distribution basis of future systems is undertaken. This effort includes basic high power component, circuit and subsystem research, automated management and ground and flight systems investigations.

It is concluded that execution of this R&T base program will increase the range of future mission opportunities that can be accommodated at acceptable levels of cost and risk. However, the pressing near term high power needs for Earth orbital systems are very great, and the impact of this R&T base program on them at present resource levels will necessarily be limited to a few key technologies. Expansion of technology effort in this area can be accommodated only by reducing efforts aimed at high performance and longer term space power needs or by seeking a focused augmentation of resources.

A specific initiative aimed at this class of needs is outlined in Figures 16 through 29 and is presented for planning purposes only in an effort to illustrate the type of technology preparation that is viewed as being reasonably consistent with orbital energy needs of the near future. The need for this initiative stems from the projected growth in space energy demand and historical evidence suggesting that past experience has been both limited in quantity and costly. The technology initiative is presented in two phases. The first treats solar power generation, bulk energy storage, and power management and distribution. The second phase deals with thermal management and with space to space transmission of power.

The expected return from the type of technology program outlined here is the provision of enabling technology for a class of space powerplants in the multi-hundred kilowatt power range. We can expect to see dramatic reductions over projected capital and operating costs and begin to see new operating concepts involving maintainability, automation, the remote transmission of space power and the beginnings of truly integrated systems operation in space.

POWER SYSTEMS

TECHNOLOGY FOR HIGH PERFORMANCE AND MULTI-KW LOW COST SPACE POWER SYSTEMS

- PHOTOVOLTAIC ENERGY CONVERSION
- CHEMICAL ENERGY CONVERSION & STORAGE
- THERMAL - TO - ELECTRIC ENERGY CONVERSION
- POWER SYSTEMS MANAGEMENT & DISTRIBUTION
- ENVIRONMENTAL INTERACTIONS

Figure 1.

CURRENT POWER PROGRAM

PHOTOVOLTAIC ENERGY CONVERSION

- *SOLAR CELLS*
- LOW COST BLANKETS & ARRAYS
- LIGHT WEIGHT BLANKETS & ARRAYS

CHEMICAL ENERGY CONVERSION & STORAGE

- NiCd BATTERY
- ADVANCED BATTERIES
- HIGH CAPACITY ENERGY STORAGE

THERMAL TO ELECTRIC CONVERSION

- THERMIONICS & THERMOELECTRICS
- BRAYTON
- THERMAL-TO-ELECTRIC POWER SYSTEMS *TECHNOLOGY*

ENVIRONMENTAL INTERACTIONS

- HIGH VOLTABE/SPACE PLASMA
- SPACECRAFT CHARGING

POWER MANAGEMENT & DISTRIBUTION

- HIGH POWER COMPONENTS
- CIRCUITS & SUBSYSTEMS
- AUTOMATED POWER SYSTEMS MGMT.
- POWER SYSTEMS & REQUIREMENTS

FLIGHT EXPERIMENTS

- SEPS ARRAY
- 5 LDEF EXPERIMENTS
- SOLAR CELL CALIBRATION FACILITY

Figure 2.

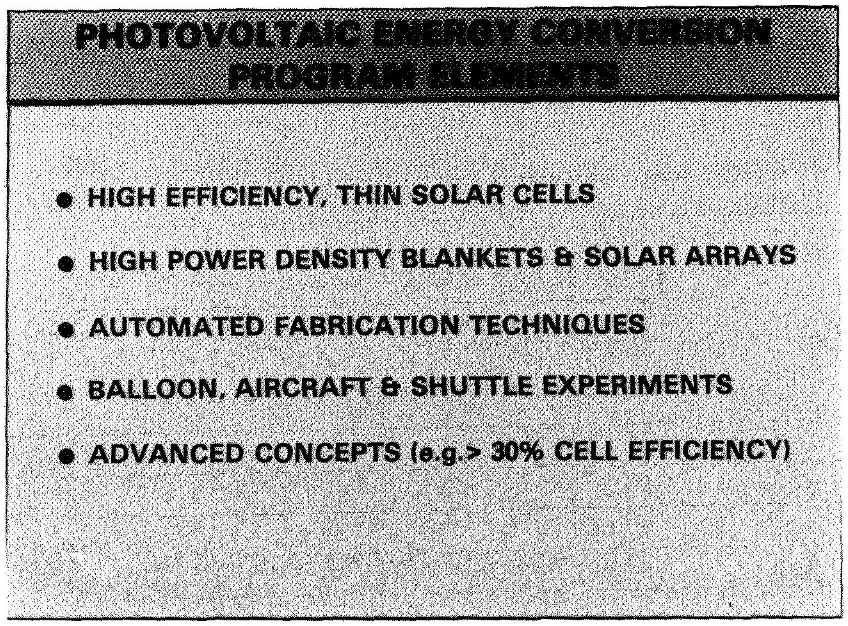
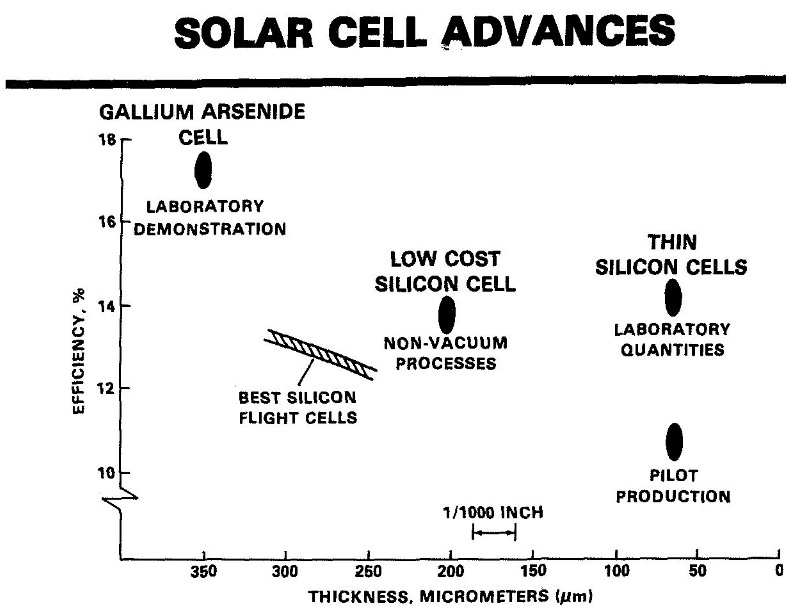


Figure 3.



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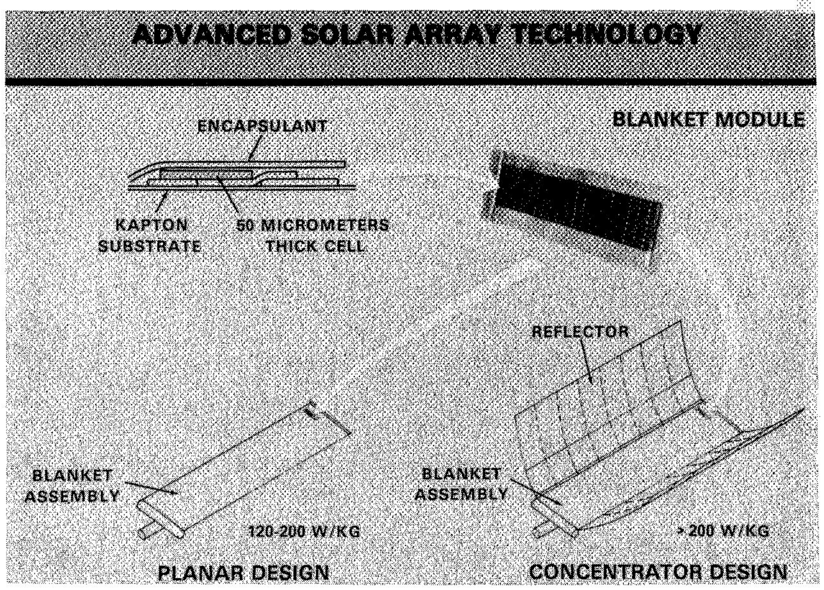
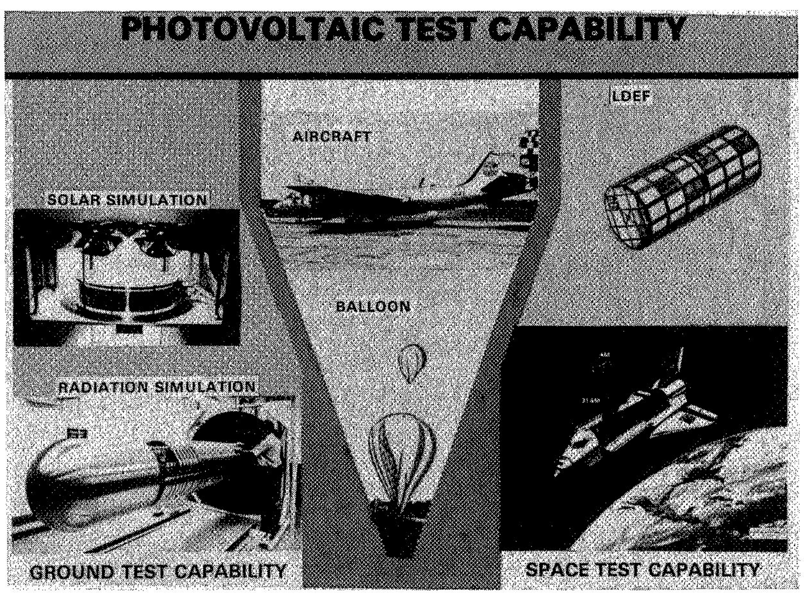


Figure 5.



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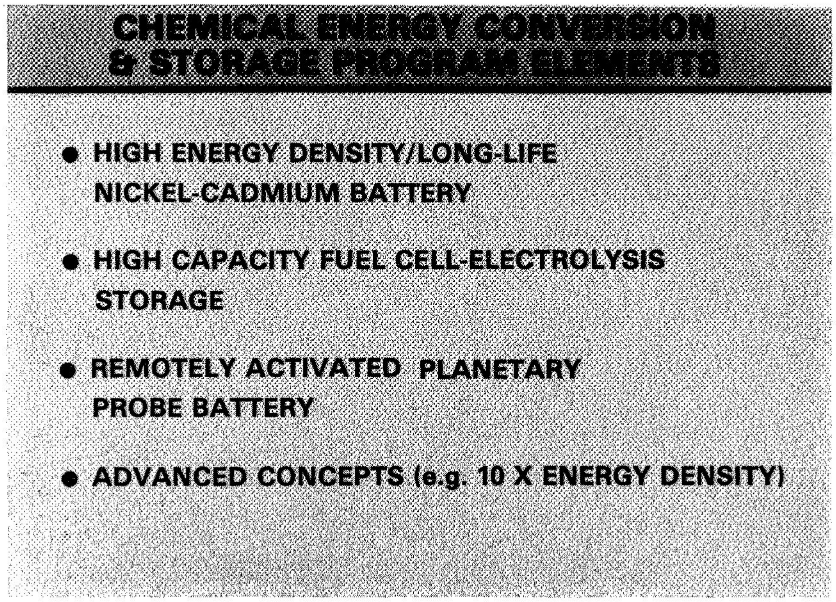

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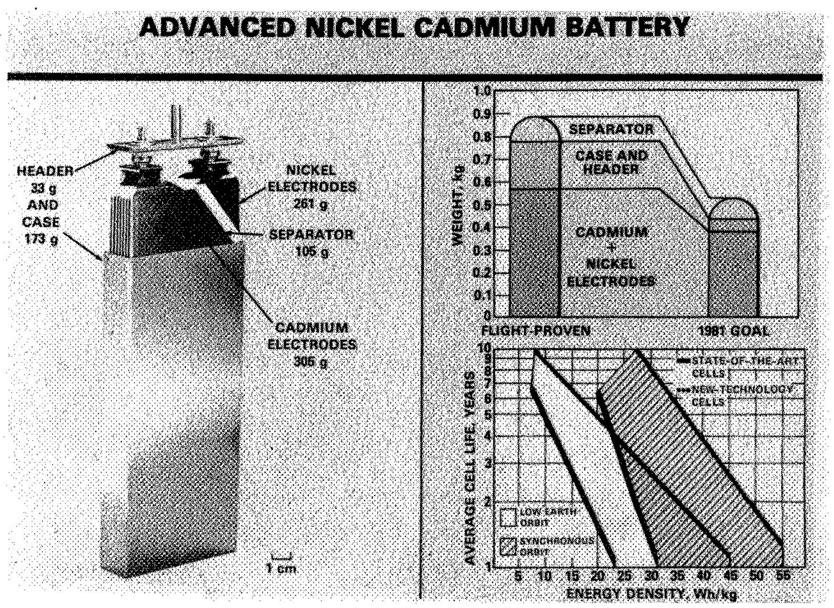


Figure 8.

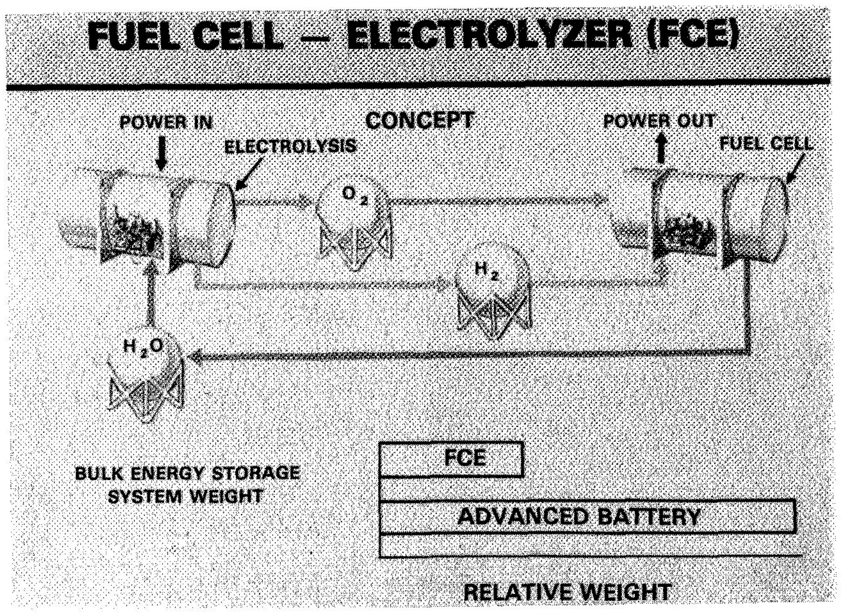


Figure 9.

THERMAL-TO-ELECTRIC ENERGY CONVERSION PROGRAM ELEMENTS

- THERMOELECTRIC ELEMENT EVALUATION
- BRAYTON POWER SYSTEMS
- HIGH TEMPERATURE THERMIONIC CONVERTER/HEAT PIPE
- HIGH TEMPERATURE MATERIALS
- ADVANCED CONCEPTS (e.g. > 15% THERMOELECTRICS & SOLAR BOILER/MHD)

Figure 10.

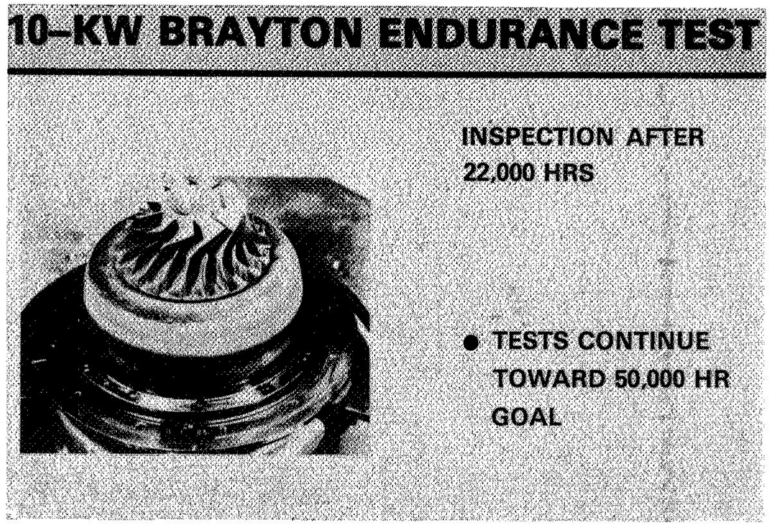


Figure 11.

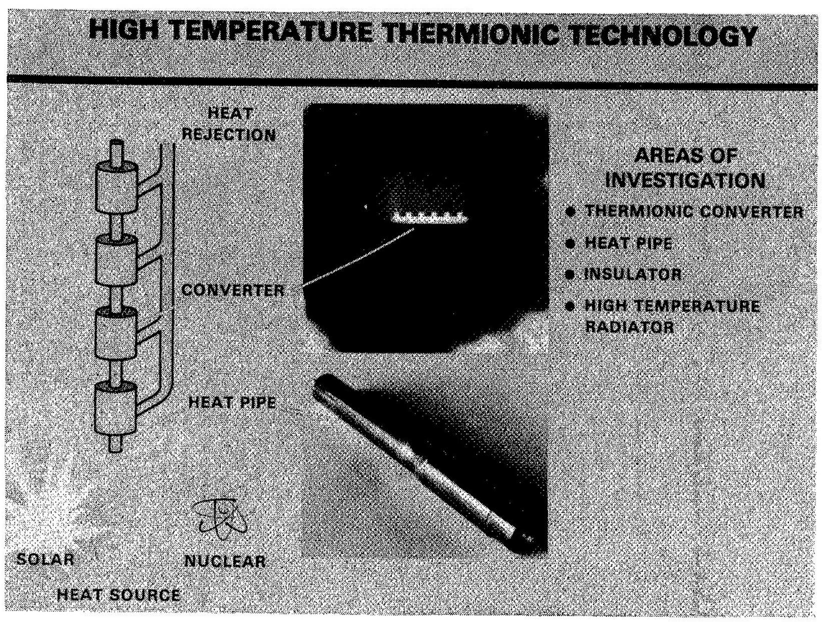


Figure 12.

ENVIRONMENTAL INTERACTIONS PROGRAM ELEMENTS

- JOINT AF/NASA SPACECRAFT CHARGING
- HIGH VOLTAGE/SPACE PLASMA
- SPACE EXPERIMENTS

Figure 13.

POWER SYSTEMS, MANAGEMENT & DISTRIBUTION PROGRAM ELEMENTS

- AUTOMATED POWER SYSTEMS MANAGEMENT
- HIGH VOLTAGE, HIGH POWER COMPONENTS & DISTRIBUTION
- USE OF TERRESTRIAL & AIRCRAFT COMPONENTS
- LASER POWER TRANSMISSION

Figure 14.

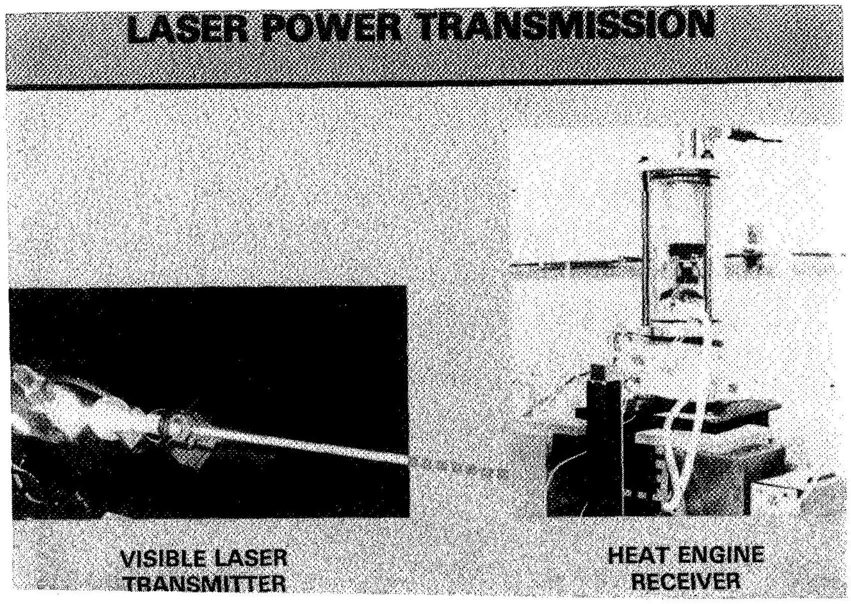


Figure 15.

LOW COST ORBITAL ENERGY SYSTEMS TECHNOLOGY

OBJECTIVES:

- PROVIDE THE UTILITY POWER PLANT TECHNOLOGY BASE FOR SEMI-PERMANENT EARTH ORBITAL FACILITIES NEEDED IN THE MIDDLE TO LATE 1980.s.

BENEFITS:

- REDUCE CAPITAL & OPERATING COST OF SPACE ENERGY SYSTEMS BY 10 TO 100X
- REDUCE RISK BY EXTENDING SPACE ENERGY EXPERIENCE BASE TO 100X LARGER SYSTEMS
- OPEN NEW OPERATING CONCEPTS & ACHIEVABLE ECONOMIES OF SCALE WITH TRANSMISSION
- REDUCE ENVIRONMENTALLY IMPOSED OPERATIONAL CONSTRAINTS
- TECHNOLOGY BASIS FOR COMBINED SYSTEMS
  - EC/LS
  - HEAT REJECTION
  - ORBITAL PROPELLANT PRODUCTION

APPLICABLE TO SPS

Figure 16.

SPACE ENERGY DEMAND

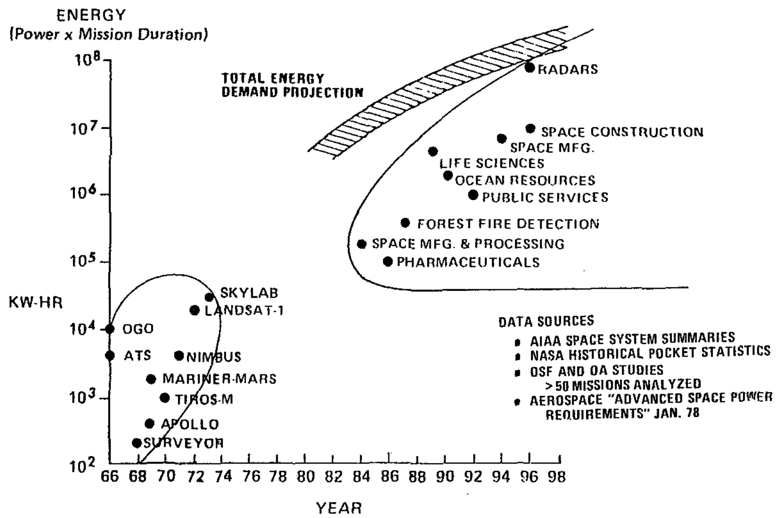


Figure 17.

LOW COST ORBITAL ENERGY SYSTEMS TECHNOLOGY

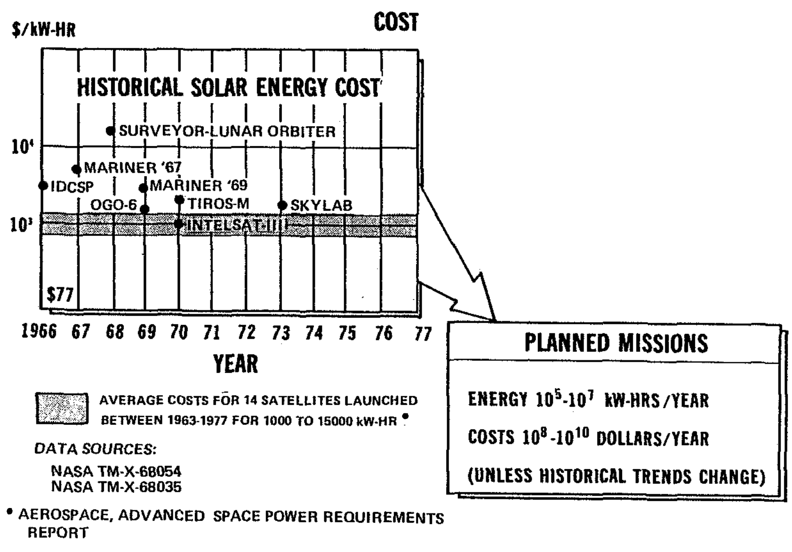


Figure 18.

MULTI-KW ORBITAL POWER PLANT

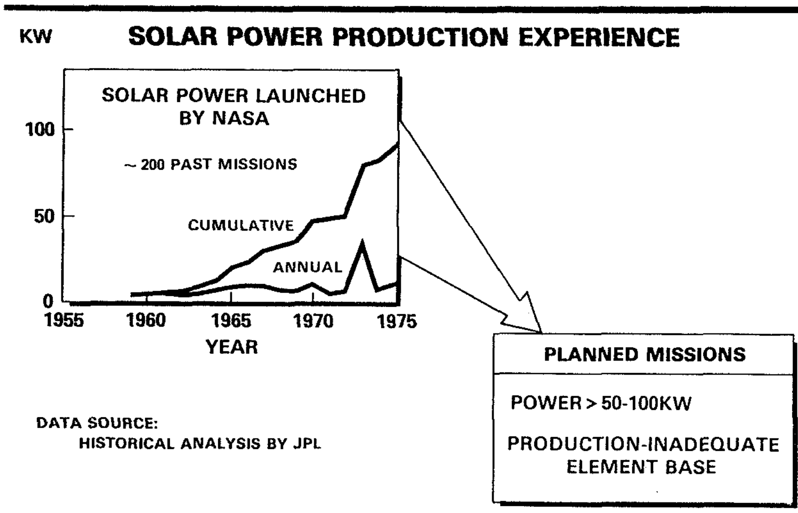


Figure 19.

LOW COST ORBITAL ENERGY SYSTEMS TECHNOLOGY

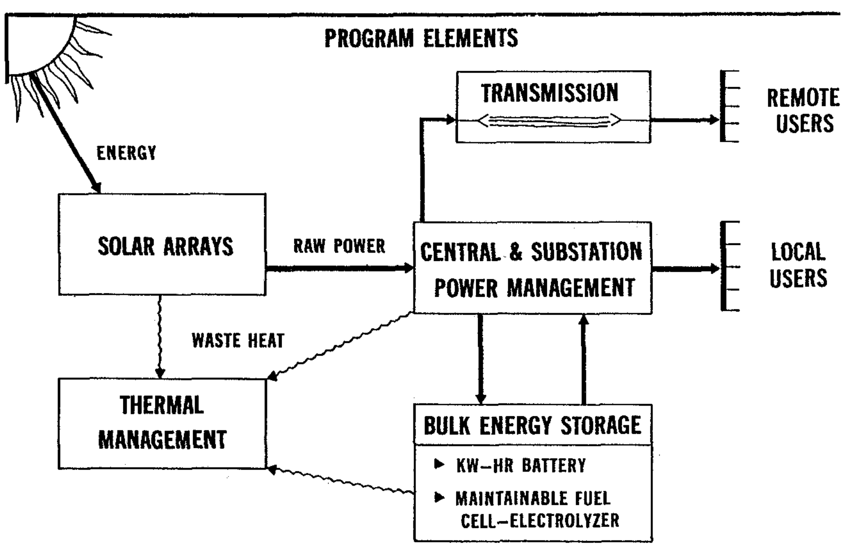


Figure 20.

LOW COST ORBITAL ENERGY SYSTEMS TECHNOLOGY

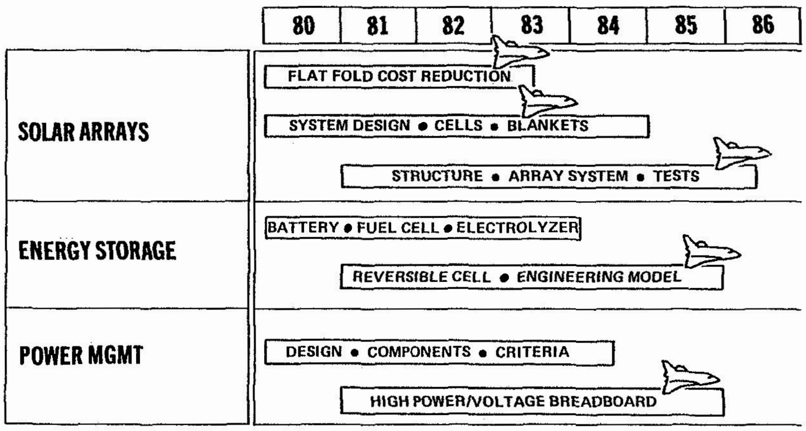
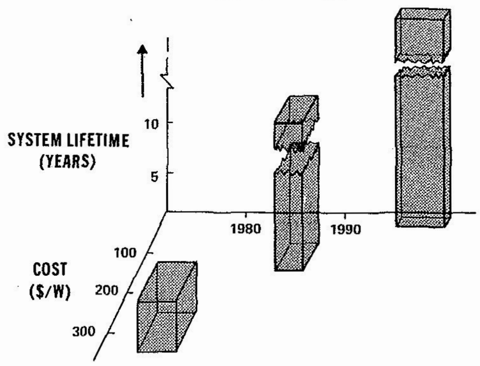


Figure 21.

SOLAR ARRAYS



NEAR TERM

REDUCE CAPITAL COST OF SEP FROM $300/W TO $100/W

FAR TERM

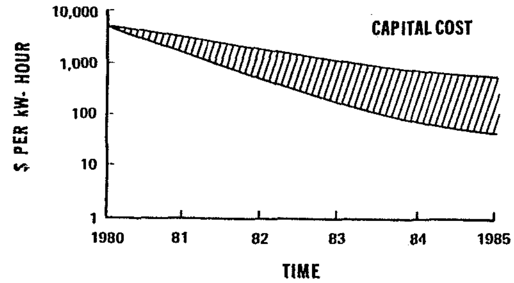
REDUCE CAPITAL COST OF BLANKET TO $10/W
- ▶ AUTOMATED ASSEMBLY
- ▶ LARGE AREA CELLS

REDUCE ENERGY COST FROM $1000/kW-HR TO $100/kW-HR
- ▶ ERECTABLE STRUCTURES
- ▶ ON ORBIT MAINTENANCE

Figure 22.

BULK ENERGY STORAGE

OBJECTIVE: REDUCE CAPITAL AND OPERATING COST* OF ENERGY STORAGE BY 10 TO 100 TIMES



>100 A-H TORROIDAL NiCd BATTERY
- PARTS REDUCTION
- HIGHER THERMAL LIMIT

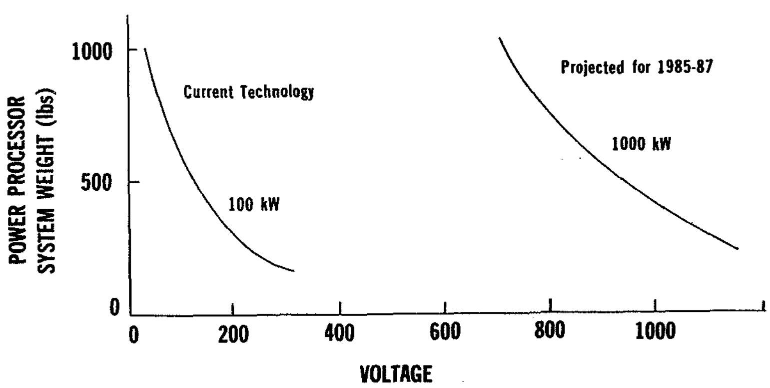
ADVANCED BATTERIES

FUEL CELL/ELECTROLYZER
- MAINTAINABLE/INDEFINITE LIFE
- LAUNCH WEIGHT SAVING, 200,000 kg/500 kW
- REVERSIBLE CELL FEASIBILITY

*PRESENT NiCd CAPITAL COST ~$8000/kW-HR

Figure 23.

POWER MANAGEMENT DISTRIBUTION AND CONTROL



COMPONENTS – HIGH POWER SWITCH, TRANSFORMER, CAPACITOR

CIRCUITS – HV CONVERTER

SYSTEM – 100 kW BREADBOARD, AUTOMATION

ENVIRONMENT – DESIGN CRITERIA FOR HV SPACE PLASMA INTERACTIONS

Figure 24.

LOW COST ORBITAL ENERGY SYSTEMS TECHNOLOGY

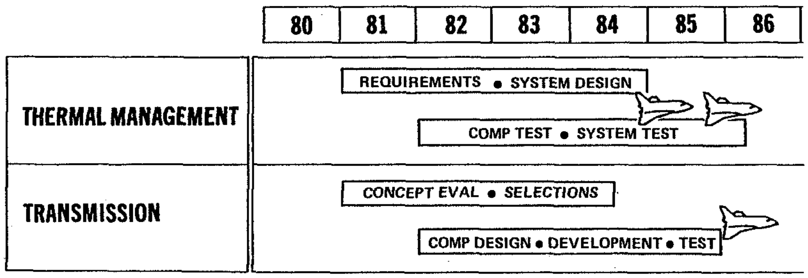


Figure 25.

THERMAL MANAGEMENT

OBJECTIVE: TECHNOLOGY TO ENABLE A SYSTEMS APPROACH TO THERMAL MANAGEMENT

ACQUISITION (Equipment Cooling)

- HIGH DENSITY COLD PLATE
- ADVANCED INTEGRATION TECHNIQUES

TRANSPORT (Circulating Systems & Heat Pipes)

- HIGH CAPACITY HEAT PIPES
- THERMAL UMBILICAL

DISSIPATION (Radiators & Coatings)

- STABLE LOW α/ϵ COATINGS
- ERECTABLE RADIATOR MODULE
- MAINTENANCE METHODS

Figure 26.

POWER TRANSMISSION

OBJECTIVE: DEMONSTRATE FEASIBILITY OF CENTRAL POWER SOURCES FOR SPACE USE

- ▶ TRANSMITTER/RECEIVER COMPONENT EXPERIMENTS
- ▶ SYSTEM CONCEPTS
- ▶ QUANTIFY COSTS & BENEFITS OF ORBIT TO ORBIT ENERGY TRANFER
    - ▶ ELIMINATE INDIVIDUAL GENERATION & STORAGE
    - ▶ ELIMINATE DRAG & GRAVITY GRADIENT TORQUES
    - ▶ PROVIDE MANEUVER ENERGY
- ▶ SUBSYSTEM & SYSTEM DEVELOPMENT & DEMONSTRATION

Figure 27.