JSC SPACE BASE/POWER MODULE STUDIES

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Studies of on-orbit systems have shown that users of the Shuttle system will require increased electrical energy and associated services. In particular, users of the Orbiter/Spacelab combination will require both higher electrical power and longer duration than is available with the current baseline system. Additionally, since operations costs (and user charges) increase slowly with duration, the economics of this system are more attractive to all users if its duration is extended beyond the baseline 5 to 10 days. Present Orbiter/Spacelab mission capability is primarily constrained by the hydrogen and oxygen available to generate power in the Orbiter fuel cells. It is also necessary to assure that considerable attitude or pointing flexibility is retained to assure efficient operation of the Orbiter radiator cooling system. Beyond these early limitations, it is foreseen that orbital operations will eventually need even greater quantities of the basic space utilities: electrical power, heat rejection, and attitude control. Such operations, forecasted for the mid to late 1980's, will be best accommodated by a module stored in orbit that can furnish these to a docked Orbiter/Spacelab or other vehicles.

The JSC approach to provision of the requisite services is the Orbital Service Module concept. The Orbital Service Module represents a concept for an evolutionary program which will provide this increasing level of utilities service. Continuous matching of capability to real user needs, while avoiding the pitfalls usually associated with prediction of long-range requirements, is a primary objective of this approach. Thus, the program is structured as a series of evolutionary steps or increments. Since each increment is, in itself, a nominal uprating of existing capability, lead times are relatively short and an OSM program commitment need not be made until user requirements are firm. As a result, annual funding (including that for initial increments required by Spacelab operations in the early 1980's) is considerably less than that needed to produce a full-capability power module.

The Orbiter baseline configuration offers tremendous operational flexibility. The initial step in the OSM approach is to assure good balance in the use of this flexibility in provision of payload services such as delivery and return weights, power, cooling, orbit location, attitude control, and duration. This is done through a large solar array deployed and positioned by the Remote Manipulator System. Power is routed to the Orbiter by a cable strapped to the RMS, where it is conditioned and placed on the Orbiter and payload buses. Fuel cells still provide power during night operation. (See figs. 1 to 5.)

In order to properly size and plan the various increments, mission requirements must be derived. This was accomplished by analysis of the STS 10-77 traffic model. Results indicate the Power Extension Package (PEP) (first step in the incremental growth of services) should be sized for a 29-kW power level, and the free-flying module (second and third steps) to provide 35 kW average power (fig. 6). These results are tentative, and additional study and user interaction will be needed to properly size the free-flying module. Figure 7 shows that Spacelab missions to many inclinations and altitudes will use the PEP and/or power module. Also note that the PEP permits sharing of Spacelab with delivery missions to 28° orbits. Most deliveries of SSUS payloads do not use the full Orbiter payload potential, therefore pallets with PEP can be co-manifested on these flights. This sharing will permit large cost savings to the user as he will then pay only a portion of the total Shuttle flight cost.

The requirements analysis results are summarized in figure 8. Note that PEP will meet all requirements through 1984. The free-flying power module will be needed as the users' free-flying payloads are developed and become available in the 1983-84 time frame. Figure 9 shows that PEP will provide 29 kW for 20 days or 21 kW for 30 days. The free-flying module will provide 35 kW indefinitely.

Figures 10 to 13 describe the PEP hardware configuration, its installation in the Orbiter payload bay, and the operational deployment sequence. Note the PEP takes virtually no usable payload bay volume. Figures 14 and 15 describe Orbiter thermal control modifications and capabilities associated with PEP. Power levels up to the full 29 kW provided by PEP (15 kW to payload) can be accommodated by the thermal control system. Figure 16 shows the PEP weight. Figure 17 is an artist's concept of the initial free-flying power module (Increment III - This module is passively stabilized and contains relatively little avionics. It will provide power and cooling to such free-flying payloads as the materials experimentation module at a minimum cost.) Figure 18 shows the relative capabilities of PEP and the free flyer. Figure 19 shows the initial deployment sequence of the free flyer. Figure 20 shows the actively stabilized free-flying power module. The CMG and avionics pod can be added to the passively stabilized free flyer (fig. 18) after it is already placed in orbit. This configuration can also support free-flying <u>manned</u> modules when they are needed to relieve constraints on Orbiter on-orbit stay time. Figure 21 shows the free-flyer weight estimates. Figure 22 emphasizes the potential commonality of the PEP and free flyers. Figure 23 reveals the JSC baseline program plan and funding. Because of the commonality of PEP and free-flyer development, the net development cost of PEP is approximately \$20 to \$25 million.

This incremental approach also permits great flexibility in the spread of funding for the program. Note the PEP will be available to support even early Spacelab missions. This early availability of increased power and duration will save up to \$0.5B in operations cost during the first 2 to 3 years of operation (as compared to similar operations using cryo kits). It also precludes the need to develop energy-conservative payload hardware.

In summary, the JSC incremental growth approach maximizes the use of the Shuttle investment, provides early services when they are needed, and permits the free-flying power module to be optimized to payload requirements as they emerge.

OSM PROGRAM RATIONALE

- MISSION ANALYSIS VERIFIES POWER AND HEAT REJECTION CAPABILITY CRITICAL TO EXPLOITATION OF FULL STS POTENTIAL FOR ORBITER ATTACHED PAYLOADS
- ORBITER FLEET SIZE AND TURNAROUND CONSIDERATIONS DICTATE FREE FLYER SUPPORT CAPABILITY NEEDED IN 1984-86 TIME FRAME
- OSM CONCEPT OFFERS INCREMENTAL GROWTH FROM THE BASELINE ORBITER
  - USE FULL ORBITER MISSION FLEXIBILITY
  - MOST COST EFFECTIVE SUPPORT OF EARLY PAYLOADS
  - EACH STEP IS BUILDING BLOCK FOR FUTURE EVOLUTION
- FREE-FLYER SUPPORT CAPABILITY OPTIMIZED TO USER REQUIREMENTS AND SCHEDULE; MINIMUM OVERALL COST

Figure 1.

INCREMENTAL GROWTH CONCEPT

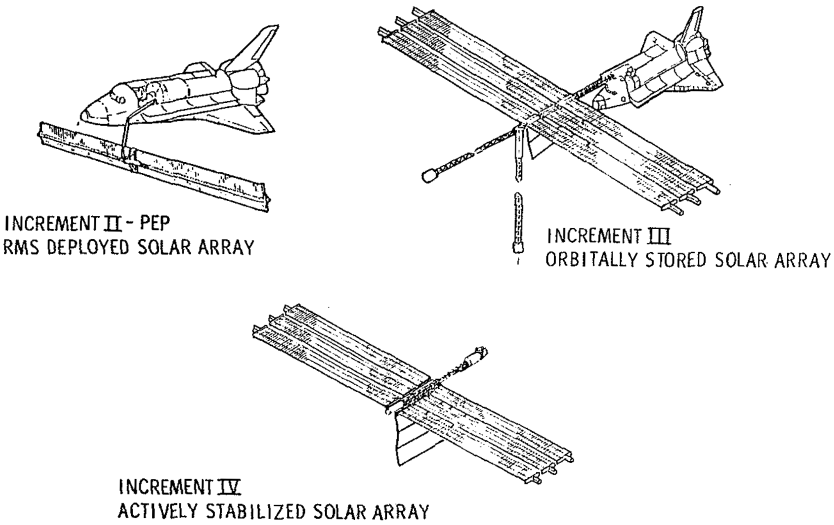

Figure 2.

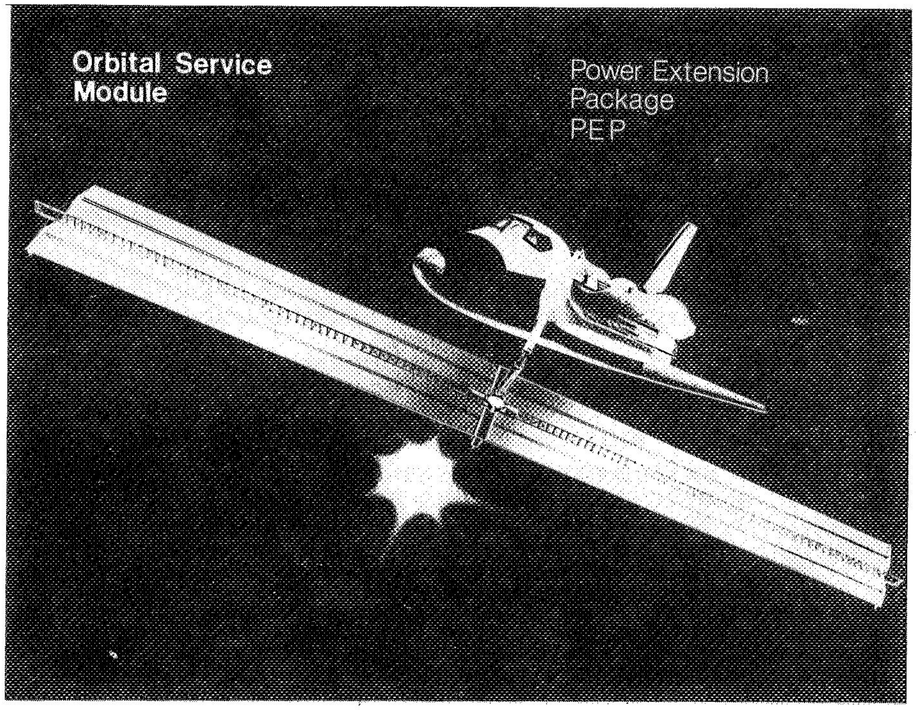

Figure 3.

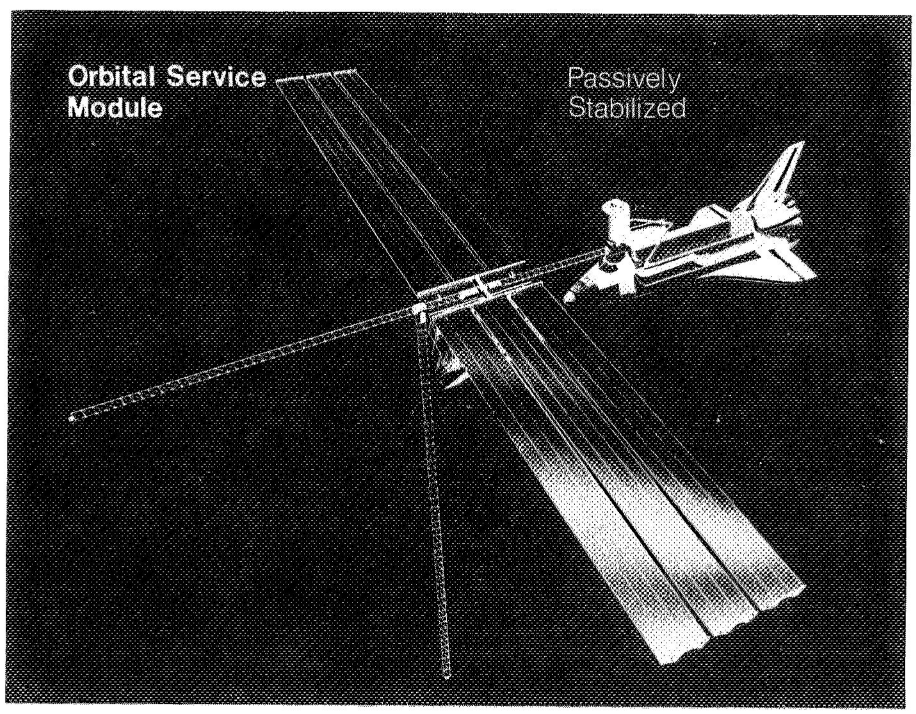

Figure 4.

NASA-S-78-11648

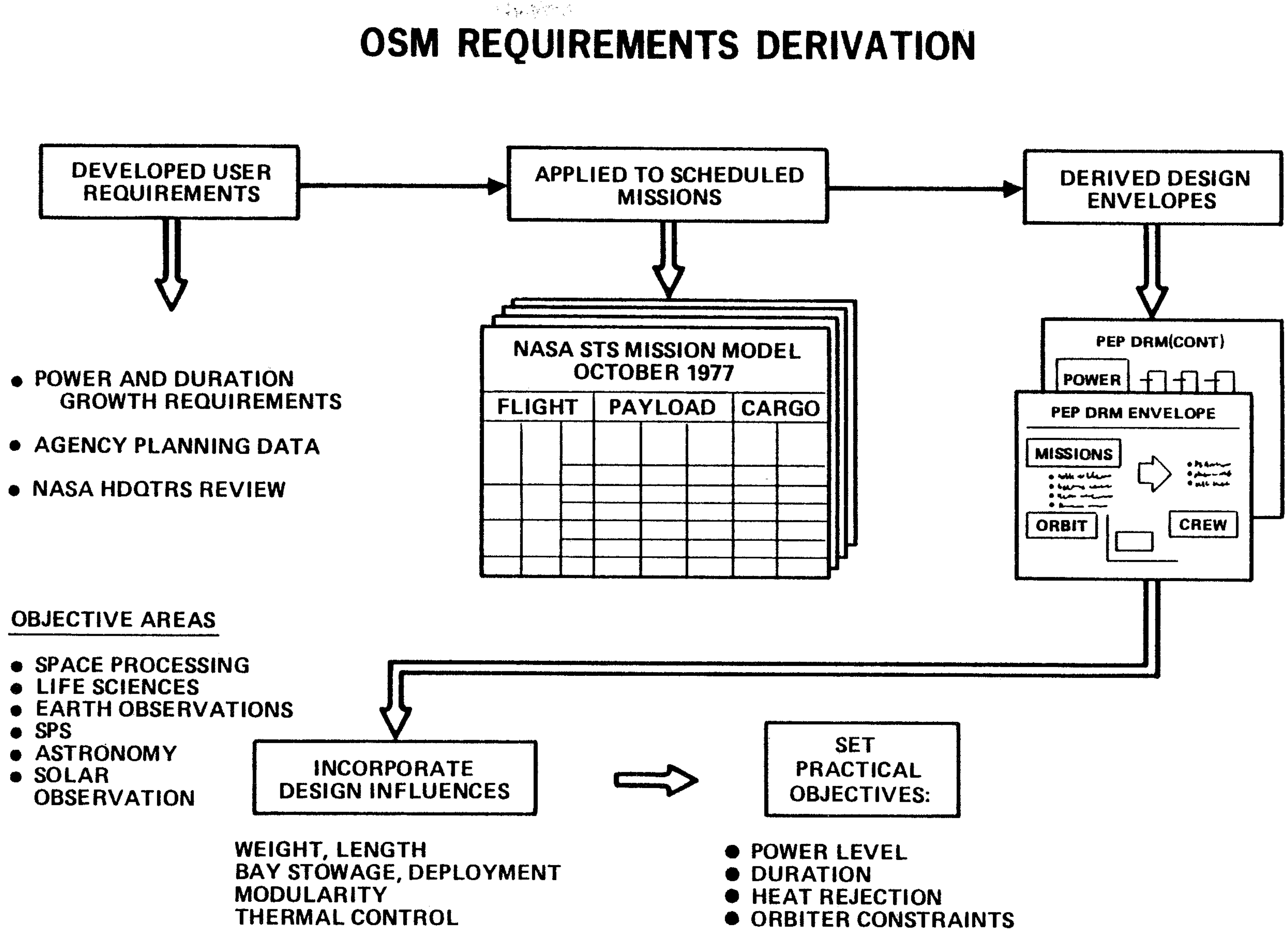

Figure 5.

NASA-S-78-11640

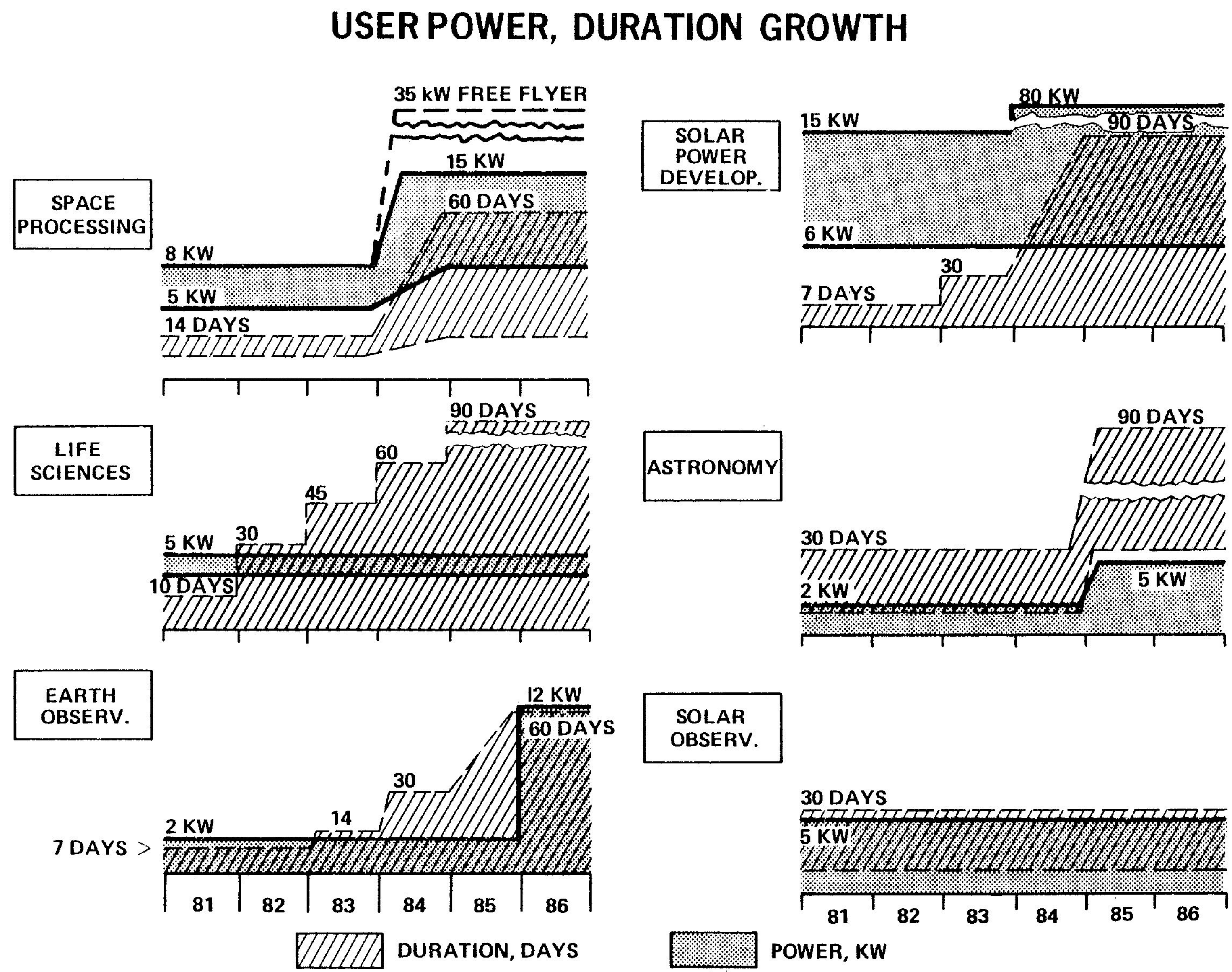

Figure 6.

NASA-S-78-11625 A

ORBIT INCLINATION/ ALTITUDE REQUIREMENTS STS 10-77 MODEL-SL

LEGEND
SL MISSION
SATELLITE/STAGE DELIVERY
MULTIPLE SL ALTITUDES
⊗ >7 kW USER POWER
● >7 DAYS DURATION

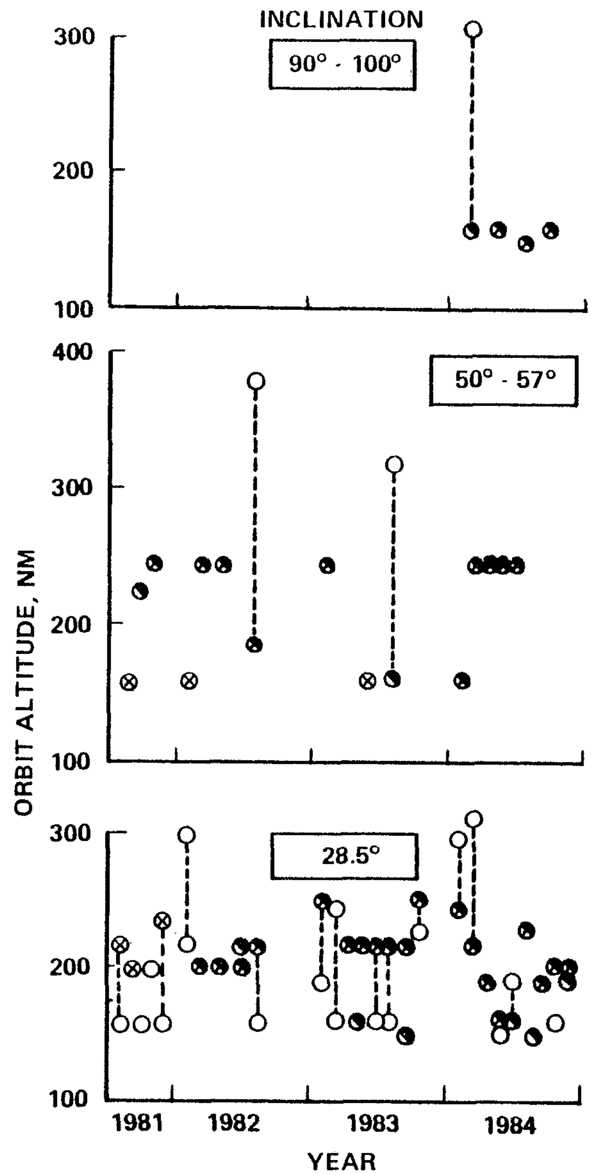

Figure 7.

NASA-S-78-11652

REQUIREMENTS ANALYSIS RESULTS

- EARLY MISSION REQUIREMENTS (1981-1983) EXCEED BASELINE ORBITER CAPABILITY

- POWER RANGE	24 TO 32 KW
- DURATION RANGE	14 TO 30 DAYS

- REQUIREMENTS INCREASE AFTER 1983

	1984		1990
- POWER	35 KW	→	100 KW
- DURATION	60 DAYS	→	CONTINUOUS
- FREE-FLYER MISSIONS			

- MULTIPLE ORBIT REQUIREMENTS EXIST EARLY AND CONTINUE

	1981-1983	>1983
- INCLINATION	28.5° & 55°	28.5°, 55° AND POLAR
- ALTITUDE	300 TO 600 KM	

- ALL ORIENTATION CAPABILITY REQUIRED
  - EARTH, SOLAR, INERTIAL, GRAVITY GRADIENT

Figure 8.

NASA-S-78-11631A

POWER PERFORMANCE ENVELOPES — ORBITER AND OSM

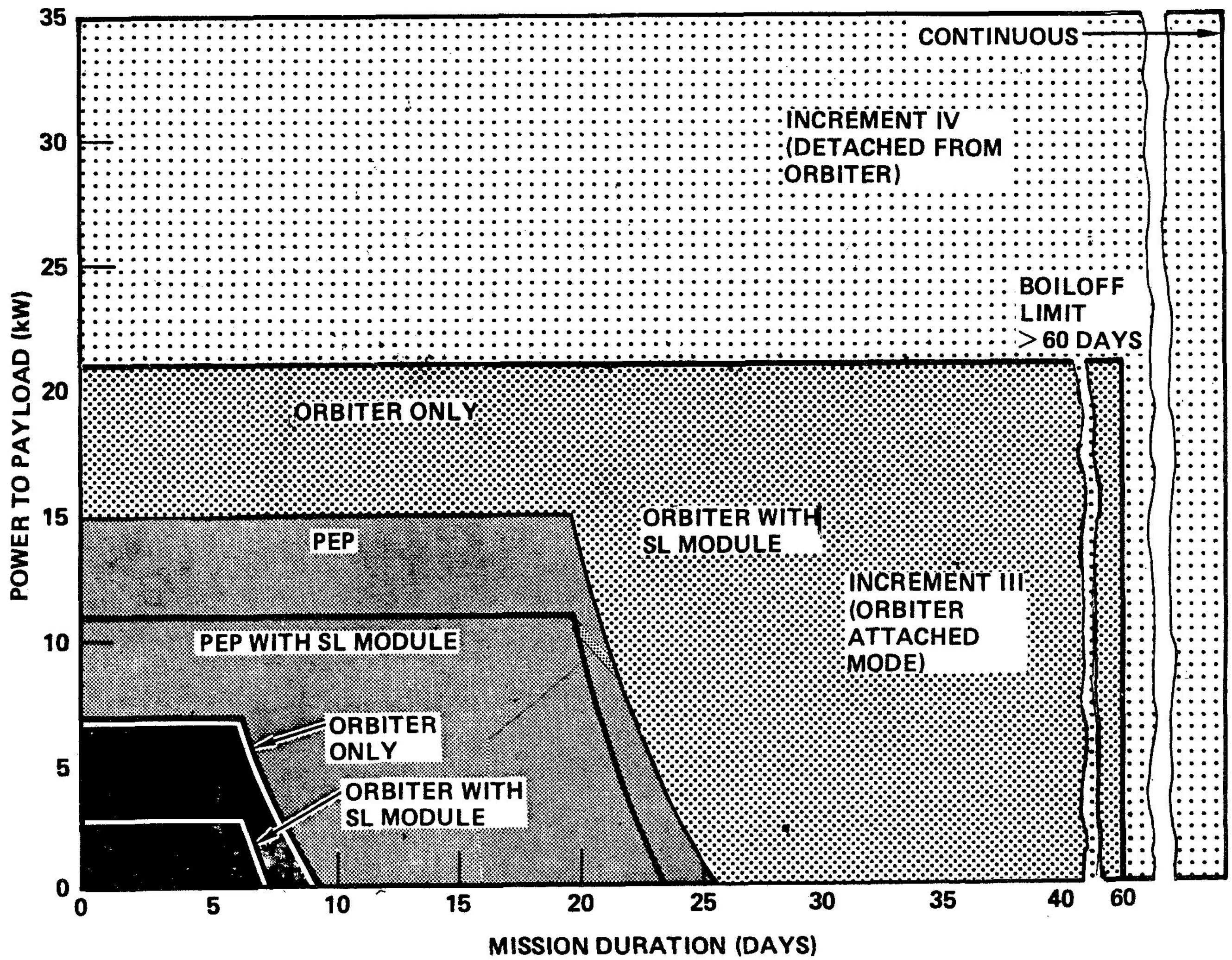

Figure 9.

NASA-S-78-11643

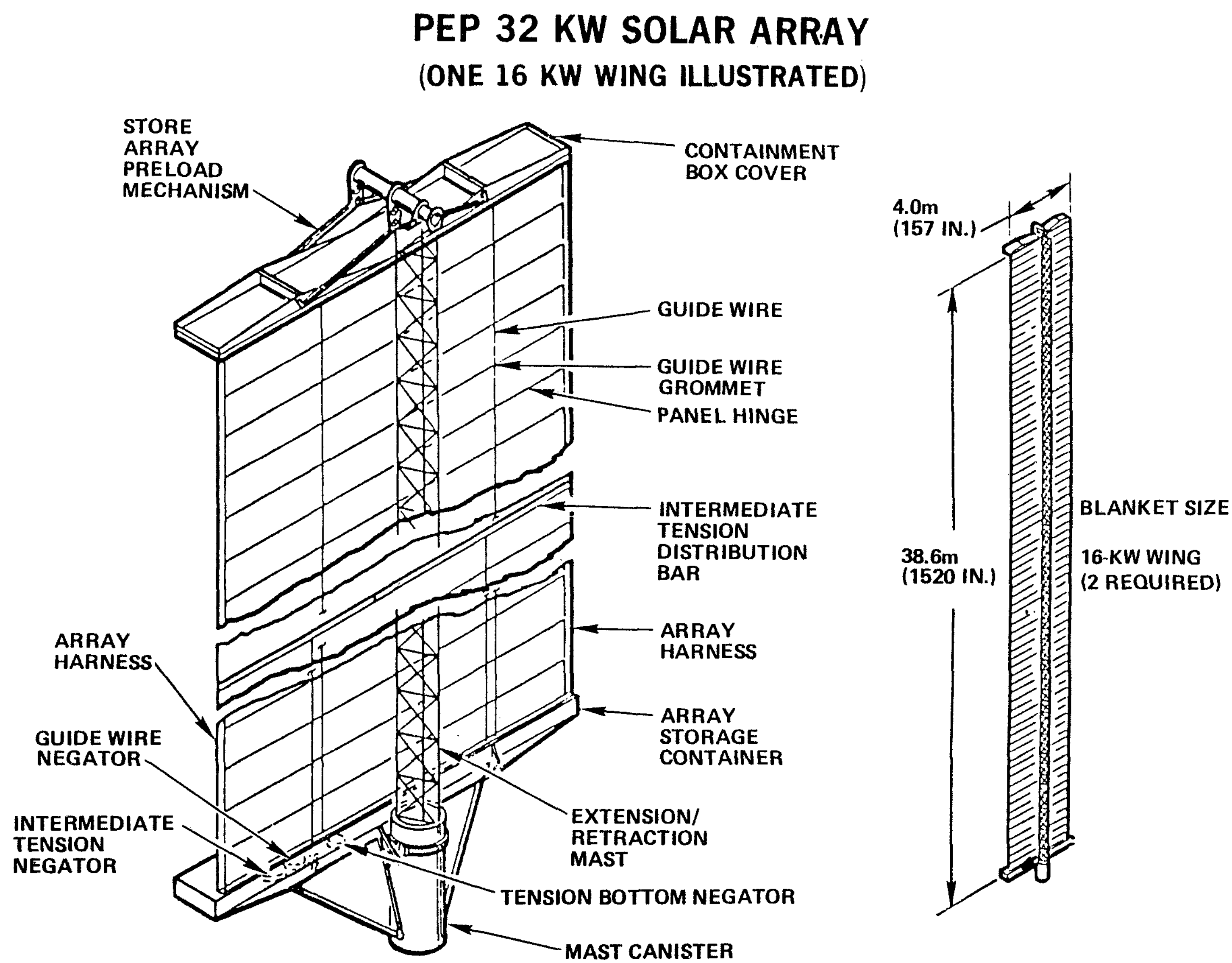

Figure 10.

NASA-S-78-11627

POWER EXTENSION PACKAGE (PEP)

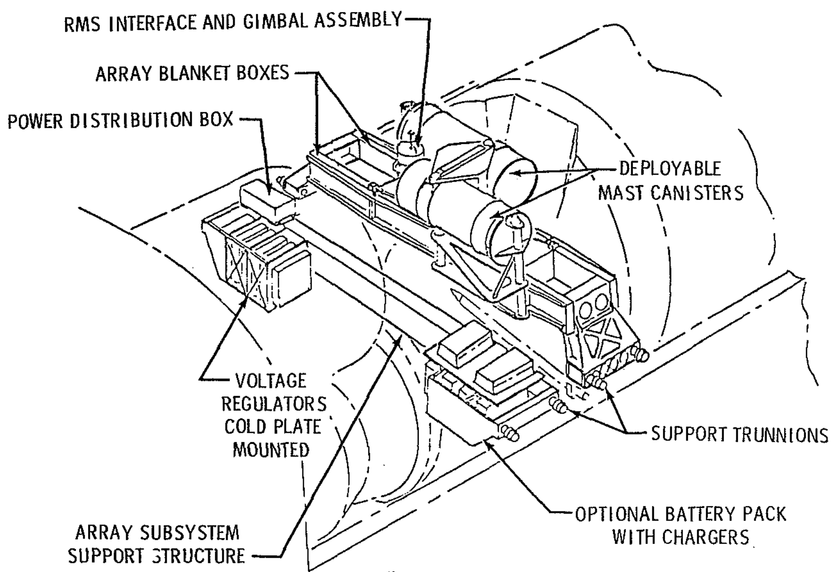

Figure 11.

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SOLAR ARRAY RMS INTERFACE

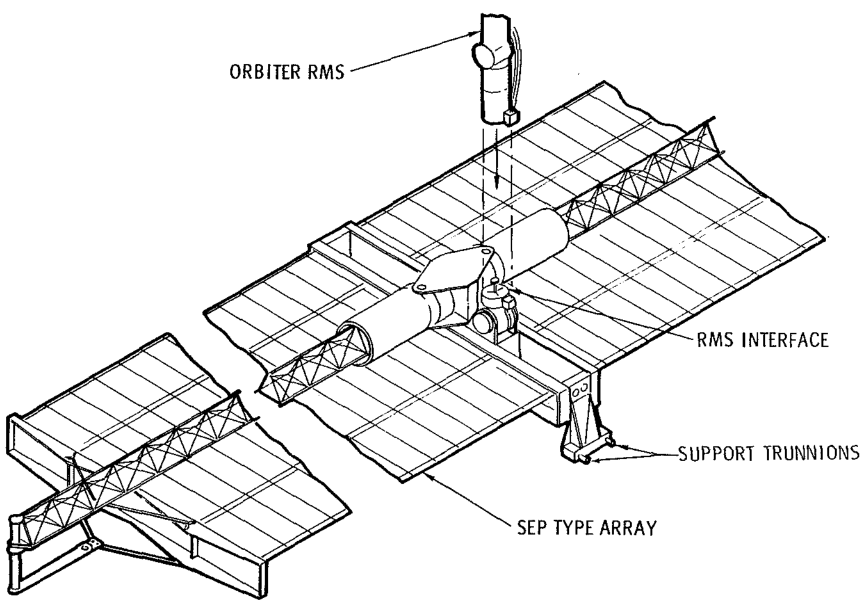


Figure 12.

41819

DEPLOYMENT SEQUENCE

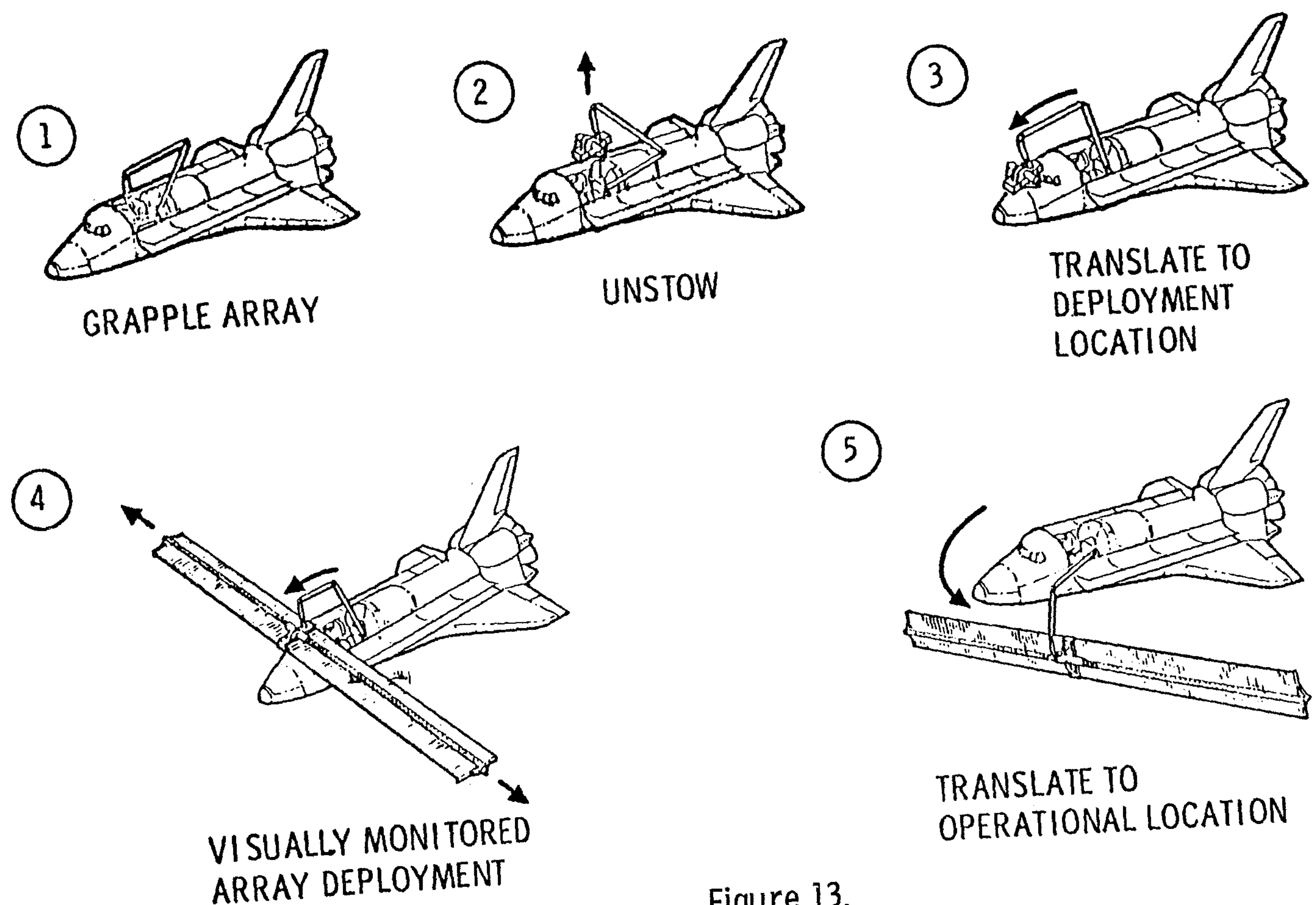


Figure 13.

NASA-S-78-11835

TYPICAL PEP ON-ORBIT HEAT REJECTION CAPABILITY

EFFECT OF PLANNING PARAMETERS IN EARTH VIEWING ATTITUDE

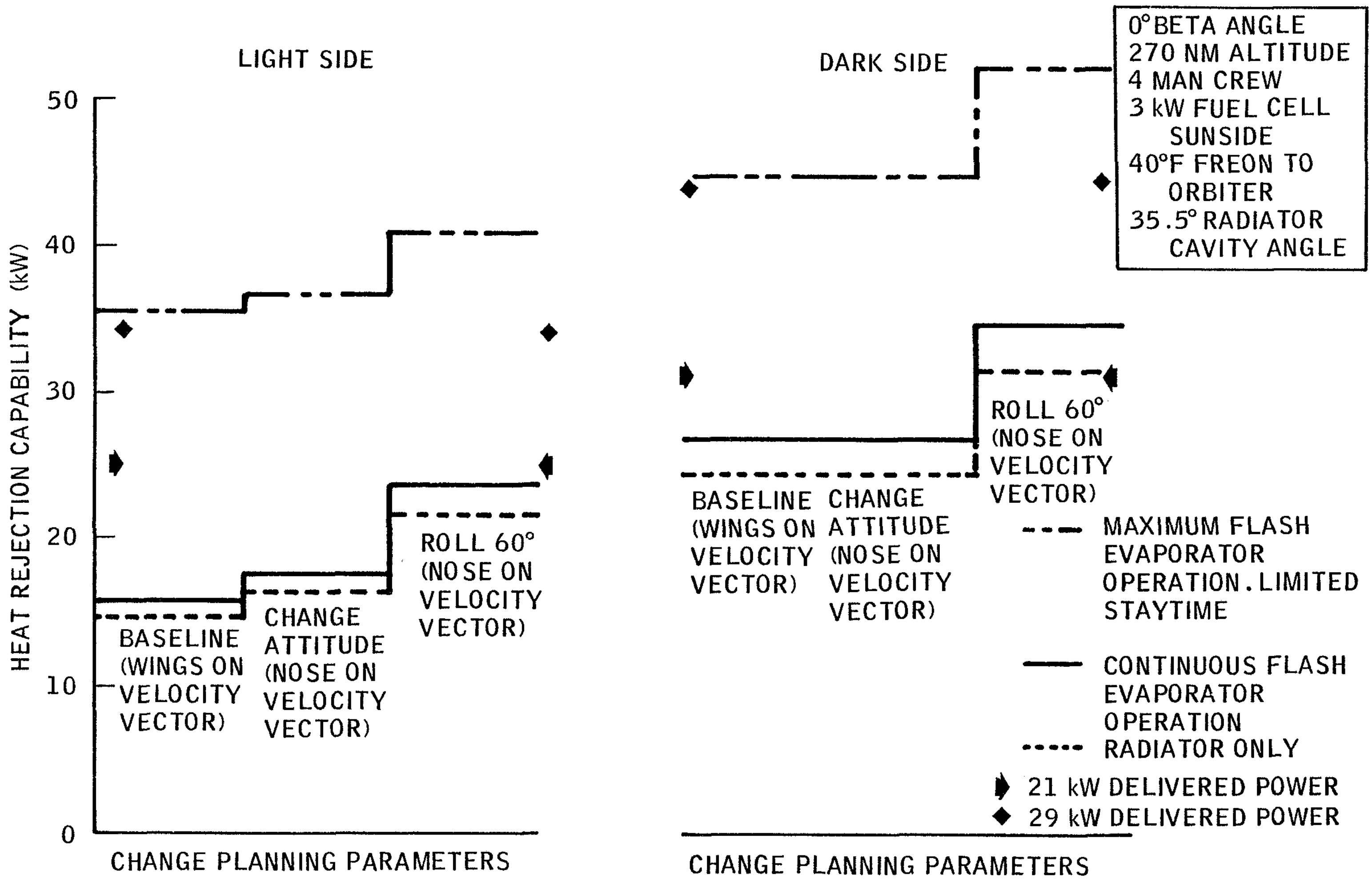


Figure 14.

NASA-S-78-11683A

PEP ACTIVE THERMAL CONTROL FEATURES

- ORBITER PROVIDES HEAT REJECTION
  - RADIATOR CAVITY INCREASED TO 60°
  - USE PAYLOAD PLANNING VARIABLES
- PAYLOAD COOLING PROVIDED BY ORBITER PAYLOAD HEAT EXCHANGER
- PEP POWER CONDITIONING EQUIPMENT COOLED BY ORBITER AFT COLDPLATE COOLANT LOOPS
- SOLID AMINE FOR CO_2 AND HUMIDITY CONTROL

Figure 15.

NASA-S-78-11832

PEP SYSTEM WEIGHT SUMMARY

	WEIGHT - LBS	
PEP	2494	
SOLAR ARRAY		1392
STRUCTURE SUPPORT		199
POWER DISTRIBUTION AND CONTROL		561
THERMAL CONTROL		88
CONTROL ELECTRONICS		254
PAYLOAD RETENTION FITTINGS	408	
CO_2 REMOVAL	-253	
LiOH		-654
SOLID AMINE (ENTRY)		401
TOTAL	2649	

Figure 16.

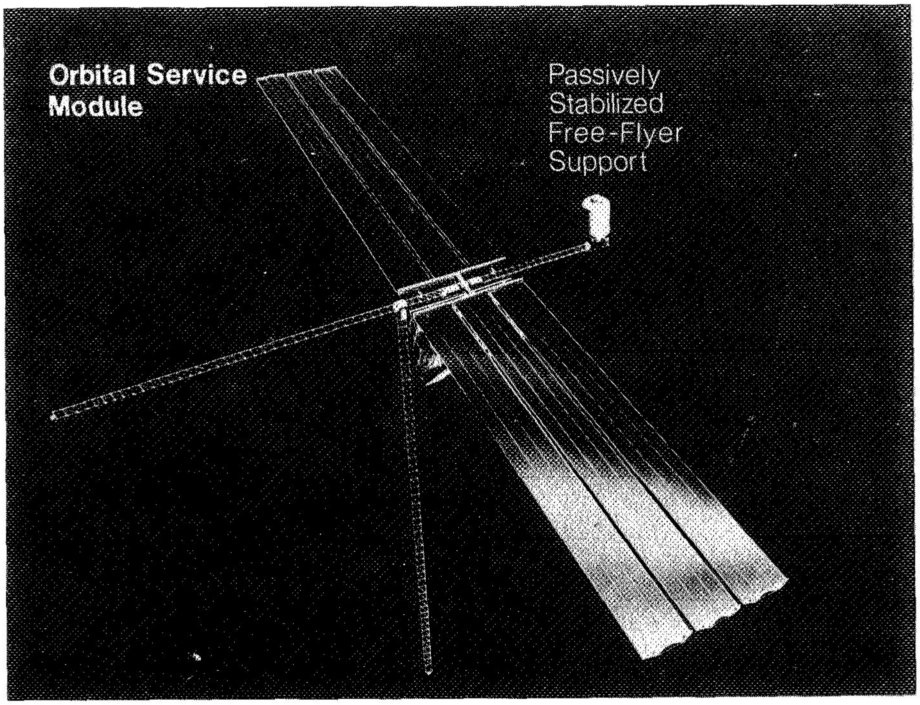


Figure 17.

NASA-S-78-11760A

OSM EVOLUTION

	BASELINE ORBITER	INCREMENT II (PEP)	INCREMENT III	INCREMENT IV
POWER SYSTEM	FUEL CELL	SOLAR CELL/ FUEL CELL	SOLAR CELL/ BATTERY	SOLAR CELL/ BATTERY
POWER AVAILABLE TO PAYLOAD	7 KW	15 KW	21 KW (1) 35 KW (2)	35 KW
TOTAL POWER OUTPUT	21 KW	29 KW	35 KW	35 KW
DURATION - DAYS	6-1/2	30 (3)	60 (4) TO CONTINUOUS	60 (4) TO CONTINUOUS
SOLAR COLLECTION AREA M^2	N/A	309	1000	1000
STABILIZATION	ORB RCS	ORB RCS	GRAVITY GRADIENT	CMG'S - ALL ATTITUDE
FREE FLYER SUPPORT	N/A	NONE	DOCKING MODULE LIMITED COMM. AND DATA	ADDS WIDE BAND DATA
HEAT DISSIPATION	ORB ONLY	ORB ONLY	ORBITER/OSM (1) OSM ONLY (2)	SYMMETRIC OSM

(1) ATTACHED TO ORBITER
(2) DETACHED FROM ORBITER
(3) AT 21 KW WITH OPTIONAL BATTERY PACK
(4) BOIL-OFF LIMITED ORBITER

Figure 18.

NASA-S-78-11646

OSM INCREMENT III DEPLOYMENT

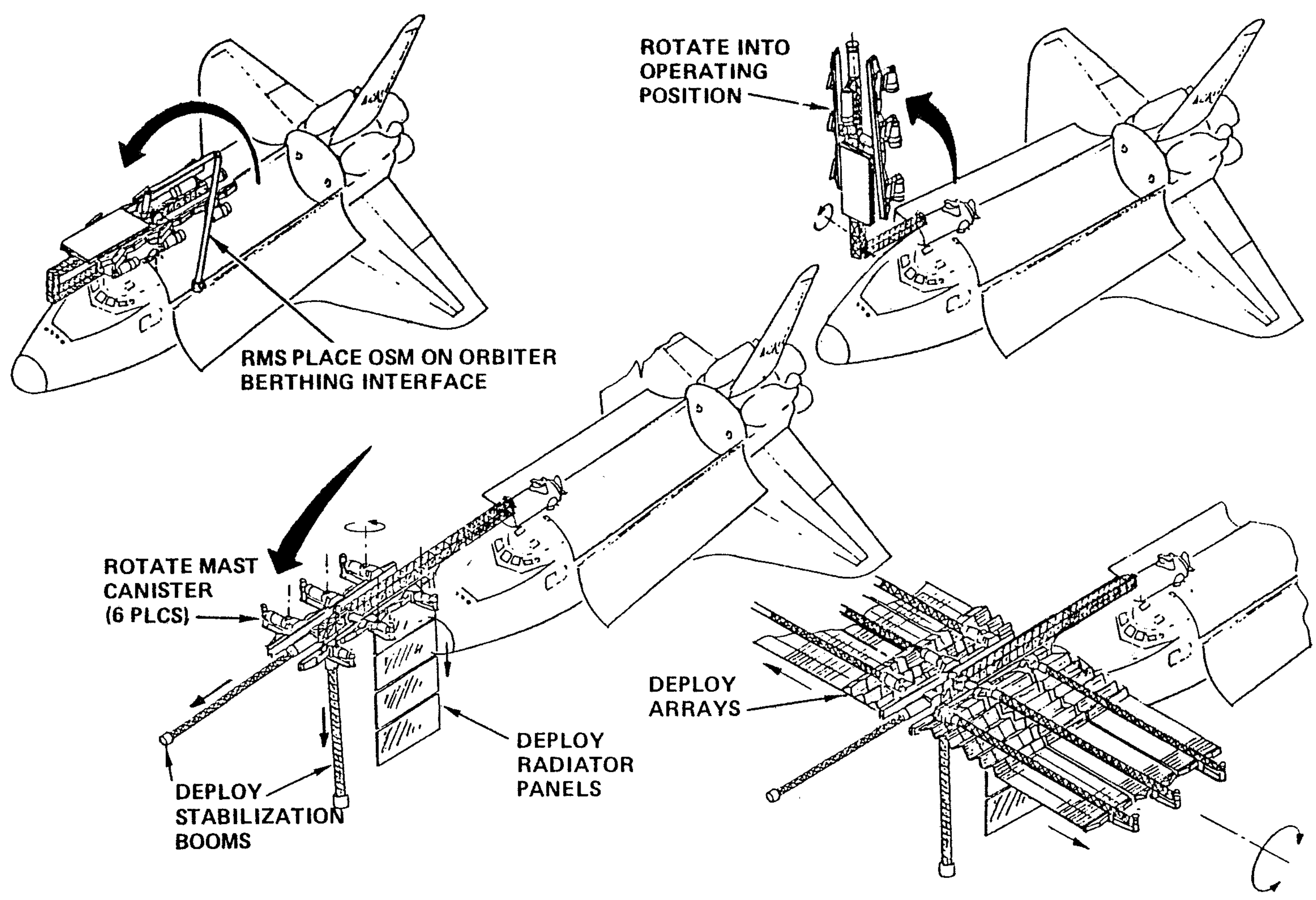


Figure 19.

NASA-S-78-11766

INCREMENT IV CONFIGURATION ACTIVELY STABILIZED

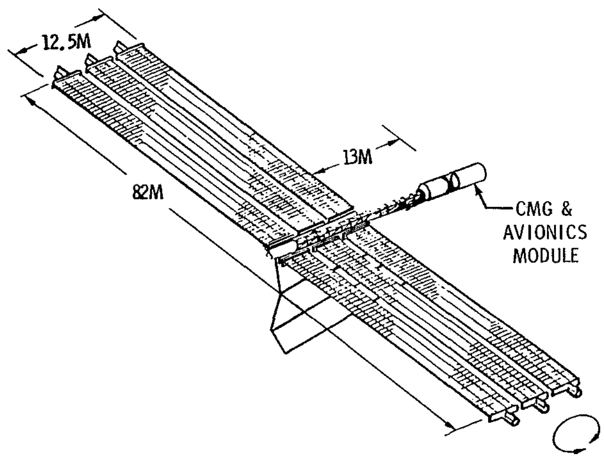


Figure 20.

NASA-S-78-11833

OSM WEIGHT ESTIMATES

EQUIPMENT	INCREMENT III	INCREMENT IV
SOLAR ARRAY	4,176	4,176
STRUCTURE SUPPORT	2,848	3,148
COUNTER BALANCE AND SUPPORT	4,792	—
POWER DISTRIBUTION AND CONTROL	11,139	11,239
THERMAL CONTROL	2,100	3,000
ATTITUDE CONTROL AND CONTROL ELECTRONICS	520	2,623
TOTALS - LBS	25,575	24,186

Figure 21.

NASA-S-78-11665

SYSTEM COMMONALITY

	INCREMENT II	INCREMENTS III/IV
ARRAY		
NUMBER OF WINGS	2	6
WIDTH OF WING (M)	4	4
LENGTH OF WING (M)	38.6	37.8
PANELS PER WING	51	50
POWER RATING PER WING (KW)	16	13
BATTERY		
BATTERY CELL RATING (AMP HR)	65*	65
CELLS PER MODULE	28*	24
BATTERY MODULES	4*	54
NUMBER OF BATTERIES	2*	18
NUMBER OF BATTERY CHARGERS	2*	9
CHARGER POWER RATING (KW)	4.38*	4.38
REGULATORS		
NUMBER OF REGULATORS	6	9
REGULATOR PEAK POWER (KW)	6	6

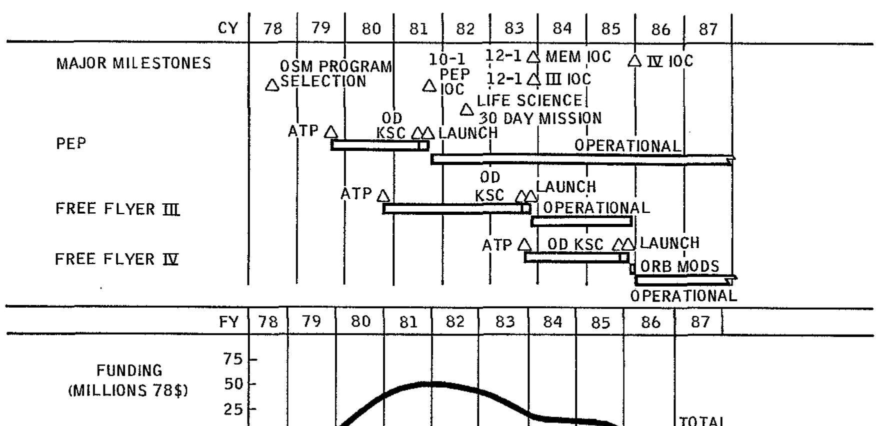
*OPTIONAL BATTERY KIT

Figure 22.

NASA-S-78-11708B

JSC BASELINE PROGRAM PLAN AND FUNDING

PEP IOC 1981, III IOC 1983, IV IOC 1985



FY	78	79	80	81	82	83	84	85	86	TOTAL
PEP			20	25						45
III				26	50	31				107
ΔIII-IV							14	14		28
(78$) TOTAL			20	51	50	31	14	14		180
(REAL YEAR$) TOTAL			23	62	66	43	21	22		237

Figure 23.