Space Station Freedom Electrical Power System Hardware Commonality With the United States Polar Platform

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ABSTRACT

The National Aeronautics and Space Administration has adopted the policy to achieve the maximum practical level of commonality for the Space Station Freedom program in order to significantly reduce life cycle costs. Commonality means using identical or similar hardware/software for meeting common sets of functionally similar requirements. Presented in this paper is information on how the concept of commonality is being implemented with respect to electric power system hardware for the Space Station Freedom and the U.S. Polar Platform. Included is a historical account of the candidate common items which have the potential to serve the same power system functions on both Freedom and the Polar Platform.

PROGRAM DESCRIPTION AND OBJECTIVES

Two of the Space Station Freedom program objectives are to establish a permanently manned research facility in low-Earth orbit and to provide an unmanned platform for long duration scientific and operational observations in near-polar orbit.

In order to bring this about, the test and development responsibilities for the program elements that form these facilities are distributed among four NASA centers - Marshall Space Flight Center (MSFC), Johnson Space Center (JSC), Goddard Space Flight Center (GSFC), and Lewis Research Center (NASA Lewis). This allows the program to draw upon unique skills and resources throughout the agency. Overall program direction and system engineering and integration (SE&I) activity is to be provided by the Program Office (Level II) in Reston, VA (Fig. 1).

In this scheme, Work Package 03 (WP-03), NASA GSFC and its prime contractor General Electric, has the responsibility for the definition, development, utilization, and servicing of platforms. Initially there were two platforms in Phase I of the program, a polar platform and a coorbiting platform. The latter, planned to occupy a low-Earth orbit the same as the space station, has been shifted downstream to Phase II of the space station program. While still considered in the design and development process, the coorbiting platform will not be discussed further here. The Polar Platform will support missions to make terrestrial, biological and geological observations, oceanographic and ice activity studies. It will also be used for Earth lower- and upper-atmospheric monitoring and research, solar observations, and plasma physics measurements (Fig. 2).

Work Package 04 (WP-04), NASA Lewis and its prime contractor Rocketdyne, has responsibility for definition and development of the space station solar power modules and distributed electric power system hardware and software. These both are part of the manned base configuration. The latter also comprises a part of the Polar Platform. The manned base has as its mission to serve as a laboratory, observatory, servicing facility, transportation node, assembly facility, manufacturing facility, storage depot, and staging base (Fig. 3).

While the mission goals and characteristics of each of these structures in space will be different, each will require development of many of the same type systems. This gives rise to the notion of using "common" hardware in order to perform similar functions in a variety of applications. This approach has been adopted by the program. A commonality program was initiated to reduce space station operating costs and crew time required for training, operations, and maintenance. The program aims at reducing costs by: (1) using existing designed hardware from other programs, (2) using identical or similar designs to satisfy similar functional requirements, (3) reducing the types of spares required, (4) using qualified standard parts, and (5) using common software, hardware, and interfaces.

The electric power system hardware candidates that could potentially perform the functions of power generation and storage, and power management and distribution on the Space Station Freedom and the Polar Platform are shown in Table I. To discuss how the commonality process has influenced the selection of this power system hardware, a historical account from the WP-04 perspective is given below.

PROGRAM DEFINITION AND PRELIMINARY DESIGN (PHASE B)

A comprehensive program definition phase was completed in January 1987, which provided a review of space station systems and a more thorough understanding of the overall space station architecture. WP-04 participated in trade studies that focused on
comparing the electric power system technology candidates and determining the best common option for the station and platforms.

**Specific Design Drivers**

Some unique characteristics of the Polar Platform must be considered in the hardware designs for use in this application. The first of these is that the platform will be unmanned and have a low visitation frequency. Therefore, a long design life, less harsh operating ranges, and high reliability are features stressed for use on the platform. Another characteristic is a requirement for solar array retractability. This is a necessity during servicing and reorientation maneuvers in order to reduce drag. In addition, the platform designs must respond to power requirements of few, relatively predictable users. In contrast, the space station will be manned, making servicing events possible, and will provide utility-type power to many users upon demand. Both the platform and station will incorporate a capability for growth.

**Photovoltaic Power Generation**

The power generation source baselined in Phase B for the station and platform was a planar silicon flexible panel array utilizing 8- by 8-cm solar cells. It included a dual blanket deployment, retraction capability, and protected Kapton substrate. Operational voltage would be a nominal 160 V dc. A summary of other options traded against the selected features are shown in Table 11.

Several key factors formed the basis and rationale for the selected design. It was the minimum cost, minimum mass choice. The dual blanket design offered an aspect ratio for the platform solar array that would minimize interference with the payloads’ field of view. The design could easily accommodate the lower platform power generation requirements by using panel and blanket box designs identical to the station but using fewer panels and adjusting the blanket box preload. This design is also compatible with the need for retractionability. The concept was favored as well from the standpoint that it had been previously demonstrated with the OAST-1 flight experiment. A schematic of the solar array assemblies is shown in Fig. 4.

Growth is accomplished by either launching the growth configuration initially or by replacing the entire array assembly on-orbit. This design is expected to have a 15 year serviceable lifetime with the design point for the station at 4 years and for the platform at 10 years.

**Energy Storage**

The energy storage device baselined in Phase B for the station and platform was an individual pressure vessel nickel-hydrogen battery. The rationale for this decision was that this choice was a low mass option, with low waste heat dissipation requirements, and high reliability. The other options under consideration were nickel-cadmium batteries, energy wheels, and alkaline regenerative fuel cells. Energy wheels were considered to be at too early a stage of development and were dropped early as a viable option (Fig. 5). Nickel-cadmium batteries would impose an extreme mass penalty for both the station and platform. Alkaline regenerative fuel cells (RFC) were the most competitive option but presented several drawbacks. The first of these was that the volume was too large for both applications but especially for the Polar Platform where it is desirable to package the energy storage device and other platform subsystem equipment in standard ORU boxes. Second, the need to dissipate high heat loads generated by the RFC requires a significantly larger radiator surface. While this imposes a mass penalty on the station, the platform utilizes a passive thermal control system by radiating off the side surfaces of the standard ORU boxes. The large size and increased mass make this approach infeasible. Finally, it is unknown if the RFC could meet a 100 percent power requirement after a single failure on the platform without incorporating an extreme amount of redundancy and increasing mass, making its reliability questionable. As a result, a nickel-hydrogen battery (Fig. 6) was selected as the baseline. It would be comprised of 3.5 in. diameter cells of the pineapple-slice design. However, the capacity remained an issue with WP-04 baselining a 65 AH cell and WP-03 baselining a 40 AH cell. The difference hinged primarily upon thermal control considerations. Nickel-hydrides are a more efficient energy storage device in spacecraft but in geosynchronous orbit with a different cycle regime than the low-Earth orbit cycle in the space station program. The five year design life needed for the batteries aboard the space station and platform is considered achievable although not yet proven. Growth would be accomplished by replication of battery assemblies to meet increasing power requirements.

**Power Management and Distribution**

The functions of power management and distribution on the Polar Platform parallel those of the Space Station Freedom. The functions begin with the acceptance of 160 V dc and inverting it to 208 V ac, 20 kHz, single-phase power. This is accomplished using a series resonant switching topology in the inverter units. Power output and voltage output ratings differ between the station and platform inverter units as expected. Each of the station inverters is rated 25 kVA with an output voltage of 440 V ac. Each of the platform inverters is rated 5 kVA with an output voltage of 208 V ac. The initial number of inverter units on the platform is four, which meet program requirements for normal and peak power and system fault tolerance.

The second function of the EPS system is to provide system and load fault protection. This function is provided by ac remote power controllers (RPC). The RPC's are solid-state switching devices which include programmable trip settings and programmable time to trip settings. The devices provide voltage, current, and status data to the power management controller for the purpose of monitoring the EPS system's health and optimizing the usage of
Additional common hardware for station and platform use are ac/dc and dc/dc converters of 100 W output ratings. These converters will provide 28 V dc, ±15 V dc and ±5 V dc outputs for control voltage required by the hardware and system control processors.

DESIGN AND DEVELOPMENT (PHASE C/D)

Phase C/D of the space station program is in progress. Work is proceeding with an interactive process between the work package centers and Level II of refining design requirements and honing in on designs. The power generation and energy storage system is the focus of Phase B. Other areas addressed during technical interchange meetings have been the use of a common gimbal control system. The solar array design point from 10 to 15 W.

In order to converge on a design in areas where a discrepancy exists, WP-03 and WP-04 continue to exchange technical information. WP-03 and WP-04 met specifically to discuss thermal considerations for the batteries on the platform and the solar array. The battery thermal control design baseline of the station was updated to include a 10 W cooling requirement for battery packs and an 11 W cooling requirement for the platform. Solar array sizing factors were discussed, leading to another alteration that shifted the solar array design point from 10 to 15 W.

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with the goal of reducing the program cost of
design, development, testing, assembly and check-
out, and operation of these facilities. The
configuration of the hardware that has been deter-
mained to be common is currently being refined.
Production of Polar Platform and Space Station
Freedom hardware is scheduled to begin in 1992.

ACKNOWLEDGMENTS

The authors wish to acknowledge and thank our
counterparts in the WP-04 Space Station SE&I Divi-
sion, and the WP-03 Space Station Project Office-
Platform Segment for their contributions in sup-
porting the effort to define common electric power
system hardware for the Polar Platform.

REFERENCES

1. Space Station Development Plan. Submitted by
NASA to the Committee on Science, Space and
1987.

2. Photovoltaic System Recommendations: Confi-
guration Selections for Station and Platform EPS.
NASA LERC Space Station Systems Presentation,

3. Energy Storage Trade Study. TRW Space and


5. Work Package 03 System Concept Review Presenta-


TABLE I. - POWER SYSTEM COMMONALITY
CANDIDATES

[The Electric power system hardware for
the platform will be provided by WP-04
unless a program decision is made to
make the item unique. In that case,
the item would be designed and devel-
oped by WP-03.]

| Photovoltaic silicon solar array |
| Nickel-hydrogen batteries |
| Battery charge regulator |
| Battery discharge regulator |
| Inverters, dc/ac |
| Remote bus isolators (RBI), dc |
| Fault isolators |
| Converters, ac/dc |
| Remote power controllers (RPC), ac |
| Beta gimbal |
| Sequential shunt unit (SSU) |

Photovoltaic silicon solar array
Nickel-hydrogen batteries
Battery charge regulator
Battery discharge regulator
Inverters, dc/ac
Remote bus isolators (RBI), dc
Fault isolators
Converters, ac/dc
Converters, dc/dc
Remote power controllers (RPC), ac
Beta gimbal
Sequential shunt unit (SSU)

TABLE II. - SOLAR ARRAY TRADE STUDY OPTIONS

(a) Cell characteristics

<table>
<thead>
<tr>
<th>Selected feature</th>
<th>Other trade study options</th>
</tr>
</thead>
<tbody>
<tr>
<td>Planar</td>
<td>Concentrator</td>
</tr>
<tr>
<td>Silicon</td>
<td>Gallium arsenide</td>
</tr>
<tr>
<td>Infrared transparent BSF&lt;sup&gt;a&lt;/sup&gt;</td>
<td>Infrared reflective BSF/BSR&lt;sup&gt;b&lt;/sup&gt;,&lt;sup&gt;c&lt;/sup&gt;</td>
</tr>
<tr>
<td>6-mil cover glass</td>
<td>2-mil cover glass</td>
</tr>
<tr>
<td>Ceria cover glass</td>
<td>Fused-silica cover glass</td>
</tr>
<tr>
<td>8-mil cell</td>
<td>6-mil cell</td>
</tr>
<tr>
<td>8 by 8 cm</td>
<td>2 by 4 cm</td>
</tr>
<tr>
<td>3 by 6 cm</td>
<td>6 by 6 cm</td>
</tr>
</tbody>
</table>

(b) Array characteristics

<table>
<thead>
<tr>
<th>Selected feature</th>
<th>Other trade study options</th>
</tr>
</thead>
<tbody>
<tr>
<td>Deployable/ retractable</td>
<td>Deployable/Erectable</td>
</tr>
<tr>
<td>Flexible blanket</td>
<td>Rigid panel</td>
</tr>
<tr>
<td>Protected Kapton</td>
<td>Kapton-F</td>
</tr>
<tr>
<td>PTFE (Teflon) and SiO&lt;sub&gt;2&lt;/sub&gt;</td>
<td>Others</td>
</tr>
<tr>
<td>Dual blanket array wing</td>
<td>Single blanket array wing</td>
</tr>
<tr>
<td>Nominal 160 V dc</td>
<td>200 V dc</td>
</tr>
<tr>
<td></td>
<td>400 V dc</td>
</tr>
<tr>
<td></td>
<td>&gt;400 V dc</td>
</tr>
</tbody>
</table>

<sup>a</sup>Back-side field.
<sup>b</sup>Back-side reflective.
TABLE III. - WP-04 TO WP-03 DELIVERABLES

[In addition to these items a solar array handling set and transport container will be shared by WP-03 and WP-04 if scheduling permits.]

Solar array wing assembly
Solar array mechanical simulator
Solar array electrical simulator
Sequential shunt unit (SSU)
Solar array cannister simulator
Nickel-hydrogen battery pack (Workhorse)
Nickel-hydrogen battery pack (Qual)
Nickel-hydrogen battery pack (Flight)
Nickel-hydrogen battery pack mounting plate simulator
Battery charger/regulator
RBI's, dc
Fault interrupters
Photovoltaic control element (PVCE)
Battery monitor
Remote power controllers, dc

FIGURE 1. - SPACE STATION ROLES.

LEVEL I

CONGRESS
NSST (CODE M) → SPACE STATION PROGRAM NASA HQ → OSSA (CODE E) → INTERNATIONAL

LEVEL II

PSC = PROGRAM SUPPORT CONTRACTOR
SSE = SOFTWARE SUPPORT ENVIRONMENT
TMIS = TECHNICAL AND MANAGEMENT INFORMATION SYSTEM
OSTA = OFFICE FOR SPACE AND SCIENCE APPLICATIONS
NSTS = NATIONAL SPACE TRANSPORTATION SYSTEM

LEVEL III

WP3

GSFC

MP4

SPACE STATION SYSTEMS DIRECTORATE

SYSTEM ENGINEERING AND INTEGRATION

PHOTOVOLTAIC POWER MODULE

SOLAR DYNAMIC POWER MODULE

ELECTRICAL SYSTEMS

OPERATIONS AND SPECIAL PROJECTS

PROJECT CONTROL OFFICE

SPACELAB

ROCKETDYNE

JSC

KSC

MSFC

NDAC

BOEING

MDAC
FIGURE 2. - U.S. POLAR PLATFORM BASELINE CONFIGURATION.

FIGURE 3. - SPACE STATION PHASE 1 BASELINE CONFIGURATION.
FIGURE 4. - NOVEMBER 1987 BASELINE STATION AND PLATFORM SOLAR ARRAY DESIGN.

FIGURE 5. - ENERGY STORAGE TRADE STUDY RATINGS.

FIGURE 6. - NOVEMBER 1987 BASELINE STATION AND PLATFORM BATTERY ASSEMBLY.
REPORT STATUS TO LEVEL II

INTEGRATE REQTS. AND PREPARE ITEM SPEC.

PROVIDER/USER MEETINGS TO RESOLVE ISSUES

UPDATE ACD

REPORT STATUS TO LEVEL II

BOTH PARTIES AGREE WITH COMMON ITEM SPEC AND SCHEDULE OF DELIVERIES

COMMONALITY BASELINE CONFIRMED

UPDATE ACD

NOTIFY LEVEL II

USER SCHEDULES FORMAL MEETING

HOLD FORMAL MEETING OF INTERESTED PARTIES

PARTIES DISAGREE

PARTIES AGREE TO MAKE ITEM UNIQUE

USER PREPARES CR

PRESENT TO SSCB

PREPARE TO PRESENT TO LEVEL II

- NATURE OF CR OR IMPASSE
- KEY ISSUES
- USER'S POSITION
- PROVIDER'S POSITION
- COST ANALYSIS

FIGURE 7. - COMMONALITY PROCESS.

WP = WORK PACKAGE
ACD = ARCHITECTURAL CONTROL DOCUMENT
CR = CHANGE REQUEST
SSCB = SPACE STATION CONTROL BOARD
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