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Launch Packaging Options for the Photovoltaic Power Module Cargo Element

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LAUNCH PACKAGING OPTIONS FOR THE PV POWER MODULE CARGO ELEMENT

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ABSTRACT

The National Aeronautics and Space Administration has recently embarked on the Space Station Freedom program, which will utilize the Shuttle Orbiter for transportation to orbit. This task will be accomplished with a number of flights over several years. Each flight is unique in terms of the hardware that is manifested and the method by which it is integrated to form viable cargo elements. Work Package 4 is responsible for the electric power system for Space Station Freedom, and has been delegated the authority to develop a photovoltaic (PV) power module cargo element.

The PV power module consists of several unique assemblies, each with its own function. These assemblies are combined in a manner such that functions are consolidated and packaging is efficient. The first of these is the combined solar array/beta gimbal assembly, of which there are two for each PV power module. The remaining assemblies form the single combined integrated equipment assembly for each PV power module. These three combined assemblies are packaged into a launch cradle to form the PV power module cargo element, which is placed in the cargo bay of the Shuttle Orbiter for transportation to orbit.

Various constraints determine the packaging options for the three PV power module combined assemblies. The size and shape of the combined assemblies in relation to the Shuttle Orbiter cargo bay dimensions and other manifested hardware are ultimately a factor in determining the acceptable packaging schemes for the PV power module cargo element. Other factors play a significant role as well, including but not limited to mass, volume, and center-of-gravity considerations in addition to on-orbit assembly and maintenance factors.

Several packaging options for the PV power module cargo element are presented. These options are discussed in terms of their impact on the overall flight hardware manifest as determined by the various constraints. Space Station Freedom program considerations are also addressed.

INTRODUCTION

The PV power module cargo element packages all hardware which constitutes an 18.75 kW PV power module, and is shown in Fig. 1. The hardware serves the following functions: power generation (solar arrays), sun tracking (beta gimbals), energy storage (batteries), power management and distribution (ac and dc electronics), and thermal control (radiators). There will be four modules on-orbit to provide 75 kW of power at the completion of Phase 1 of the Space Station Freedom program. Each PV power module occupies two truss bays along the transverse boom of Freedom. As seen in Fig. 1, one of the truss bays contains a pair of solar arrays mated to their respective beta gimbals to form two combined solar array/beta gimbal assemblies. The other truss bay contains the remaining module hardware, all mounted to a single combined integrated equipment assembly (IEA). These three combined assemblies are packaged together in a launch cradle to form a PV power module cargo element, which is placed in the payload bay of the Shuttle Orbiter for transportation to orbit.

LAUNCH PACKAGING REQUIREMENTS AND CONSTRAINTS

A number of requirements and constraints determine the packaging options for the PV power module cargo element. Those discussed are not complete, but serve to illustrate the many parameters that all must be taken into consideration as part of the packaging effort. The major requirement driving all work packages is the Freedom assembly sequence, which dictates the total number of flights required to place Freedom into orbit as well as the hardware manifested on each individual flight. This assembly sequence is structured to satisfy major program milestones, including first element launch (FEL), man-tended capability (MTC), permanently manned capability (PMC), and assembly complete (AC). Another requirement is the need to safely maintain an operable spacecraft with all necessary functions until the next assembly flight. These requirements provide the guidelines for the various constraints which ultimately determine the acceptable packaging schemes for all manifested hardware.

Launch packaging constraints can be grouped into several categories, the majority of which relate to the Shuttle Orbiter. An example of a processing constraint is the need to allow for hazardous servicing of individual cargo elements without interference from other cargo elements. Several performance constraints also exist. The first relates to mass limitations based on maximum cargo lift and landing capabilities. These are a function of both ascent and descent performance for the Shuttle Orbiter. The second is a center-of-gravity limitation, which dictates that all manifested hardware fall within a specific center-of-gravity envelope in the Shuttle Orbiter payload bay. Other constraints of importance include payload bay volume limitations, rapid safing contingencies, assembly operations, extravehicular activity (EVA) limitations, maintainability, and failure tolerance considerations. Taken together, these constraints make the task of launch packaging a formidable one, with mass and center-of-gravity being the most challenging. The key to successful packaging of the PV power module cargo element is thus to minimize its mass while optimizing its placement in the Shuttle Orbiter payload bay relative to other manifested hardware.

PV POWER MODULE CARGO ELEMENT OPTION DESCRIPTIONS

Six options have been identified and studied to date. These were identified over the course of the proposal and development work during the early part of the Space Station Freedom program for Work Package 4. The progression of options has evolved as a result of working with NASA-Level II as well as other work package teams. The presentation here will be in chronological order.

Option 1 was the Rocketdyne "baseline proposal IEA", and is shown in Fig. 2. The three separate PV power module combined assemblies, two solar array/beta gimbal assemblies and a single IEA, are packaged in the launch cradle as shown. One of the key features of this scheme is that the resulting cargo element is the same for each of the four modules that are launched. Thus, all design verification testing and analysis will only need to be performed once for the four cargo elements. In addition, two launch cradles can be built to accommodate all four PV power modules. This is because the baseline Freedom assembly sequence dictates that the four modules are launched on three different flights, resulting in only one flight where two PV power modules are launched together.

Option 2 was created as a minimalist approach to solving the specific problem of manifesting as little photovoltaic hardware as possible. This "minimum IEA" option, shown in Fig. 3, is a unique power system designed to be used only until a complete PV power module can be launched on a later flight. It would provide the minimum amount of power needed to run the station during the early buildup sequence. It would be returned to earth when the first complete module was installed, and would result in having to add an extra replacement PV power module into the assembly sequence later in the program. The advantage of this configuration is that it makes the maximum mass and volume in the Shuttle Orbiter payload bay available to other manifested hardware. The primary disadvantage is that it results in having to assemble additional photovoltaic hardware and integrate it in a unique configuration, which would expand the electric power system development program considerably.

Option 3 is essentially the same as option 1 with three batteries removed. Since each battery consists of three battery assemblies and a single battery charge/discharge unit, a total of twelve orbital replacement units (ORU's) were removed to create this configuration. Because of the location of the ORU's and the way in which they are mounted to the IEA, the cargo element volume is the same as for option 1 but the mass is reduced considerably. The batteries would not be removed permanently however, and would be brought up on a later flight. Additional EVA time would be needed to install the ORU's at that time. As with the previous option, mass on this flight would be reduced at the expense of increasing total program mass and cost.

Option 4 was created by making two changes to the baseline PV power module design. The configuration of the IEA was changed from being roughly square to that of a lower rectangular profile. This reduced the effective packaging volume of the IEA. The second change was to replace the two-phase thermal control system and erectable heat pipe radiator panels with a single-phase thermal control system utilizing a smaller, direct deployable radiator. The deployable radiator fits within the existing envelope of the module cargo element. The reduction in volume of the IEA also allows room for other manifested hardware, such as boxes containing truss members, to be packaged onto the cargo element. This "low profile IEA" option is shown in Fig. 4.

Option 5 was the result of another PV power module design change. After an internal Rocketdyne design review, it was decided to reconfigure the IEA into a flat plate with the ORU's mounted on both sides. This is a minimum volume configuration. An additional benefit is that the "flat plate IEA" is more easily maintainable via EVA. The single-phase thermal control system with its deployable radiator was retained in this option because of its packaging advantages.

CARGO ELEMENT DESIGN SELECTED

The PV power module cargo element design currently being pursued by Work Package 4 is the option 5 configuration. As with the previously described options, the cargo element configuration will be the same for all four modules. By maintaining this separate cargo element, the PV power module can be integrated and fully checked out on the ground before shipment to the launch site. All connections in the thermal system can be made and leak checked as well.

A refinement was made to this design which allowed the launch cradle to be eliminated as a separate item. The longeron and keel attach fittings were integrated into the end plates of the IEA structural framework, which essentially combines the IEA and launch cradle into one unified structure. This is shown in Fig. 5. The two solar array/beta gimbal assemblies can then be attached to one of the end plates via slide mechanisms. The resulting cargo element, shown in Fig. 6, is a minimum mass configuration.

FUTURE PLANS

The major launch packaging challenges for the Freedom program are to maintain payload bay mass and center-of-gravity within Shuttle Orbiter limitations. Since many launches are shared by several work packages, an extensive integration activity will be necessary to successfully accomplish this task. NASA-Level II, its support contractor, and all work package teams are well on their way to meeting these challenges.

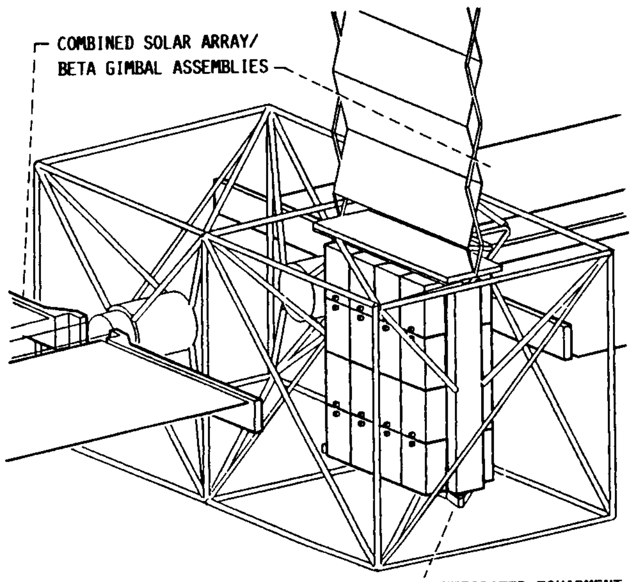

FIGURE 1. - PV POWER MODULE.

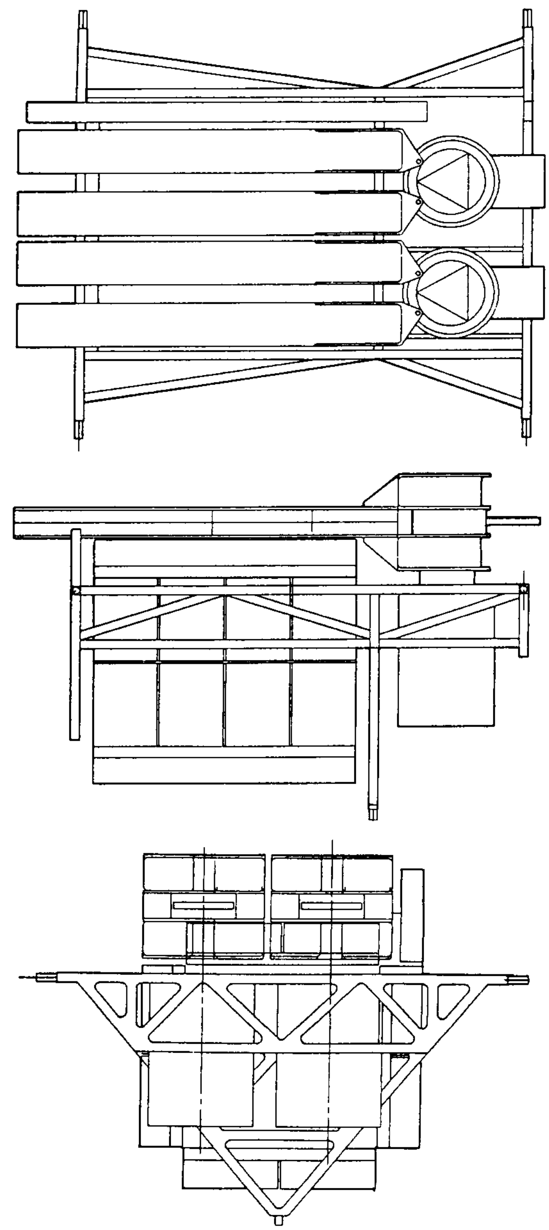

FIGURE 2. - OPTION 1 CONFIGURATION, "BASELINE PROPOSAL IEA".

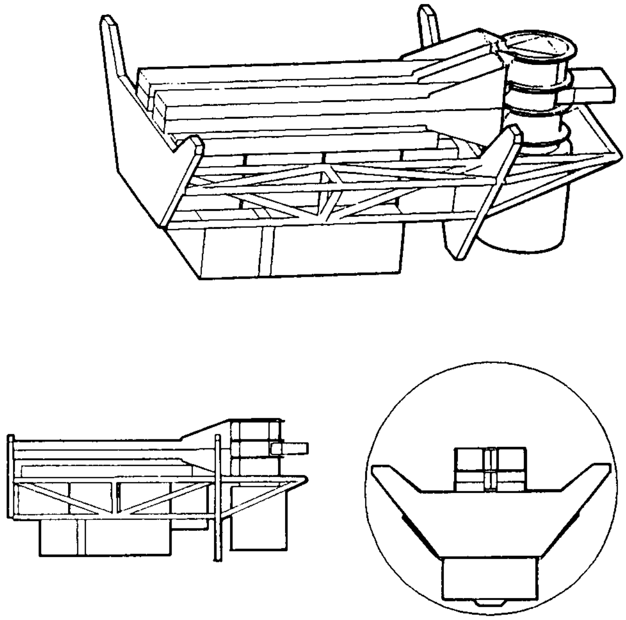

FIGURE 3. - OPTION 2 CONFIGURATION, "MINIMUM IEA".

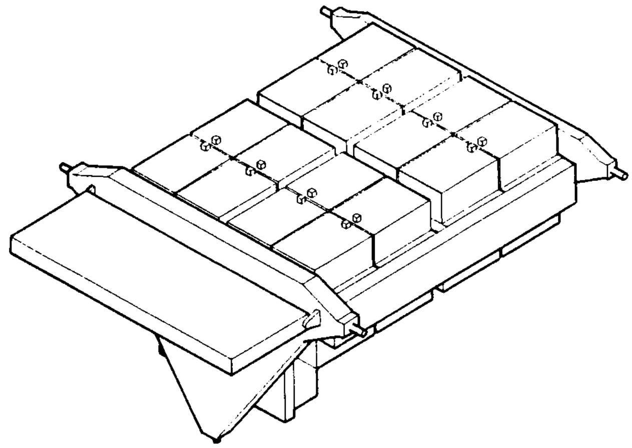

FIGURE 5. - OPTION 5 CONFIGURATION, "FLAT PLATE IEA".

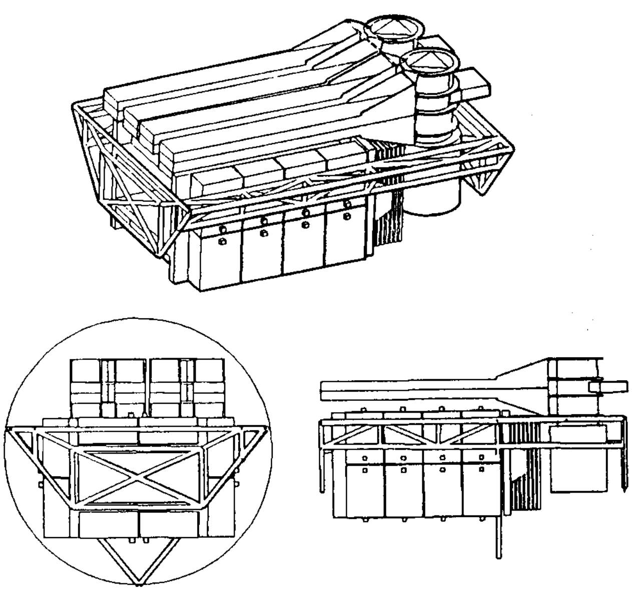

FIGURE 4. - OPTION 4 CONFIGURATION, "LOW PROFILE IEA".

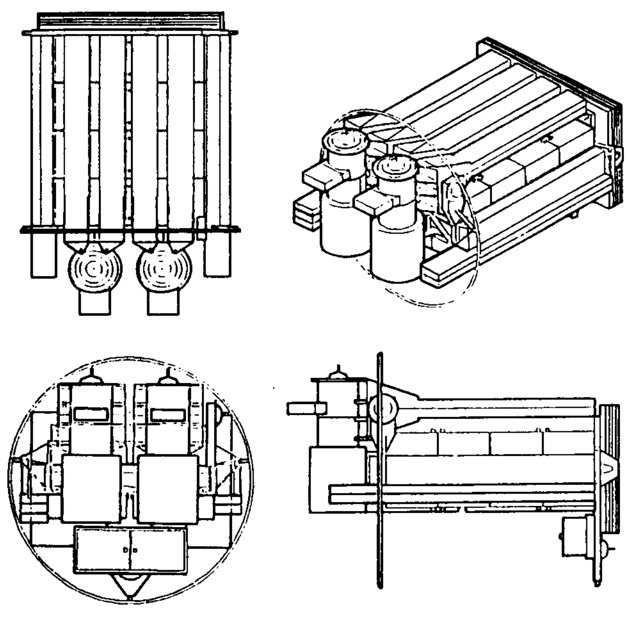

FIGURE 6. - "FLAT PLATE IEA CARGO ELEMENT".

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16. Abstract
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