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SPACE PLATFORMS: AN EVOLUTION
FROM SPACELAB PAYLOAD OPERATIONS

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ABSTRACT

The Shuttle/Spacelab mode of orbital operations will provide the user community significant new capabilities to accomplish their missions in space. As these capabilities are utilized, it is readily recognized that, if some of the available resources were augmented, considerable extra benefits to the user could be provided. This paper reports on the planning efforts in progress which are examining the evolution of the present Spacelab mode of operation into an optimal utilization of the newly developing augmentation systems.

The initial Spacelab activities are projected into the second half of the 1980 decade when these new systems will become available. Descriptions of each of the systems considered; the Power Extension Package, The Power System, and the Science and Applications Space Platforms, are provided. The projected model is then analyzed, showing how each system would be utilized to provide benefits to the users' missions. A summary of these results along with a general analysis of the evolutionary program is then presented.

I. INTRODUCTION

The Shuttle/Spacelab approach to space experimentation has significantly influenced the user community in exploiting that mode of operations to accomplish their investigations. This fact is clearly evidenced by the payload development and mission planning which has been described during the previous Space Congresses and in this, the Seventeenth Space Congress. Many new instruments have been conceived and some old techniques have been revised to provide for the operation capabilities offered by this unique mode of experimentation. It is expected that Spacelab missions will continue to be important tools in various research and development phases of the Science, Applications, and Technology discipline programs.

As preparations continue for implementing this new mode of operations, it is recognized that, if some of the basic services offered by the Shuttle/Spacelab were augmented, considerable extra benefits could result. There are several options which may provide for this augmentation. One possible means might be a system which could be attached to the Shuttle/Spacelab configuration and carried into orbit in the normal Spacelab mission mode. A second option could be to provide an orbiting system to which the Shuttle/Spacelab could be attached and operated while in orbit, and onto which Spacelab carrier elements (i.e., pallets) could be attached and left in orbit to operate after the Shuttle returns. A third option could be an extension of this latter mode, a Space Platform. The Space Platform would allow a number of payload carrier elements (∼ 6 or more) to be left in orbit and operated simultaneously, pointing in different directions, easily serviced, refurbished or replaced.

Each of these systems will be discussed in more detail and their potential contributions to augmenting the Spacelab mode of operations will be described. The role of a Space Platform closely approaches that of a free spacecraft but with significant
advantages and certain disadvantages. To provide a model for determining the requirements for augmentation systems, a projection of Spacelab activities in the latter half of the 1980 decade has been developed. This model is then used as a reference point for comparisons of each new system.

The more critical of the resources which the user community has clearly indicated for augmentation are (1) duration on orbit and (2) power. The new systems now envisioned will allow various combinations of these resources to provide for a range of operations. However, as a general rule from the user perspective, the most attractive systems will be those which will enhance the initial seven to ten days on orbit operations of the Spacelab by at least an order of magnitude. Thus, the Space Platform should offer to the payload community an operational range from three or four months to twelve or more months. A platform program with these characteristics could allow replacement or rotation of payload elements at regular intervals; repairs; refurbishment; or replacement of sensors or smaller portions of the payload elements. Some general characteristics that a Low Earth Orbit Space Platform would provide are:

- extended duration in space for instruments initially developed for Spacelab and easily transitioning to platforms;
- discipline oriented or problem oriented groupings of instruments to provide comprehensive investigations of major science and application problems;
- extended development testing for instruments or systems which would be used later in research or operational systems;
- ease of maintainability via shuttle servicing and refurbishment visits;
- evolutionary growth as required for both manned tended and manned operated payloads, and
- experience in operational characteristics of multiple systems/interactive elements on sizeable structures.

There is increasing interest in capitalizing on the investments in various space systems to maximize their effectiveness to the user community. The space platform appears to be a very attractive concept to fulfill that interest. In this paper, an evolving path progressing from the initial space-lab approach to a space platform concept will be developed.

II. PROJECTED SPACELAB MISSIONS

The number of presently approved Spacelab missions are indicated in Figure 1. From several Announcements of Opportunity for proposals for Spacelab Investigations, a number of instruments have been selected and the development processes for the instruments have been initiated. As these activities progress, it is anticipated that new Spacelab mission assignments for the instruments will be formulated and approved. On Figure 1, a forecast of these missions in the major discipline areas indicated is provided through the year 1990. The presently approved missions include three major configuration modes of Spacelab hardware along with single pallet missions. These modes: Long Module/Long Module plus a pallet; short module plus pallets; igloo plus pallets; and single pallets; have been projected consistent with the previous model and are indicated on Figure 2. Most likely, any new augmentation system will not be available until the mid-1980's; therefore, only the missions from 1985 through 1990 as shown in Figure 2 will be used in the analysis of an augmented Spacelab program. For these six years, a total of about 55 missions are estimated: 20 in the long module/long module plus pallet mode; 9 in the short module plus pallets mode; 18 in the igloo plus pallets mode; and the remainder in the single pallet mode. Approximately 50% of the missions would utilize a pressurized module in the shuttle cargo bay. The application of the new augmentation systems with the Spacelab will be structured to maintain as closely as possible this important manned interactive mode of Spacelab operations.

III. AUGMENTATION SYSTEMS

The three most promising system concepts which can augment the Spacelab mode of operation are: (1) The Power Extension Package; (2) The Power System; and (3) The Science and Applications Space Platforms. However, before any consideration is given to these new systems, it is first necessary to establish the basic capabilities of the shuttle and the general requirements for the Spacelab configurations to be considered. Again there are several parameters to be considered, but the most significant ones probably will be duration on orbit...
and power. Figure 3 summarizes the expected capabilities of the Shuttle/Spacelab systems. With this basic capability established, each of the proposed new systems are now discussed.

A. Power Extension Package (PEP)

The Power Extension Package is a flexible flatfold solar array deployed by the Shuttle remote manipulator system (Figure 4). The solar arrays (approximately 4 meters by 76 meters) along with power distribution equipment have a total mass nearly 1,000 kilograms which must be transported into orbit and returned with each mission. A summary of the general characteristics of the PEP is provided in Figure 5. The interdependence of maximum power, duration on orbit, and time of year launch is shown in Figure 6.

B. Power System

The Power System is an orbiting space system with solar arrays, storage batteries, control and momentum subsystems, berthing ports, and antenna, which can operate in two different ways. As shown in Figure 7A, the Shuttle/Spacelab can dock to the Power System and operate in the normal Spacelab mode for periods as long as desired. A second operational method shown in Figure 7B is the support of attached payload elements in a free flying mode when the Shuttle has returned to Earth. A summary of the characteristics on the Power System in both these modes is shown in Figure 8.

For the purpose of this analysis, it will be assumed that the Power System will support each mode of operation for equal times. Thus half the time, the Power System would be operating with the Shuttle attached and the other half in the free flying mode. Although other combinations of these two modes are possible, none will significantly add to the general capabilities considered in this analysis.

C. Science and Applications Space Platforms (SASP)

A concept of an SASP is shown in Figure 9. A Power System provides support service to simple structural members on to which payload carriers containing the experimental equipment are mounted. This configuration includes elements which are independently rotated, providing the capability to view simultaneously in several different directions.

Except for power and communication links provided by the power system, each payload carrier would be self-supporting and can be added or removed, active or dormant, without affecting the other carriers. Periodic visits by the Shuttle would permit replacement or servicing of the payloads. Operational autonomy and ease of access and return should be attractive to commercial ventures as well as for science investigations.

The Space Platform will permit Spacelab instruments to be off-loaded from the Shuttle cargo bay. Power, telemetry, stabilization, and other support services previously provided in the cargo bay by Shuttle/Spacelab would be derived from the platform system. The instruments will be provided with a common interface, mimicking the Spacelab interfaces. They would be serviced during the occasional visits of the Shuttle to the platform. Upon completion of their investigations, the payload elements would be returned to Earth for possible refurbishment, reconfiguration, and reuse. A platform capability is viewed as a natural extension of, and complementary to, the Spacelab mode of operations. Initial platforms most likely will provide the man tended type of payload elements with significantly larger durations on orbit and at much higher power levels than in the standard Spacelab mode. Also, by offloading the payload elements, the Shuttle will be available to return for other mission assignments.

Specialized configurations will also be possible by utilizing the modular design concept of the platform. For example, Figure 10 illustrates a discipline oriented configuration where only one structural member is required. Also illustrated in this concept is another capability of a platform, a docking base for a maneuverable sub-satellite which operates in concert with other payload elements. To provide for active manned operations, pressurized modules as shown in Figure 11 would be required. In this Life Science configuration, the modules are Research Laboratories, habitability modules and service modules. Crew sizes with as many as eight people with periodic crew rotation would be envisioned.

To limit the degree of analysis, this paper will only consider a single platform capable of supporting approximately six unpressurized payload elements.
IV. AUGMENTATION ANALYSIS

Each of the proposed augmentation systems described in the previous section was used in an analysis to scope the benefits that each would provide to the projected Spacelab mission model. While these benefits include resources such as stability, heat transfer, viewing and power as indicated in Figure 12, it is most convenient to illustrate these benefits in terms of duration on orbit. The unit of measurement in this analysis is Spacelab equivalent days on orbit; that is, the number of days of operation in orbit that a complete Shuttle/Spacelab complement of instruments would achieve. For the projected mission model, the number of Spacelab equivalent days for the years 1985 through 1990 is approximately 383.

The potential capabilities in Spacelab equivalent days on orbit for each of these augmentation systems are shown along with the Shuttle baseline in Figure 13. For each system the total days are shown and the days associated with the mode of operation of the particular system also are indicated. For example, the power system data shows a total of 2244 days with 54 days in an orbiter only mode, 930 days in the Shuttle/Spacelab attached mode, and 1260 days in the free flying mode.

Equally important from a total systems perspective are the days required for the Space Shuttle to support these potential modes. In Figure 14 the total Spacelab equivalent days are presented along with the Shuttle orbit time for each system. On this Figure, the total days are again indicated and the ratio of total days for each system with respect to the Shuttle only days are shown. A similar notation for the Shuttle time is also indicated. Again, using the power system as an illustration, it could increase time on orbit by nearly a factor of six for the total payload program compared to the Shuttle/Spacelab mode while requiring the Shuttles to stay in orbit only slightly more than twice the days than in the Shuttle only mode. Another way of illustrating these potential capabilities is provided in Figure 15 where the cumulative equivalent Spacelab days are shown by year.

To determine the sensitivity of these results to the parameters chosen, several aspects of the analysis were examined. One of these considered the effect of different mission models on the benefits. The baseline model was varied by decreasing it by 50% and increasing it by 50%. The results of this approach are shown in Figure 16. There are several interesting features in this data. It is easily seen that, for the Shuttle only and the PEP cases, the Spacelab days vary directly with the mission model size as expected. For the PS and the Space Platform, it is noted that little change in the total capabilities is due to the model size. To understand this result, the other information provided in this Figure must be considered. On each bar there are shown the relative time in the two modes involving manned modules and pallet missions. In varying the mission models for the Shuttle only case, this feature was preserved. The PEP essentially continues this same relationship in operations. For the PS and Platform cases, however, the characteristics of the systems and the operational concepts caused a variance in this ratio. For the PS case, the leading factor for this change was the decision to limit the manned modules utilization of the PS to approximately one-half the time available. Of course, the platform cannot support manned modules and the manned operations, therefore, was the same as the Shuttle only case.

A second aspect examined was the effect of a Shuttle orbiter duration near 14 days rather than the up-to-60 days capability user earlier. In Figure 17, it is seen that, with this assumption, the total days are reduced proportionately in the PEP case while, in the PS case, only the manned modules days are affected. To illustrate this aspect even further, Figure 18 indicates that the total Shuttle on orbit time is significantly reduced by a 14 day orbiter limit. Also indicated is the fact that a 7 day shuttle limit utilizes the Shuttle on orbit time in the same manner as the Spacelab only case, but would permit a significant free flying pallet mode of operation.

Other measures of effectiveness are under consideration and combinations of these systems are being examined. Results similar to those presented in this paper will be obtained and
compared with these and further insight into the path of evolution from the Spacelab mode of operations to include these systems will be obtained. A final measure to be examined in this paper is a projected cost per Spacelab day for each of the systems. It is anticipated that the payload costs will not be affected by the system in use. Thus, the costs to be considered are those for the Shuttle/Spacelab Flights, for the Shuttle days over the standard 7 days in orbit, and for the investment in the various systems. These costs are listed in Figure 19 and the total costs for each case indicated in Figure 20. Using these costs and the equivalent Spacelab days from Figure 14, a comparison of these systems is provided in Figure 21. Here it is seen that the cost per day for the PEP system should be about 55% of the Shuttle only case. The PS cost per day would be less than on-half of the PEP or about 25% of the Shuttle only case. The lowest cost per day of all systems considered is that from the Space Platform and it is about 15% of the Shuttle only case. As stated before, the complete analysis of these systems must consider many more aspects and combinations before any definitive cost analysis can be established. These results do project, however potential benefits which must be explored further.

One should not conclude from this analysis that any of these systems stands clearly as the choice for augmenting the Shuttle/Spacelab activities. Each system has distinct advantages and disadvantages. For example, the space platform clearly can provide much more total duration in orbit but only for those payload elements which do not require significant manned interaction. Certainly, manned experience in orbital functions is considerable less with a Space Platform than with either the PEP and Power System. In addition, both the PS and the space platform operations limit the orbit to a single location while the PEP allows a full range of inclination and altitudes to be utilized. Thus, before final selection of a system or a combination of systems to be pursued to augment the Shuttle/Spacelab activities is made, full consideration of all implications to operations in space must be examined.

V. SUMMARY AND CONCLUSIONS

Although the new capabilities of the Shuttle/Spacelab mode of operation have yet to be fully exploited by the user community, some additional benefits to the program already can be identified by the augmentation of certain resources. Several augmentation systems are under consideration, each of which contributes in unique ways in providing extra benefits. Planning efforts are in progress to consider in some detail the evolutionary process which must be achieved to transition from the presently defined Shuttle/Spacelab mode of operations into the effective use of these new resources. The selection of one more of the augmentation systems must be guided by the particular emphasis desired by the user community and the national science goals. This paper attempts to illustrate a few of the aspects which must be considered in this process. The significant advantages of each concept have been provided and at least one major measure of the effectiveness of the augmentation system has been shown. It is anticipated that further analysis such as these will be accomplished in the next few years as preparations increase for accommodating the desire for more effective utilization of the Spacelab mode of operations.