NASA Technical Memorandum 104214

SPACE STATION FREEDOM RESTRUCTURE IMPACTS ON TECHNOLOGY EXPERIMENT ACCOMMODATION

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(NASA-TM-104214) SPACE STATION FREEDOM RESTRUCTURE IMPACTS ON TECHNOLOGY EXPERIMENT ACCOMMODATION (NASA) 29 p CSCL 05A

N92-25142

Unclas

G3/81 0089338

FEBRUARY 1992

National Aeronautics and Space Administration
Langley Research Center
Hampton, Virginia 23665-5225

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Abstract

This paper is a follow up to NASA Technical Memorandum (TM) 102766; it provides an overview of the Office of Aeronautics and Space Technology (OAST) Space Station Freedom technology development payload program, reviews the OAST Station resource requirements, and contrasts the requirements with the resources that are available to OAST since the restructure of Space Station Freedom. A discussion of the issues, as well as conclusions and recommendations, is provided. It is concluded that, even after adjustments to the OAST traffic model to reflect restructure, some resources will be inadequate even at the 20% allocation level. It is also concluded that bartering resources among U.S. users and international partners, and increasing the level of automation may be viable solutions to the resource constraint problem. The final conclusion is that, to facilitate the performance of technology experiments on Space Station Freedom, OAST should fund Station experiments and update its traffic model as soon as possible, and should provide technical and programmatic assistance to technology experiment developers.

Introduction

In November 1990, the Office of Aeronautics and Space Technology (OAST) published TM 102766 (ref. 1), which investigated the impacts of varying Space Station Freedom resource allocations on the accommodation of technology experiments. This paper concluded that the reference payload set, defined by OAST's July 1990 traffic model, would require an overall allocation of at least 20% of available Station resources. The traffic model payloads were selected in July 1990 to provide a balanced Research, Technology, and Engineering (RT&E) program in OAST's research thrust areas; to provide continuity with ongoing National Space Transportation System (NSTS) research; and to include focused technology program inputs of NASA, the Department of Defense (DoD), industry, and university experts.

Since the development of the traffic model and the publication of the previous TM, the Space Station Freedom Program (SSFP) has undertaken a major restructuring activity to meet Congressional guidelines in scope and funding. The resulting changes in Station design and resource availability will have major impacts on the science and technology research programs planned for the Station.

Purpose

The objectives of this paper are to review the changes in the Station as they apply to technology experiment accommodation; to summarize technology payload resource requirements; and to discuss options for reducing OAST's Space Station Freedom technology experiment program to meet current resource allocations.

Data Sources and Assumptions

The data for the reference set of OAST experiments were obtained from the In-Space Experiments (ISE) Database, which is maintained at the Langley Research Center (LaRC) Space Station Freedom Office (SSFO). This information was compiled and maintained in the Space Station In-Space Technology Experiments Model Source Book (ref. 2) from 1988 to 1990. The ISE Database has been updated periodically by the Principal Investigators (PIs) for the reference payloads. The OAST Space Station Freedom Traffic Model (Table 1) was used to determine the launch and return dates for OAST payloads through 1999. Payloads are assumed to be launched in July of the traffic model year. Space Station data sources include the "Overview of WP01 User Accommodations as of Restructure" (ref. 3) presented by J. Michael Vaden of Boeing at the Payload Integration Management Forum in June 13, 1991, and the Space Station Freedom Utilization Sequence Status update (ref. 4) presented by Mark Uhran (Space Station Freedom Program - Utilization) at the same meeting. The Space Station Freedom assembly, outfitting, utilization, and logistics flight schedule (Figure 1) was also obtained from Mr. Uhran's presentation.

In order to derive the payload resource consumption profiles, certain assumptions were made. The power profiles show a 24-hour period in which each OAST experiment is run one time. At present, some OAST payloads run continuously; however, no OAST payloads call for multiple runs in one 24-hour period. The experiment run times have been staggered to minimize instantaneous peak and sustained nominal power levels over the 24-hour period. Since there will be days in which only a portion of the full complement of payloads is operational, this approach represents a "worst case" scenario in terms of resource consumption.

For all payloads, it was assumed that the peak power consumption will occur at start-up. Also, any payloads designated as continuous were assumed to run continuously. In reality, these payloads will shut down periodically for maintenance, repair, or sample changeout. Extravehicular activity (EVA)/intravehicular activity (IVA) manhour computations were based on the requirements as provided by the PIs.

Restructured Space Station Freedom User Accommodations

One of the results of the restructure is that the period of man-tended operations (Man-Tended Capability or MTC) will be extended to a total of three years. The extended MTC will be characterized by three utilization flights each year, in which crew members will be available to set up, reset, change out, operate or tear down experiments. During the unmanned periods, which will last up to six months, the experiments on the Station will run in an automated mode.

Because of the downsizing of the Station, the number of racks available for user payloads has been reduced. Previously, there were 21 racks available for NASA use in the US Laboratory module. The restructured Station will have a smaller Lab module, US Lab-A, and will provide only 15 NASA payload racks prior to the addition of the U.S. Hab module. At that time the number of NASA payload racks available in the U.S. Lab will decrease to 12.

OAST Space Station Freedom Utilization Traffic Model

The OAST Space Station Freedom Utilization Traffic Model projects technology flight experiments that represent a balanced technology program consistent with OAST's outyear funding strategy. The traffic model is shown in Table 1. These payloads comprise the reference set of payloads that are the basis for the following analyses.

OAST Resource Requirements and Constraints

This section will illustrate the resource consumption profiles of the payloads in the traffic model from 1997 to 1999. Although the traffic model contains payloads to be launched from 1996 to 2002, the restructure assembly sequence does not provide a laboratory module until 1997. The payloads on the traffic model before 1997 are assumed to be launched with the Lab; the 1997 payloads are assumed to be launched later in 1997. With respect to the later years, the resource allocations and utilization options are not well-defined at present. Therefore, the following analyses were confined to dates for which data on resource allocations were available.

At present, OAST is allocated 12% of the overall NASA allocation of restructured Station resources. Since, it will be shown, this level of allocation negatively impacts the OAST technology experiment program on Station, additional analyses were performed to demonstrate the impact of a 20% allocation on the OAST program. The restructure resource constraints have been superimposed on the OAST resource requirement profiles shown in this section.

Crew Requirements

One of biggest impacts on user payloads as a result of Station restructure is the decrease in crew availability during the extended MTC Phase. During the almost three-year MTC period, the crew will be available for payload operations only during the three utilization flights each year. Some crew time may be available for critical payload functions during assembly flights, but that time will be so minimal that it should be considered only on a contingency basis.

The IVA manhours required for experiment operations per increment are depicted in Figure 2. The increases in manhours required are concurrent with the addition of payloads to the Station as indicated in the OAST traffic model. In the first half of 1997, it is assumed the original 1996 payloads are manifested. Additional automation beyond the initial PI requirements or deletion of crew-intensive payloads were not considered in the derivation of the overall OAST requirements. IVA time required for EVA support was not included in Figure 2. The station constraints were taken from the Utilization Sequence document (ref. 3) up to Permanently Manned Capability (PMC) in September of 1999. At that time, it is assumed that the four crew members will be conducting payload operations for eight hours per day, six days per week. When the international partners' modules and payloads are brought to orbit, the manhours available for U.S. experiments decrease.

OAST crew requirements for the original traffic model payloads generally fall into the turn-on, monitor and turn-off categories to mid-1997. Prior to mid-1997, all payloads, except Manned Observations Techniques, are automated. After mid-1997, more experiments requiring crew involvement are scheduled to be brought to orbit. With a 12% allocation level, OAST's crew requirements are almost met for the first part of 1997; the payloads require 52 manhours during the 13-day utilization flights, and there are 48.5 manhours allocated. A 20% allocation of 80.8 manhours would allow OAST to support all of the early 1997 payloads and have a margin with which to barter other resources, including crew time later in the MTC phase.

In mid-1997, when the 1997 payloads are brought to orbit, the crew requirements increase from four hours per day to ten hours per day. However, the allocation remains constant. The 130 manhour requirement exceeds even the 20% allocation (80.8 hours) by approximately 60% (49.2 manhours).

In July 1998, when the traffic model calls for the addition of the Risk-Based Fire Safety, Flight Dynamics Identification, and Flight Crew Health Experiments, the requirement increases to 140 manhours per increment. At that time, the Japanese Experiment Module (JEM) will be brought to orbit, along with some international payloads. This means that the crew's payload operations time on utilization flights is more divided, and only 42.1 hours per increment will be available to OAST with a 12% allocation. The requirement exceeds the 12% allocation by almost 250%, and the 20% allocation would be exceeded by nearly 100%. By October, the available crew time decreases to 35.8 manhours per utilization flight for OAST payloads. This is due to the addition of the European Space Agency (ESA) Attached Pressurized Module (APM).

The crew time needs of OAST payloads increase again in July of 1999 to 147 hours per utilization flight. From July to September, when the permanent crew will be on-board the Station, the requirements will exceed the available resources (12% allocation) by almost 350%. When the four member crew is on the Station the OAST requirements will be 509 manhours per 45-day increment, and the 12% allocation will be 172.8 manhours. Even a 20% allocation (288 manhours per 45 days) would be 75% short of the requirement.

<u>Rack Requirements</u>

Only pressurized rack space was examined in detail for this paper, since the number of external payload attachment points is dependent on unresolved change requests (CRs). However, it can be assumed that, with the deletion of the Attached Payload Accommodations Equipment and sites in the restructured Station, the accommodations for attached payloads will be insufficient to support the July 1990 OAST traffic model.

Figure 3 shows the build-up of Station pressurized volume racks required to accommodate OAST's pressurized payloads. This build-up, based on the July 1990 traffic model was developed to reflect the build up of pressurized volume in the pre-restructure Station assembly sequence. The dates for each incremental increase are based on the projected launch dates, with the original 1996 payloads assumed to be manifested for early 1997. Return of payloads to Earth is also taken into account.

As shown in Figure 3, an OAST rack allocation of 12% yields a maximum of 1.8 racks in the U.S. Lab Module and 1.8 racks in the international modules. When the Hab Module is brought to orbit (July 1999), the number of available payload racks in the U.S. Lab Module will decrease, and OAST will then have only 1.4 U.S. Lab Module racks. In early 1997, the OAST requirement is for 1.75 racks and the allocation is 1.8 racks, which is adequate. A 20% allocation of three racks would give OAST room to barter for other resources. By mid-1997, when more payloads are launched, the requirement increases to 4.2 racks, but the allocation does not increase until mid-1998, when JEM is launched. Even the 20% allocation falls short by 40%.

In mid-1998, more payloads are changed out, and JEM is brought to orbit. This increases the number of racks for OAST to 2.4 (12% allocation). However, OAST's requirements also increase to 7.7 racks. A 20% allocation of four racks is 90% less than the required number. The addition of the APM in September of 1998 will provide 1.2 more racks (12% allocation) for OAST, bringing the total to 3.6. The 20% allocation of six racks is much closer to the 7.7 rack requirement.

In 1999, the new payloads brought to orbit in July will need 10 racks, but only 3.6 will be available (six, for the 20% allocation). The shortfall is almost 200%. The situation worsens in September, when the addition of the Hab Module necessitates the use of Lab Module racks for systems, and the number available to OAST drops to a total of three, a 250% shortfall.

Power Requirements

Figure 4 depicts the build-up of OAST power requirements over the course of Station assembly. Typical Station power levels available to OAST (both 12% and 20% allocations) are superimposed on the figure.

Figures 5 through 10 illustrate daily power profiles for 1997 through PMC. Since OAST payloads are projected to be launched in July of the traffic model year and Station power resources vary throughout the year, depending on the elements on orbit, each figure depicts one half of a year. The profiles represent one 24-hour period in which all OAST attached and pressurized payloads run one time. The individual experiment run times were staggered throughout the day to minimize the peak and nominal power levels required. The Station power allocations are based on typical power available for both attached and pressurized payloads in that period.

For early 1997 (Figure 5), the power available to all U.S. users is 11.2 kW. For this time period OAST's 12% allocation is not sufficient, and a 20% allocation falls just short of the peak 2.4 kW required. Peaks in the In-Situ trace Contaminants Analysis and Manned Observations Techniques experiments cause the requirements to exceed the 2.24 kW limit. In mid-1997, when the 1997 payloads are launched (Figure 6), the power available remains constant. The OAST requirement, however, is projected to increase to a peak of 5.2 kW.

In December of 1997, the second photovoltaic (PV) array is scheduled to launched. With its integration, the OAST 12% allocation increases to 3.5 kW (Figure 7). A 20% allocation of 5.8 kW would match OAST peak requirements well until mid-1998. In mid-1998, JEM and the APM are brought to orbit in July and September, respectively, resulting in decreases of power availability for U.S. users. July also brings additional payloads to orbit (Figure 8), thus increasing the power demands. A 20% allocation of the U.S. 13.5 kW after the APM is on orbit would fall short of the OAST requirement in mid- and late-1998 by over 230%.

In early 1999 (Figure 9), the third PV array is integrated, and the OAST power budget (12%) increases to 2.6 kW. However, even a 30% allocation (6.45 kW) will not meet the peak power levels needed (9.1 kW). The late-1999 payloads (Figure 10) bring peak power demands of up to 14.2 kW, with sustained nominal levels as high as 10.4 kW. Neither the pre-restructure or post-restructure Station designs meet OAST traffic model payload power requirements.

Data Requirements

Although the datalink capabilities of the restructured Station have been reduced, OAST's demands on this system remain small relative to the needs of other users and relative to Station resources. OAST should not have trouble obtaining the data resources required for its payloads.

Optical Window Requirements

OAST continues to coordinate an effort to return optical windows to the Station program. An effort is also underway to produce a common glass specification for general viewing windows in the Hab module and optical windows in the Lab. A common structural design has already been completed. The proposed optical windows would have the minimum optical properties needed for Earth or celestial viewing. If better quality glass is required in the future, the common structural design will allow for IVA change out of the optical window. With the proposed optical window, quality viewing could be performed in the shirt-sleeve environment of the the Station without space qualifying or protecting sensor systems. This accessibility to sensors and sensor components would enhance the ability to conduct sensor development programs in a much less costly approach. Also, if adequately attached payload sites are not available on the truss, viewing payloads could be located in the pressurized volume with viewing through the windows. It has been proposed that optical windows be located in the U.S. Lab and Nodes to cover all viewing directions. However, at a minimum, there should be nadir optical windows located in the U.S. Lab A and a port window in Lab B, and the Station operational windows should be shared with the users as windows of opportunity.

Discussion

The Space Station Freedom program provides an excellent opportunity for OAST to have an in-space laboratory for technology development payloads. The Station will enhance several resources that are available in limited quantities on the Shuttle. Resources such as on-orbit time, payload volume, and access to more power are important in the development of technologies for future space platforms.

In the current program, all Station resources will be allocated on a percentage basis to the international partners. The partner resource allocations have been stated in the Memoranda of Understanding (MOUs); and the allocations among the U. S. users have been defined in a letter from the Office of Space Flight (OSF). On Space Station Freedom, planning an in-space experiments program is more than resolving simple manifesting issues. User resources allocated up front will be difficult to reallocate once the Station is operational. Therefore, if OAST deems it necessary to obtain a larger resource allocation, interaction with OSF must start immediately. The primary purposes of this paper are to review the currently projected OAST Space Station Freedom resource requirements and to determine if proposed resource allocations are sufficient to support the technology development program. If OAST does not acquire the needed resources up front, budgetary planning will be difficult, and execution may be impossible.

For technology experiment principal investigators (PIs), the process of developing, integrating and operating an experiment on Space Station will be complicated and confusing. One of the primary functions of user sponsors for Space Station utilization is to provide the single interface with the Program for the PIs. By working with the other user codes and the Station Program, OAST can try to simplify these processes as much as possible as they are baselined. After that, OAST will need to work with the PIs directly to assist them with technical and programmatic issues that arise.

On-orbit crew time has always been recognized as a limited and precious resource; however, the extended MTC Phase makes it even more so. It is apparent that the current traffic model must be revised to take advantage of the new operational philosophy of the Station. A major consideration will be selecting payloads that can operate autonomously for launch early in the Station's operational life. Crew-intensive payloads currently on the traffic model, such as Flight Crew Health and Manned Observation Techniques, will have to be modified, deleted, or postponed until more crew time is available. Even after the permanent crew is on-board the Station, a 12% allocation of crew time will severely limit crew activities for OAST payloads. As was shown in the Multilateral Utilization Study (MUS, ref. 5), OAST payloads continue to be crew-intensive. The Flight Crew Health Experiment will require the use of two crew members for almost an entire operations shift. While it may be possible, through careful payload manifesting, for OAST crew time requirements to be satisfied during an increment or utilization flight, this cannot be done on an annual basis. If OAST is allocated only 20% of this resource, at no time will the annual requirements be accommodated. There are several courses of action that may remedy this situation including bartering excess resources among other user codes, bartering among the international partners, and aggressively pursuing the use of automation and teleoperations in payload operations. Augmented programs investigating advanced teleoperations may be required. Also, because EVA requires IVA support, EVA requests should be limited to activities that cannot be performed robotically.

Prior to restructure, the 10% allocation of rack space was inadequate for OAST's in-space technology development program. With the downsizing of the U.S. Lab, rack requirements will have to be another major consideration in the revision of the OAST traffic model. The Flight Crew Health experiment, which is crew-intensive, has a high rack requirement (2.6 racks). Deletion of this payload alone would help the rack problem in 1998 and 1999. However, the 12% post-restructure allocation is not enough, even in the years prior to the planned launch of Flight Crew Health. Another issue regarding racks, is the need for well-defined integration, accommodations, and operations processes for sub-rack payloads. All of the user codes have sub-rack/drawer level payloads planned for Station; however, no provision has been made for the sharing of racks between codes. Also, the issue of sub-rack integration on orbit has not been settled. This capability is vital for the user sponsors to be able to fly small payloads without having to fill an entire rack.

A 12% power allocation will not be sufficient to support current OAST Payload requirements. However, with a power reduction effort undertaken by OAST payload developers and the deletion of payloads that cannot fit within crew or rack allocations, the 12% allocation may be adequate in early 1997. After that time, at least a 20% power allocation is needed. At present, four 6.25 kW DC-to-DC power conversion units (DDCUs) are located in the pressurized laboratory module. Even though there will be 30 kW available for users in the U.S. Lab after system allocations and manager's reserve, the limitations on the size and number of DDCUs will reduce the overall power available in the U.S. Lab to 25 kW. After housekeeping loads are accommodated, the power to all users in the U.S. Lab will be limited to 12 kW. Clearly, a 12% allocation at this level will be inadequate.

At present, Space Station Freedom does not meet OAST, Office of Commercial Programs (OCP), and Department of Defense (DoD) requirements for optical windows. OAST should continue with its effort to have them returned to the Station program. Data requirements for technology, however, appear to be well within the 12% resource allocation.

Bartering is a recognized user option in the Space Station Freedom Program and is a viable option for obtaining resources insufficient for user program needs. Bartering was shown in the MUS, the Joint Science Utilization Study (ref. 6), and the Multilateral Strategic and Tactical Integration Process Simulation (MUSTIP, ref. 7) to be an effective means of improving overall Station resource utilization. However, bartering resources must be considered an iterative process, since additional payloads accommodated by rack space exchanged for OAST data resources may also require additional crew time and power. Therefore, it may be difficult to barter for or with some resources. As a general policy, OAST should barter to the full extent useful to support the technology development program. A prime example of this technique is negotiating the exchange of an attached payload location and resources for the design, development, fabrication, and testing of an attached payload facility which accommodates the requirements of both parties.

A recommendation of TM No. 102766 was that OAST should accept OSSA's offer to participate in discussions of Small and Rapid Response (SARR) hardware/Station resource exchanges with the international partners through the SARR Steering Committee. OAST is currently participating in these activities.

The MUS included an evaluation of the possibility of determining resource allocations by means other than straight percentages. A promising option was the concept of specialized flight increments. In these specialized increments, only experiments relating to a particular emphasis (technology, life science, materials processing, etc.) would be manifested and performed. Other payloads outside the scheduled discipline could be accommodated on a resource availability basis.

Additional studies of this concept should be undertaken to fully evaluate its feasibility and its benefits.

Finally, while payload integration is not, strictly speaking, a Space Station resource, it must also be considered by OAST. In the past, Office of Space Science and Application (OSSA) has provided all payload integration for Shuttle technology payloads. Currently, OSSA is planning to discontinue this activity and is sizing their integration facilities accordingly. The Station program is planning to provide payload physical integration facilities for all user sponsers. At present, it is unclear to whom that capability will be made available and at what cost. While this physical integration is included in the budget, corresponding analytical integration costs are currently carried only as a lien against the Program. If OAST opts to utilize Station program integration facilities or some other integration facilities, rather than to develop their own payload integration infrastructure, the decision must be made soon, and the request negotiated with the facility sponsor.

In general, the restructure will cause all of the users of the Space Station Freedom to re-evaluate their flight experiment programs. The revision of traffic models to meet restructured resource envelopes will be an iterative process. OAST is in the process of reviewing its in-space technology development program to ensure that the technology requirements for future NASA programs will be met. As a part of this process, the OAST traffic model should be revised to reflect these needs, as well as the changes that have been incorporated in the Station design.

Conclusions and Recommendations

The following are the conclusions reached from this study:

1. Even after adjustments are made to the OAST traffic model, a nominal 20% resource allocation will still be required. This need must again be brought to the Station program's attention. Proper development, budget and increment planning will require that OAST understands clearly the allocations. A 12% allocation is simply insufficient for RT&E payload requirements as they are currently understood. If future OAST budgets do not allow the realization of 20% resource utilization, then increased emphasis on SARR payloads may be needed.

2. OAST should develop a program to assist technology experiment principal investigators in understanding the payload accommodations, integration, and operations processes required for Space Station experiments and to resolve technical and programmatic issues as they arise.

3. In view of the crew time problem, OAST should consider enhancing the automation and robotics program to include work on teleoperations. This recommendation was made in the previous paper, and OAST should continue to support these efforts.

4. OAST should recommend to its payload developers that automated procedures and controls be incorporated into their equipment as much as is practical. Previously, this was considered particularly important for payloads with manifested flight dates of 1998 and beyond, when the mismatch between crew time requirements and availability was larger.

However, the extended MTC Phase makes this a critical issue throughout the life of the Station.

5. As it is becoming apparent that operations planning will likely be performed in detail, OAST must recommend to the Station program that some means be found to return to the original goal of flexible payload operations. Detailed Spacelab-like timelining should be avoided as much as possible.

6. OAST needs to ensure that both the Small and Rapid Response (SARR) class and distributed sensor class payloads are included in the program.

7. OAST needs to work with the Rack Drawer Steering Committee to ensure that sub-rack level accommodations are provided and that common drawer designs are adopted.

8. OAST payload developers should be required to minimize power consumption.

9. Certain aspects of OAST, OCP and DoD payload planning require the use of optical windows; OAST should continue to work with OCP, DoD and the Station program to ensure inclusion of this design feature. OAST should also continue to solicit OSSA to join the effort as recommended by the Space Station Science Applications Advisory Committee (SSSAAS).

10. OAST needs to ensure that the allocations from the Station program are considered to be guidelines and that inter-user code bartering is used to enhance technology payload utilization, as well as overall resource utilization.

11. OAST must develop a payload analytical and physical integration infrastructure as soon as possible.

12. OAST is also responsible for acting as the "conduit" into the Station program for all U.S. government technology development agencies, such as DoD. Therefore, OAST should remain cognizant of their technology program needs and represent these needs to the Station program. OAST must also develop a policy and a plan for interaction between these technology agencies, OAST, and the Station program.

13. OAST should issue a Dear Colleague Letter immediately to obtain updated information regarding the interest within the technology community in the Space Station as a technology development platform.

14. OAST should release the next In-Space Technology Experiments Program Announcement of Opportunity (AO) as soon as possible, and Space Station should be included as a potential carrier for these experiments. The focused technologies called out in the AO should include those carried in the early traffic model years, as well as those of interest to DoD.

15. The OAST traffic model must be revised to reflect the impacts of restructure on Station payload accommodations, the Integrated Technology Plan, the Dear Colleague Letter, the AO, and the needs of other U.S. government technology development agencies.

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4. Space Station Freedom Utilization Sequence Status, SSFP - Level II, June 10, 1991.

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7. Multilateral Strategic and Tactical Integration Process Simulation, CSA, ESA, NASA, NASDA, August 1991

APPENDIX A - OAST Payload Descriptions

1. Modal Identification Experiment NT001.01A

Its objectives are to characterize the space station's structural dynamics and to develop advanced modeling techniques. It will be pre-integrated with the truss and will run for six minutes at a time with nominal power of 0.35 kilowatts (kW). Its peak power is 0.53 kW, and it will run seven times every 45 days. No crew time is required.

2. Manned Observation Techniques NT002.00P

The objectives are to develop observations/communications technologies and techniques, to develop on-board analysis techniques, and to perform on-orbit tests of remote sensing devices. It will require one rack and will run for four hours at a time once a day. Its nominal power requirement is 0.5 kW, and its peak power is 0.75 kW. It will require four manhours of uninterruptable crew time for each run.

3. In-Situ Trace Contaminants Analysis NT003.00P

Its objective is to develop technologies required for analysis and measurement of trace constituents in the space station cabin environment. NT003.00P will use 1.5 kW nominal power and 2.25 kW peak power as it runs continuously. No crew time will be required. It will require 0.4 space station racks.

4. Transient Upset Phenomena in VLSIC NT004.00P

It will contribute to the understanding, characterization and circumvention of alpha particle and cosmic ray induced single event upsets of very large scale integrated (VLSI) circuits in space applications. This payload will use 0.3 racks. It will operate continuously using 0.1 kW and no crew time.

5. VHSIC Fault Tolerant Processor NT005.00P

This payload will demonstrate technologies and acquire realistic data on single upset detection and recovery in a self-testing, general purpose computer configuration which uses very high speed integrated circuit (VHSIC) technology. It will occupy 0.2 racks. It will require minimal power (0.05 kW nominal and 0.08 kW peak) and will run continuously. No crew time is needed.

6. Spacecraft Strain and Acoustic Sensors NT008.01A, NT008.02P

This will operate continuously. Its internal portion will require 0.3 kW nominal and 0.4 kW peak and will occupy 0.2 racks. The external portion requires no power. No crew time is required.

7. Spacecraft Material and Coatings NT014.00A

This attached payload will expose truss-mounted trays of materials and coatings to the space environment to provide a technology base for the development of advanced long-term structural materials and coatings. It will operate continuously on 0.46 kW nominal and 0.65 kW peak power. No EVA will be required.

8. Microelectronics Data Systems NT036.00A

This attached payload will operate continuously and will use 1 kW peak power and 0.25 kW nominal power. No crew time is needed.

9. Acoustic Control Technology NT006.00P

Its objective is to develop the technologies and methods required to design and operate the station to ensure acceptable levels of vibroacoustic exposure. It will occupy 0.2 racks and will operate continuously. Its power requirement is 0.1 kW, and it will require two hours of uninterruptable Intravehicular Activity (IVA) time per day.

10. Technology SARR (Internal) NT021.00P

This placeholder Small and Rapid Response (SARR) experiment will occupy one rack. It will use 0.4 kW nominal power and 0.6 peak. It will operate for six hours per run, requiring six hours of uninterruptable crew time. It will run fifteen times in each 45-day increment.

11. Advanced Sensor Development NT022.00P

This is a DoD/NASA joint payload. It will need 1.6 racks and 3 kW nominal power (4 kW peak). It will run for eight hours a day every day and will require two hours of uninterruptable crew time per run.

12. Technology SARR (External) NT026.00A

This placeholder attached payload will operate for 24 hours a day, five days out of each 45-day increment. When running, it will require 1 kW of nominal power and 1.5 kW peak power. No EVA is required.

13. Thermal Interface Technology NT010.00A

It will operate for 20 consecutive hours, seven times in the 45-day increment. Its power levels are 3 kW peak and 2.5 kW nominal. It requires 4 hours of EVA time.

14. Flight Dynamics Identification NT012.01A, NT012.02P

It will determine the dynamic characteristics of large structural systems for use in orbital operations. Its internal portion will occupy 0.85 racks and will require 1.05 kW peak power and 0.7 kW nominal power. Its external portion has no power requirements. The experiment will run for five hours at a time, ten times in the 45-day increment. No crew time will be required.

15. Polymer Matrix Composites NT039.00A

Polymer matrix composite materials will be exposed to the space environment and will be monitored for damage and deterioration. Each run will be two hours long. It will run 45 times in the 45-day increment. No power or crew are required.

16. Risk-Based Fire Safety NT013.00P

This will be designed to observe the properties of materials used in spacecraft under radiative heating. It will expand the understanding of the fundamental characteristics of ignition, combustion and flame front propagation in a variety of samples, atmospheres and geometries. It will occupy 0.25 racks and will run for eight hours at a time, three times in a 45-day increment. The power required will be 0.25 nominal and 0.38 peak. As the experiment operates for eight hours at a time, it will require eight hours of uninterruptable crew time. This experiment will three times in each 45-day increment.

17. Flight Crew Health NT015.00P

This experiment will study technologies and techniques for providing data on human space adaptation systems, muscular strength and endurance, and bone demineralization. It will operate for 13 hours at a time, seven times in an increment. It will take up 2.6 racks and will require 0.5 kW nominal power (0.75 kW peak). IVA time required will be 14.5 manhours.

18. Cryo-Tank Replacement and Servicing NT027.00A

This experiment involves the critical technologies required for handling cryogens on orbit. It will run continuously, and it requires 1 kW of power.

19. Large Deployable Reflector NT008.01A, NT008.02P

This experiment studies the structural dynamics of a large-scale deployable reflector. Once the reflector is deployed, the experiment will run continuously, and will require 0.2 kW power and 2 manhours of crew time to operate its internal console each day.

20. Liquid Stream Technology Test Bed NT009.00A

This experiment's basic facility for initial development work is an instrumented flight tube held at ambient pressure. The facility will have the capability of being selectively exposed to optical and physical load environments. The experiment operates for one hour each day. Its power requirements are 1 kW nominal and 1.5 kW peak. No crew time is required for operations.

21. Microbiological Monitor for Spacecraft NT024.00P

The Microbiological Monitor will run continuously to detect and analyze any microbes present within the pressurized volume of the Space Station. It will validate technologies that will be required to perform this function on long duration manned missions. It requires 0.5 kW nominal power, and 0.75 kW peak power.

22. Regenerative Life Support System Test NT023.00P

This experiment tests and validates technologies required for crew life support during long-duration manned missions. It operates continuously and requires 3 kW nominal power and 10 kW peak power.

TABLE 1.- OAST PAYLOAD TRAFFIC MODEL (Modified for U.S. Lab Launch Slippage)

YEAR	1995	1996	1997	1998
ATTACHED PAYLOADS				
UP	Modal Identification Experiment		Spacecraft Strain and Acoustic Sensors (ext) Spacecraft Materials and Coatings Microelectronics Data System Experiment Laser Communication Terminal (*)	External SARR Pallet Thermal Interface Technology Flight Dynamics Identification (ext.) Polymer Matrix Composites
DOWN				
PRESSURIZED PAYLOADS				
UP		Manned Observation Techniques In-Situ Trace Contaminants Analysis Transient Upset Phenomena in VLSIC VHSIC Fault Tolerant Processor	Acoustic Control Technology Spacecraft Strain and Acoustic Sensors (int) Internal SARR Rack Advanced Sensor Development	Flight Dynamics Identification (int.) Risk-Based Fire Safety Flight Crew Health
DOWN			In-Situ Trace Contaminants Analysis	VHSIC Fault Tolerant Processor Acoustic Control Technology Risk-Based Fire Safety

LSE/GLSF				
		Battery Charger Camera Camera Locker Passive Dosimeter Film Locker	Digital Recording Oscilloscope General Purpose Handtools EM-Shielded Locker	Life Sciences Electrode Impedance Monitor -20°C Freezer 4°C Refrigerator Specimen Labeling Device Refrigerator Centrifuge Cleaning Equipment Macroscope Fluid Handling Tools

* Joint program with Code S. Code R developing laser component, Code S responsible for payload development

June 27, 1990

TABLE 1.- CONCLUDED

YEAR	1999	2000	2001	2002
ATTACHED PAYLOADS				
UP	Cryo-Tank Replacement and Servicing Exp. LDR Structural Experiment (ext) Liquid Stream Technology Test Bed	Advanced Adaptive Control (ext) FTS Force Reaction System Spatial Perception Auditory Reflex (SPAR)	Advanced Optical Receiving Station Advanced Structural Dynamics and Control SEI Vehicle Servicing	Advanced Radiator Concepts Low Acceleration Propulsion Technology Thermal Shape Control
DOWN	Thermal Interface Technology Flight Dynamics Identification (ext) Polymer Matrix Composites	FTS Force Reaction System LDR Structural Experiment (ext) Liquid Stream Technology Test Bed	Advanced Adaptive Control (ext) Cryo-Tank Replacement and Servicing Experiment Advanced Optical Receiving Station	Advanced Structural Dynamics and Control
PRESSURIZED PAYLOADS				
UP	Microbiological Monitor for Spacecraft Regenerative Life Support Subsystem Testing - 1 LDR Structural Experiment (int)	Robot for Science Laboratories Advanced Adaptive Control (int) Quantized Vortex Structures in Superfluid He Two-Phase Fluid Behavior and Management	Advanced Automation Technology Solar Array Energy Storage Technology High Stability Hydrogen Maser Clocks	Growth of Compound Semiconductor Crystals Regenerative Life Support Subsystem Testing - 2
DOWN	Flight Dynamics Identification (int)	Regenerative Life Support Subsystem Testing - 1 LDR Structural Experiment (int)	Transient Upset Phenomena in VLSIC Advanced Adaptive Control (int) Quantized Vortex Structures in Superfluid He Two-Phase Fluid Behavior and Management	

LSE/GLSF				
				Digital Multimeter Etching Equipment Small Mass Measurement Device X-Ray System Microgravity Sciences Glovebox Laboratory Sciences Workbench

June 27, 1990

STATION FLIGHT RATE:
1995 = 4
1996 = 7
1997 = 8
1998 = 8
1999 = 4

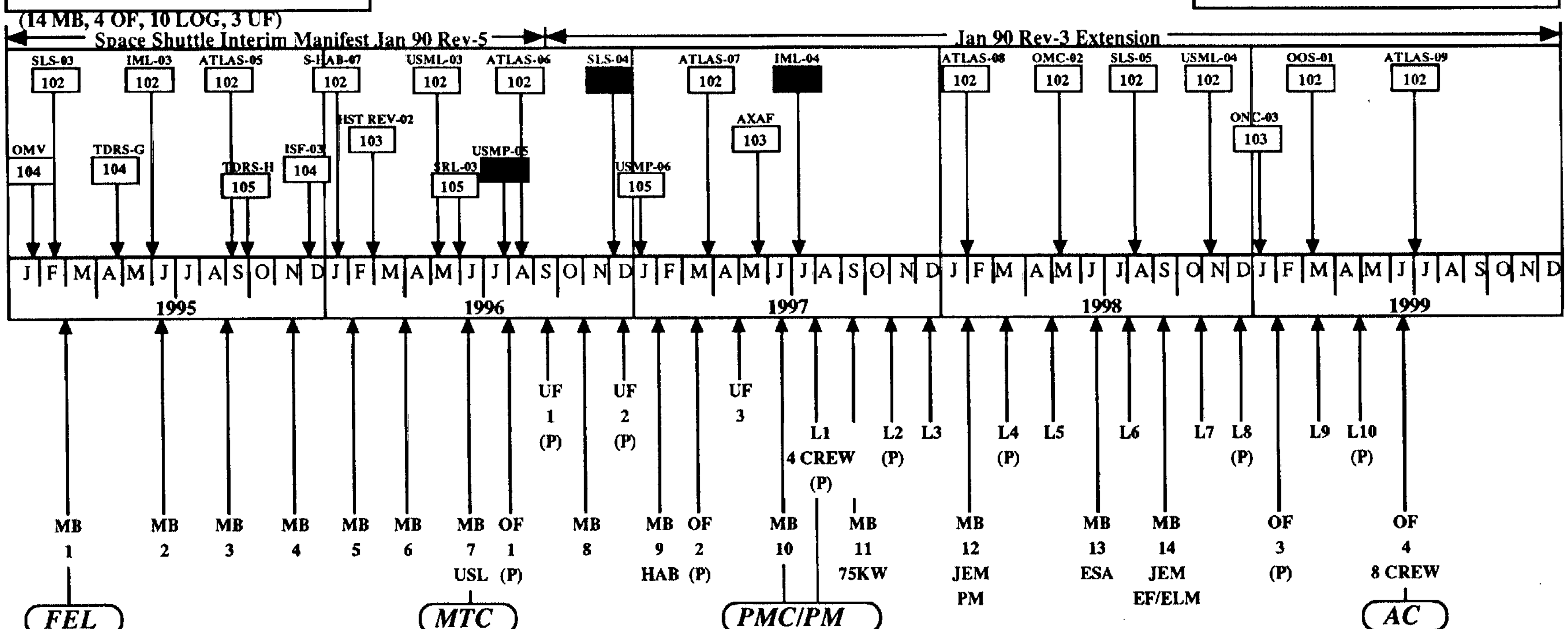
TOTAL = 31

STUDY DRAFT

UTILIZATION SEQUENCE
SCENARIO 1
PERMANENTLY MANNED AT PMC

12 September 1990

MILESTONE Δs:
MTC: No Δ 06/15/96
PMC: No Δ Re-Defined as MB-10
PM: No Δ 08/01/97
JEM: No Δ 02/01/98
ESA: No Δ 06/15/98
AC: No Δ 06/15/99



HIGHLIGHTS:
(1) Station flight rate does not exceed 8 flights per year.
(2) Milestones do not slip.
(3) U.S. Lab is outfitted with material science payloads (UF-1 and UF-2) prior to Habitat module delivery.
(4) Early OSSA attached payloads (2 sets) deployed on UF-3 (05/01/97).
(5) Meets OSSA pressurized payload traffic model for CYs 1996-1997.

IMPACTS:
(1) Drives earlier requirements for ground support infrastructure and manpower.

- Payload Operations Integration Center (POIC)
- Payload Training Facility (PTF)
- Space Station Processing Facility (SSPF)
- Payload Analytical Integration
- Payload Ground and On-Orbit Operations Integration
- Payload Training

LEGEND:

XXX-##	Re-Programmed Flight
(P)	Pressurized Log Module
MB#	Manned Base Flight
OF#	Outfitting Flight
L#	Logistics Flight
UF#	Utilization Flight

Figure 1.- Integrated Flight Sequence.

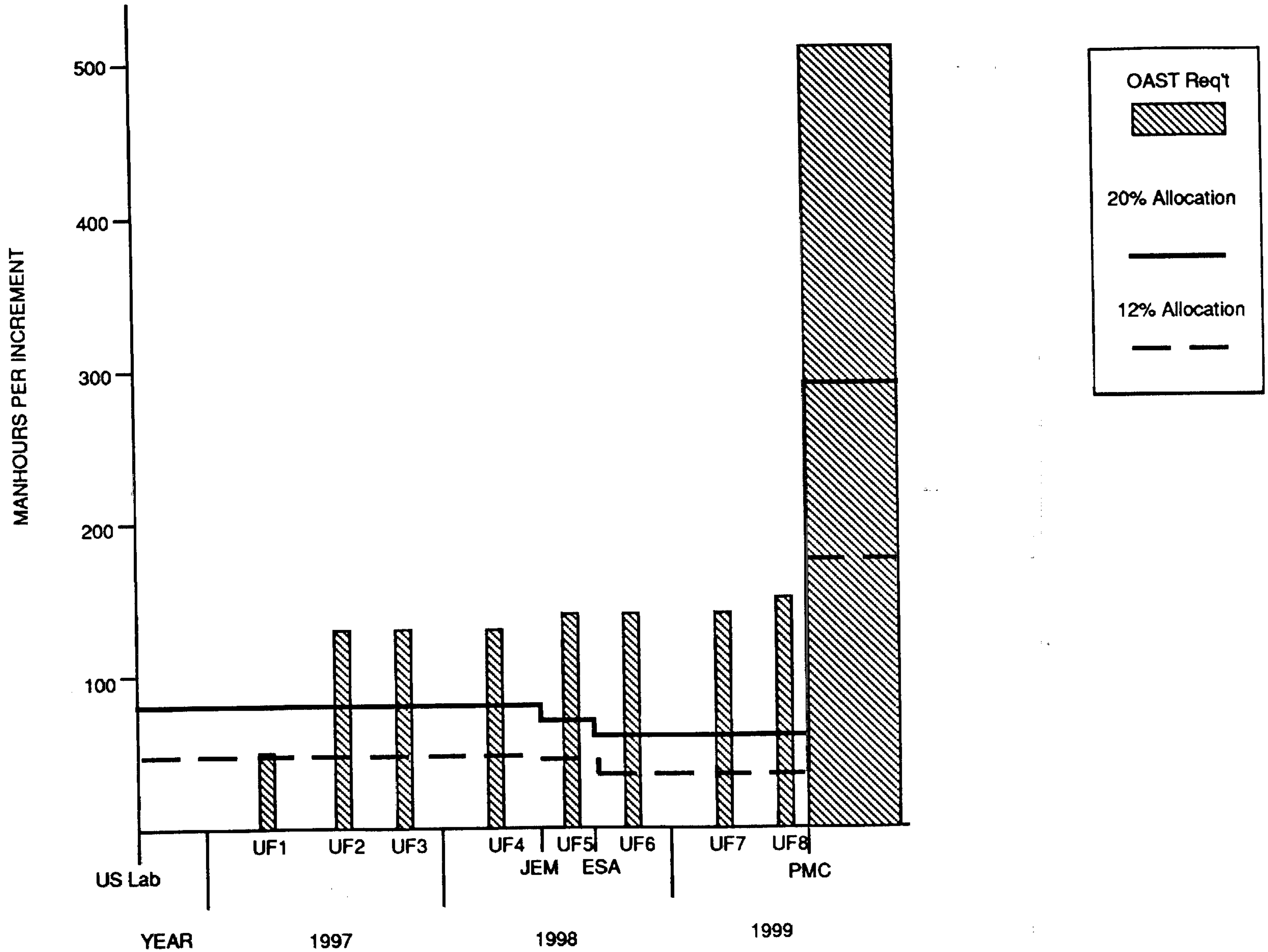


Figure 2. - OAST IVA Requirements

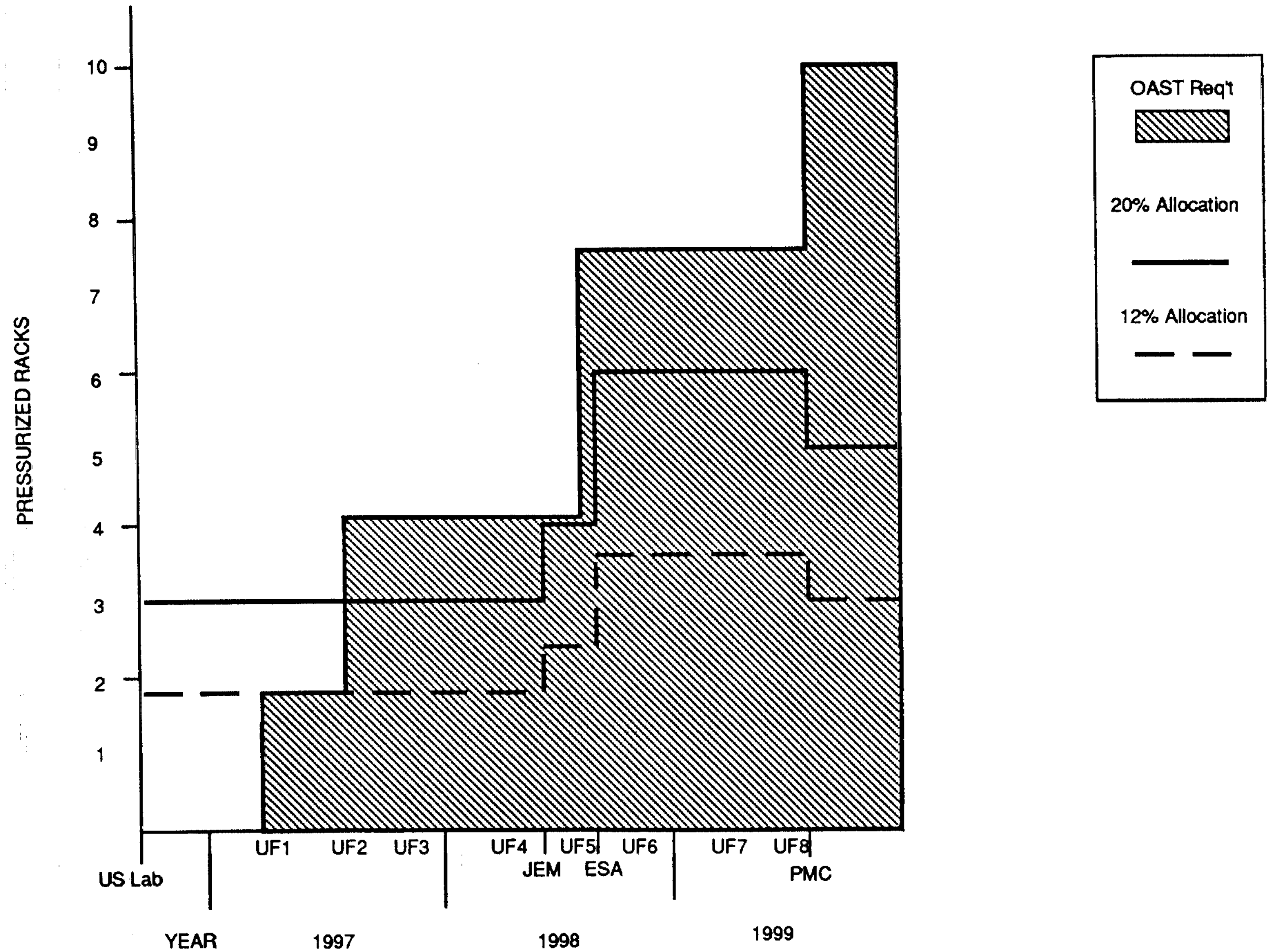


Figure 3. - OAST Rack Requirements

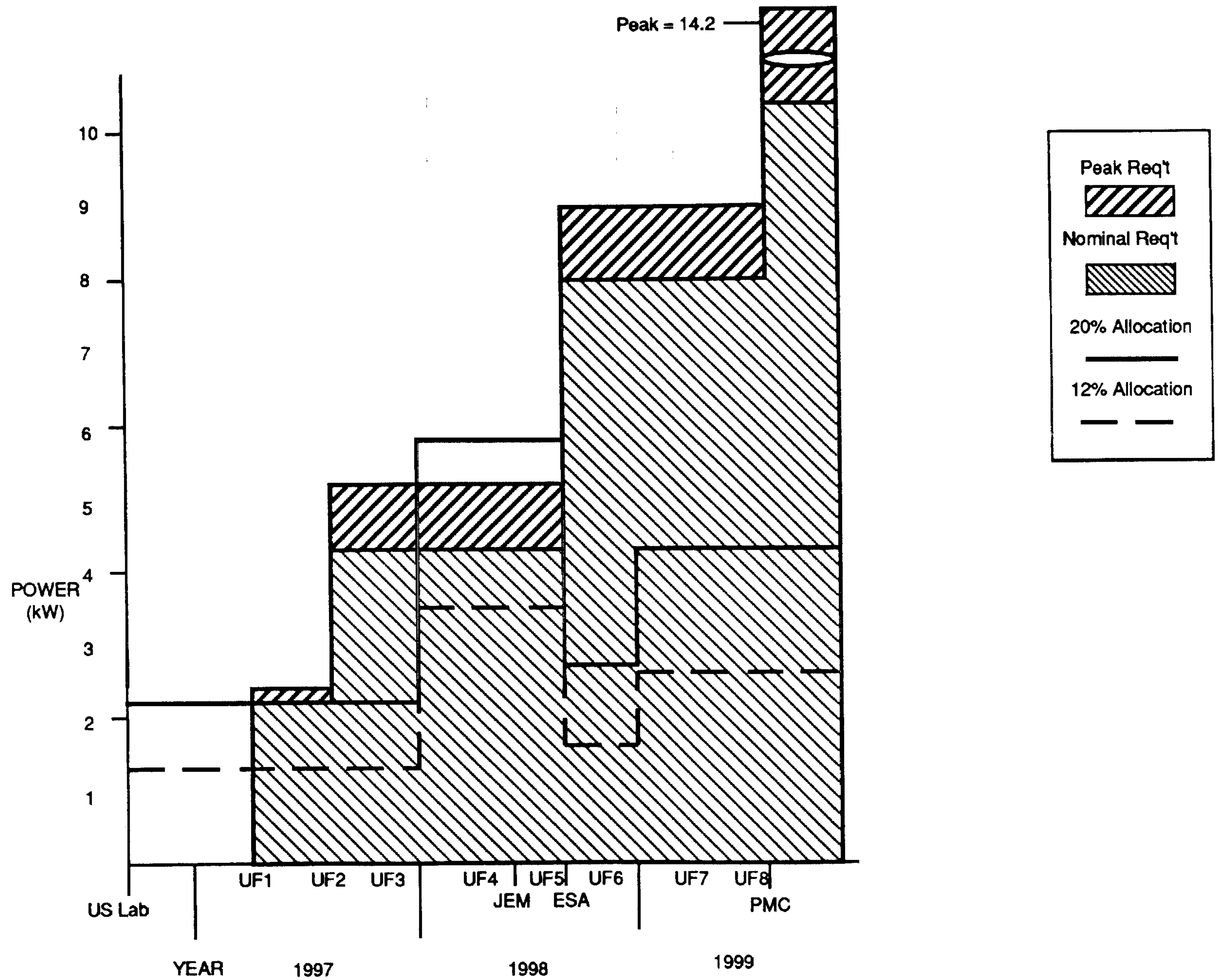


Figure 4. - OAST Power Requirements

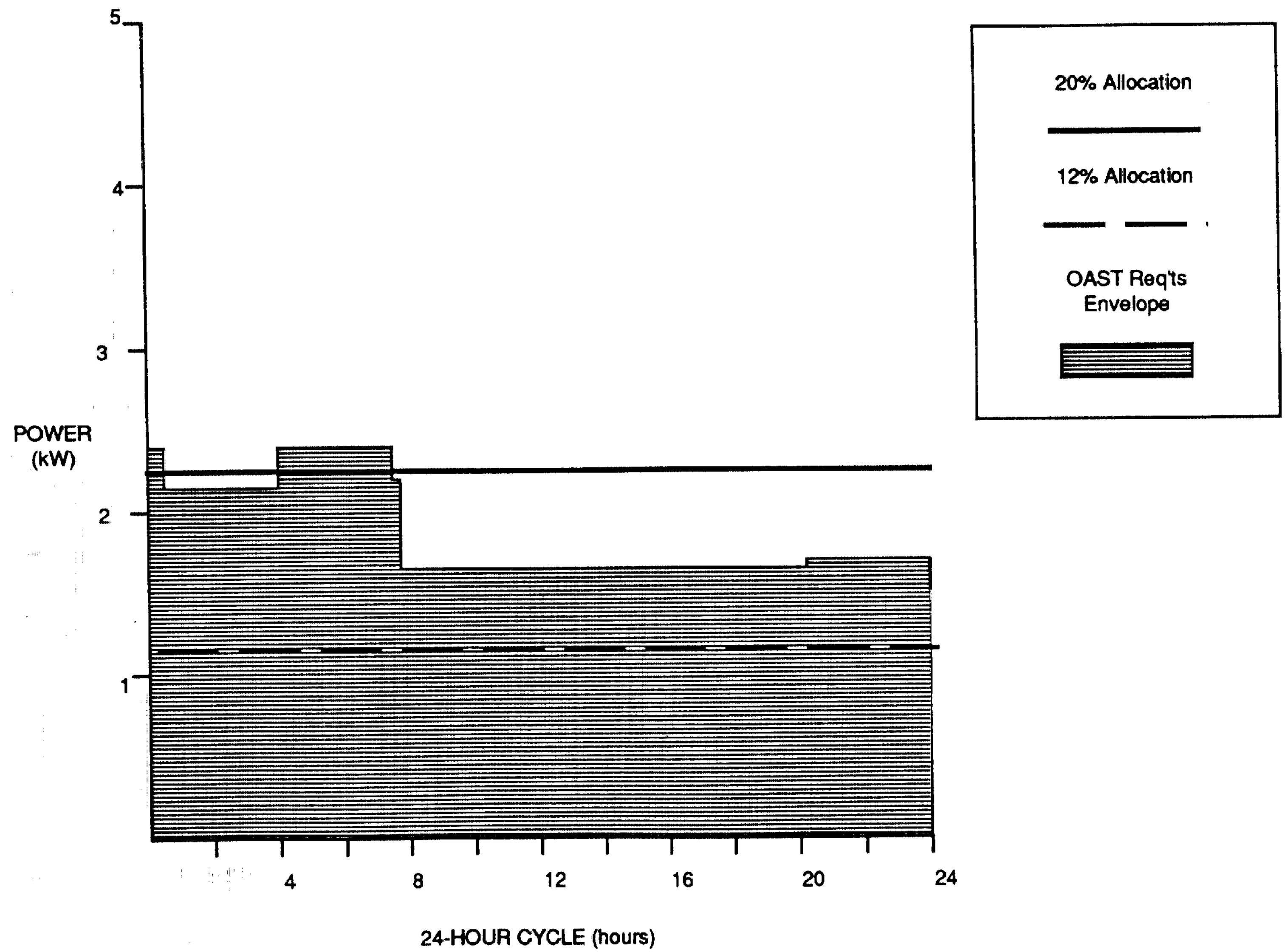


Figure 5. - Typical OAST Power Consumption Profile
1997 - First Half
11.2 kW AvailableTo NASA Users

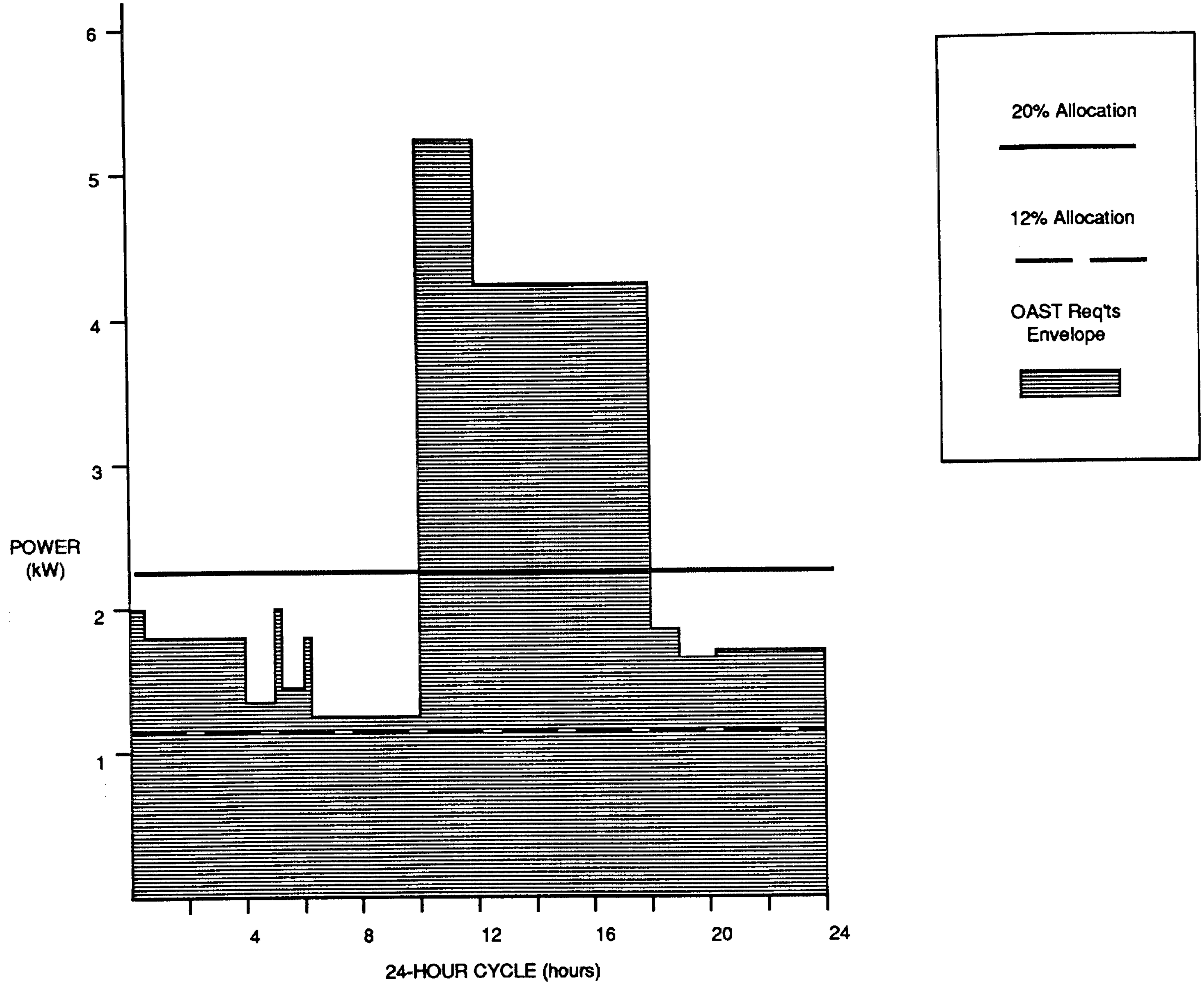


Figure 6. - Typical OAST Power Consumption Profile
1997 - Second Half
11.2 kW Available To NASA Users

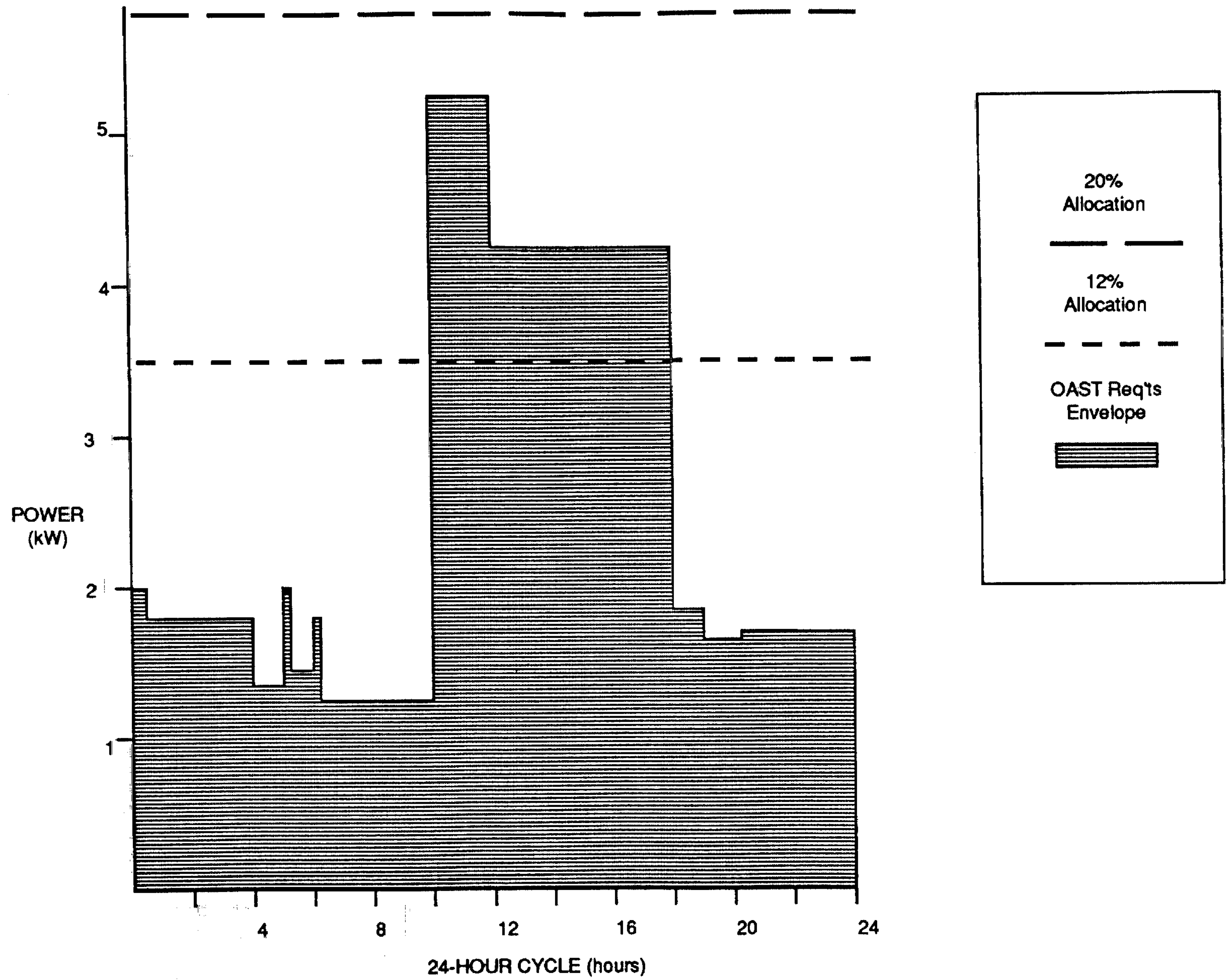


Figure 7. - Typical OAST Power Consumption Profile
1998 - Pre-JEM (With PV 2)
29.1 kW Available To NASA Users

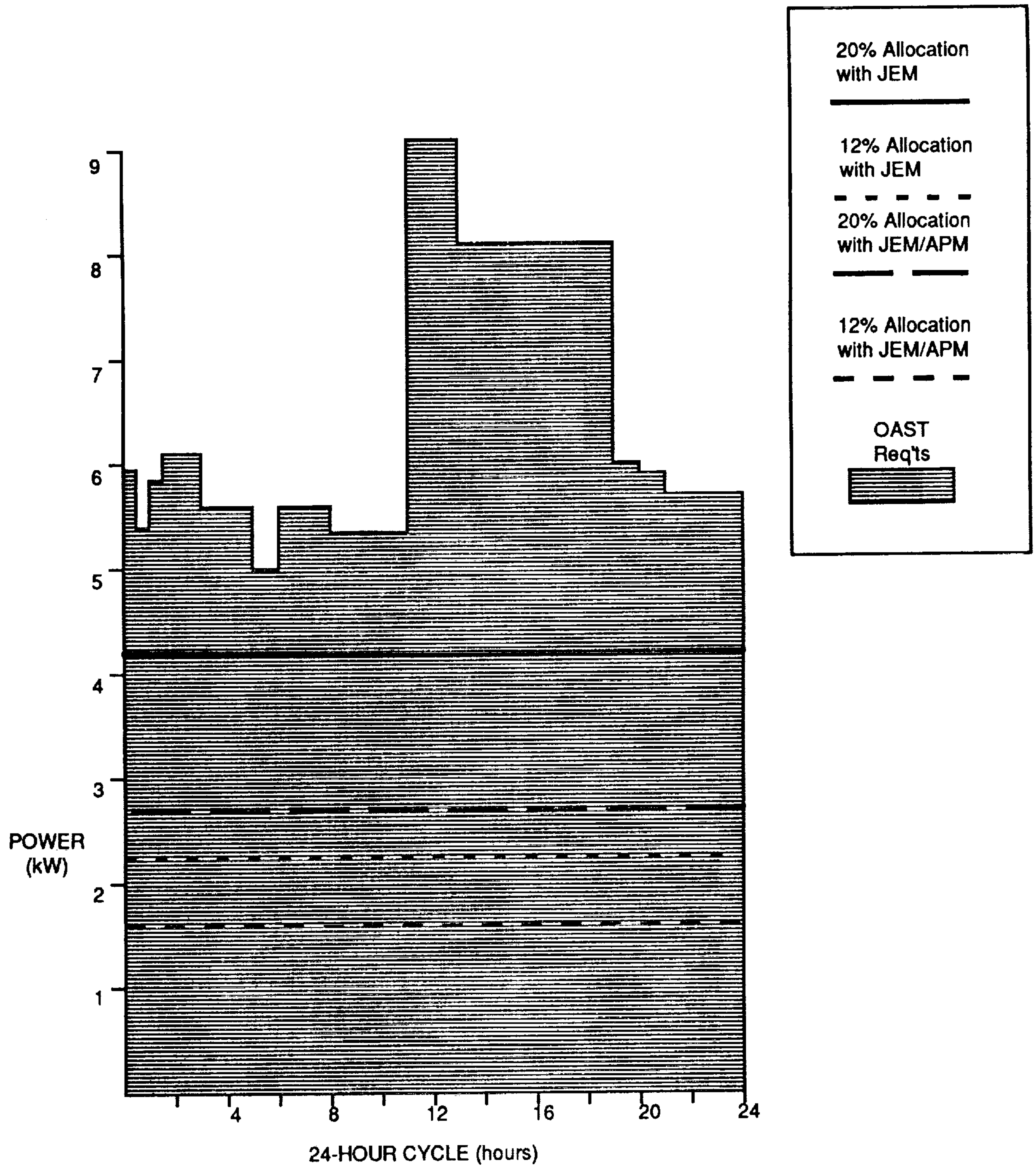


Figure 8. - Typical OAST Power Profile 1998 - Second Half 21/13.5 kW Available To NASA Users

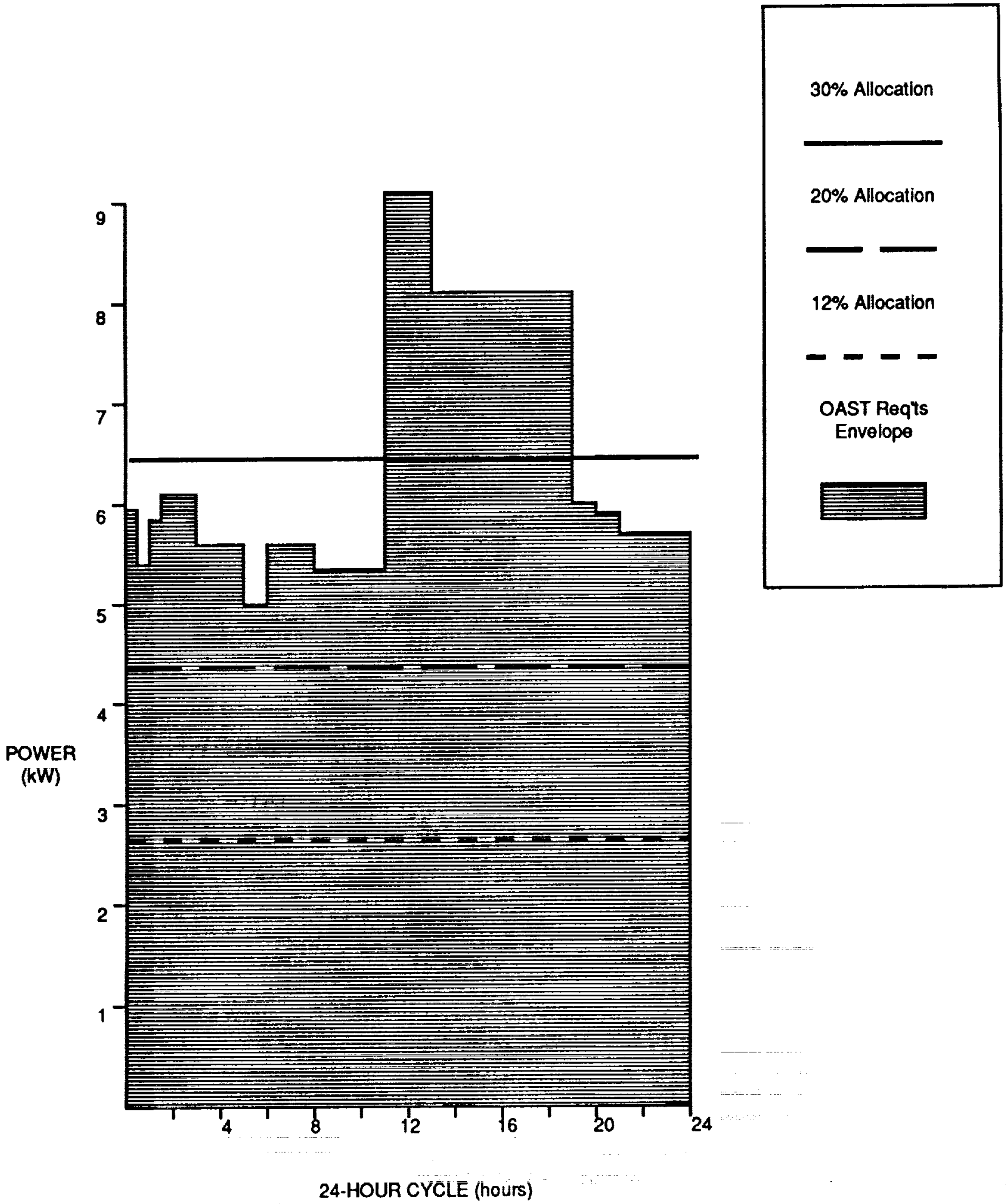


Figure 9. - Typical OAST Power Consumption Profile 1999 - PV 3
21.5 kW Available To NASA Users

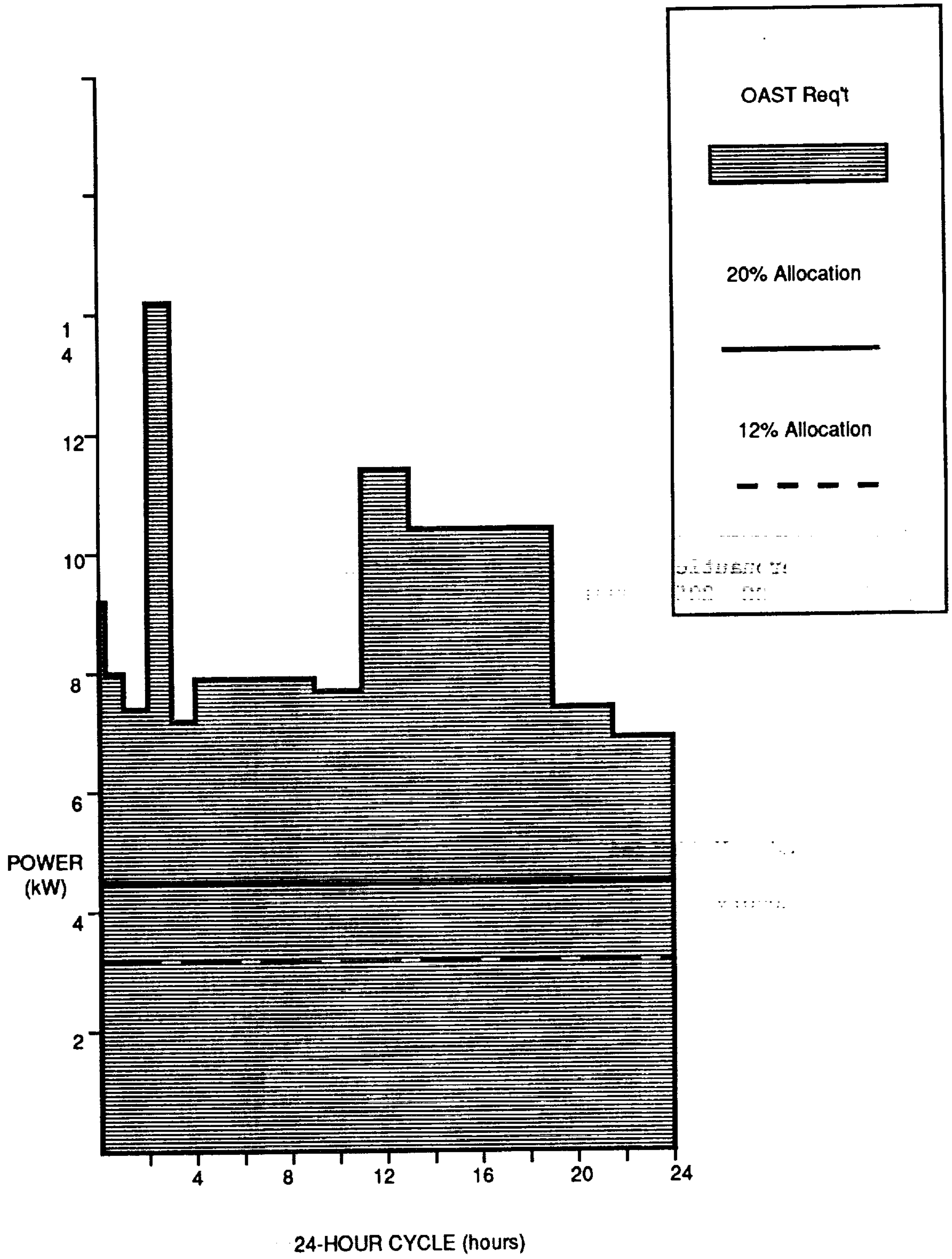


Figure 10. - Typical OAST Power Profile -1999 - 2nd Half
21.5 kW Available To NASA Users

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY *(Leave blank)*	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	February 1992	Technical Memorandum

4. TITLE AND SUBTITLE
Space Station Freedom Restructure Impacts on Technology Experiment Accommodation

5. FUNDING NUMBERS
506-49-31-03

6. AUTHOR(S)
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7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
NASA Langley Research Center
Hampton, VA 23665-5225

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
National Aeronautics and Space Administration
Washington, DC 20546-0001

10. SPONSORING/MONITORING AGENCY REPORT NUMBER
NASA TM-104214

11. SUPPLEMENTARY NOTES
Avery: Langley Research Center, Hampton, VA; Collier and DeGrace: CTA Incorporated, Hampton, VA; Thomas: Langley Research Center, Hampton, VA

12a. DISTRIBUTION/AVAILABILITY STATEMENT
Unclassified - Unlimited

Subject Category 81

12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*
This paper is a follow up to NASA Technical Memorandum (TM) 102766; it provides an overview of the Office of Aeronautics and Space Technology (OAST) Space Station Freedom technology development payload program, reviews the OAST Station resource requirements, and contrasts the requirements with the resources that are available to OAST since the restructure of Space Station Freedom. A discussion of the issues, as well as conclusions and recommendations, is provided. It is concluded that, even after adjustments to the OAST traffic model to reflect restructure, some resources will be inadequate even at the 20% allocation level. It is also concluded that bartering resources among U.S. users and international partners, and increasing the level of automation may be viable solutions to the resource constraint problem. The final conclusion is that, to facilitate the performance of technology experiments on Space Station Freedom, OAST should fund Station experiments and update its traffic model as soon as possible, and should provide technical and programmatic assistance to technology experiment developers.

14. SUBJECT TERMS
Space Station Freedom
Restructure Impact
Technology Experiment
Resource Allocations

15. NUMBER OF PAGES
28

16. PRICE CODE
A03

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
Unclassified	Unclassified		