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Space Station Freedom Resource Allocation Accommodation of Technology Payload Requirements

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Abstract

This paper provides an overview of the Office of Aeronautics, Exploration, and Technology (OAET) Space Station Freedom technology payload development program, reviews the OAET Station resource requirements, and contrasts the requirements with current proposed resource allocations. A discussion of the issues and conclusions are provided. It is concluded that an overall 20% resource allocation is appropriate to support OAET's technology development program, that some resources are inadequate even at the 20% level, and 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.

Introduction

The Office of Aeronautics, Exploration, and Technology (OAET) has defined a reference set of payloads which represents OAET's best estimation of the types of technology development experiments to be performed on Space Station Freedom. This reference set was selected to provide a balanced Research, Technology, and Engineering (RT&E) program in OAET's research thrust areas (See Figure 1), to provide continuity from ongoing National Space Transportation System (NSTS) research, and to include the focused technology program inputs of NASA, the Department of Defense (DoD), industry, and university experts. In addition, potential opportunities for international cooperative payloads have been considered. This reference set of payloads involves technologies that will support the Space Exploration Initiative (SEI) and the Civil Space Technology Initiative (CSTI) and will enhance safety and productivity on the Station, as well as meet the technology goals of other technology development agencies. These payloads have been compiled in an official OAET traffic model (Table 1) detailing pressurized and attached payload launch and return dates from 1995 to 2002. This traffic model has been transmitted to NASA's Office of Space Flight. For planning purposes, resource requirements were derived for these experiments from the best available technical information on the types of systems and equipment to be used and on the engineering requirements of similar, NSTS-based experiments. Currently, a number of technology experiments are funded for development through the OAET In-Space Technology Experiments Program (IN-STEP). Additional experiments with objectives similar to those of the reference set payloads will be selected from future IN-STEP Announcements of Opportunity.

Purpose

The purpose of this paper is to present the resource requirements (electrical power, pressurized rack volume, crew time, and experiment data generation) of the OAET traffic model payloads and to illustrate the impacts of varying Space Station resource allocations on the technology development program. In addition, this paper will identify the constraining resources for the reference set and will provide recommendations for options to maintain the integrity of the OAET program within Space Station Freedom's resource constraints.

Data Sources and Assumptions

The data for the reference set were obtained from the March 1990 Space Station In-Space Experiments Model Source Book (Reference 1). The Model Source Book has been maintained for Space Station technology experiment program planning since 1988. Updates to the Source Book have been provided by Principal Investigators (PIs) for the reference payloads where funded, for similar experiments, or by PIs of proposed research efforts. This information is also maintained electronically in the Langley Research Center (LaRC) Space Station Freedom Office (SSFO) In-Space Experiments (ISE) data base. The OAET Space Station Freedom Utilization Traffic Model (Table 1) was used to determine the launch and return dates for the payloads. Table 2 shows these dates for OAET payloads up to Space Station Freedom Assembly Complete (AC). Payloads are assumed to be scheduled for launch in July of the traffic model year. OAET's payloads will be discrete packages that will be launched, will remain on orbit for a specified period, and then will be returned to Earth. The Space Station Freedom Utilization Sequence Databook's (Reference 2) resource allocations were used for crew, racks, power, and data. The Space Station Freedom assembly, outfitting, utilization, and logistics flight schedule (Figure 2) was also obtained from the Utilization Sequence Databook.

In order to derive the payload resource consumption profiles, certain assumptions were made. The power profiles show a 24-hour period in which each OAET experiment is run one time. At present, no OAET payloads call for multiple runs in one day, although some do run continuously. The experiment run times have been staggered to minimize instantaneous peak and sustained nominal power levels for 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 actually 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; additional automation was not considered.

OAET Space Station Freedom Utilization Traffic Model

The OAET Space Station Freedom Utilization Traffic Model (Table 1) projects technology flight experiments that represent a balanced technology program consistent with OAET's outyear funding strategy. The traffic model has been transmitted to NASA's Office of Space Flight and is being used in current analyses of the Space Station. The payloads described in the traffic model are based on the best current understanding of the projected technologies required to support NASA's major thrusts: exploration, transportation, station evolution, and science. OAET's technology development thrusts are described in Figure 1. The payloads in the model are separated into attached and pressurized categories, and launch and return dates are shown. In addition, the time phased requirement for common laboratory support equipment (LSE) is shown in Table 1. The Station program or other U.S. users will provide all of the common LSE except the Life Sciences Electrode Impedance Monitor. This monitor must be provided by the payload requiring its use and, at that time, will be offered to the Station program as additional common LSE. While the traffic model contains payloads planned up to the year 2002, this paper will consider only those projected up to Space Station AC in 1999. It is important to note that the number of payloads, as well as racks occupied, builds up in a fashion consistent with Station build-up until approximately 20% of the overall U.S. resources are utilized.

Descriptions of the payloads projected for OAET's Space Station Freedom technology development development program up to AC are listed in Appendix A. They are listed in chronological order with a brief description and a unique alphanumeric mission code for each.

Space Station Freedom Resource Allocations

The resources that Space Station Freedom will supply to the user are described in the Program Design Requirements Document (PDRD, Reference 3). Resource allocations among the international partners are described in the Memoranda of Understanding (MOUs). The resource allocations among the different NASA users, however, have not been formally defined. Different multilateral studies have made various assumptions regarding these allocations. The Multilateral Utilization Study (MUS, Reference 4) assumed that the Office of Space Science and Applications (OSSA) would receive 55% of the U.S. user resource allocation, OAET would receive 20%, the Office of Commercial Programs (OCP) would receive 20%, and the Office of Space Flight (OSF) would receive 5%. However, during the Utilization Sequence Scenario Study (Reference 2), the Director, Space Station Freedom Program, directed study participants to use a resource allocation of OSSA 70%, OAET 10%, OCP 10%, and OSF 10%. As stated in the Purpose section of this paper, this electrical power, pressurized rack, crew time, and data resource allocation is a concern. Each of the user codes has developed a traffic model, and, cumulatively, the traffic model requirements exceed the U.S. Station resource allocations. The Station resources and user allocations are shown in Table 3 for two time frames in the Station assembly sequence.

OAET Resource Requirements and Constraints

This section will illustrate the resource consumption profiles of the payloads in the OAET traffic model from 1996 to 1999. The current (1 October 1990) Station resource constraints have been superimposed on the profiles.

Rack Requirements

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, if the Utilization Sequence Scenario Study allocations are assumed to be correct, the attachment points will be insufficient. OAET's attached payload traffic model requires a complete attached payload accommodations equipment (APAE) set. Other Small and Rapid Response (SARR) class attached payload sites may be required, as well.

Figure 3 shows the build-up of Station pressurized volume racks required to accommodate OAET's pressurized payloads. The dates for each incremental increase are based on projected payload launch dates. Return of payloads to Earth is also taken into account.

As shown in Table 3 and Figure 3, an OAET rack allocation of 10% yields two racks in the U.S. Lab Module and 1.5 racks in the international modules. The 10% rack allocation will be adequate only until mid-1997 when OAET's 1997 payloads are launched. With the addition of four pressurized payloads and the return of only one, the requirement increases to 4.4 racks , while only two racks are available. The addition of 0.5 racks when the Japanese Experiment Module (JEM) is brought to orbit and another rack in the Columbus module still does not meet the requirement for early 1998. In mid-1998, volume equivalent to 0.65 racks will be returned to Earth; however, the Flight Crew Health experiment alone, launched in 1998, will require 2.6 additional racks.

A 20% allocation would be sufficient for OAET payloads only up to PMC (Figure 3). In late 1996/early 1997 and again in early 1998, the 20% figure would exceed OAET's current projected demand. This margin would allow for some increased rack requirements due to payload packaging design problems and some additional space for SARR payloads. The objective of the SARR payloads is to provide fast access to the Station for users, while minimizing the use of Station resources. The SARR payloads would not enter the program until approximately two years before launch. Therefore, a rack margin is necessary in the early planning years.

Crew Requirements

The IVA manhours required for experiment operations per increment are depicted in Figure 4. The increases in manhours required are concurrent with the addition of payloads to the Station as indicated in the OAET traffic model. Additional automation beyond the initial PI requirements was not taken into account in deriving the overall OAET requirement. IVA time required for EVA support was not included in this figure. The station constraints are derived from the availability of a total of four crew members for eight hours a day for IVA for payloads. As the international partners' payloads are brought to Station, the manhours available for U.S. experiments decrease. For the period prior to Permanently Manned Capability (PMC, mid-1997), crew will be available for the users only during the manned portions of the three utilization flights (UF-1, UF-2, and UF-3).

OAET crew requirements generally fall into the turn-on, monitor, and turn-off categories to mid-1997. Prior to mid-1997, all payloads except Manned Observation Techniques are automated. After mid-1997, more experiments requiring crew involvement will be brought to orbit. With a 10% allocation level, OAET's crew requirements are not met even during the utilization flights. An allocation of 20% would suffice in 1996 and early 1997; however, after the launch of the 1997 payloads, even 20% falls short. As indicated in Figure 4, completely automating as many of the 1998 to AC payloads as possible will still result in an IVA requirement that exceeds 20% of the available manhours. At PMC, with an allocation of 20% (280 manhours per increment), OAET's current crew time requirement (450 manhours) exceeds the allocation by 60%, and, by AC, the allocation is exceeded by more than 130%. The inclusion of EVA support time (six hours of IVA per hour EVA for the Thermal Interface Technology experiment) would increase the gap between requirement (650 manhours) and resource (205 manhours) to 220% of the allocation.

As an indication of overall requirements, Figure 5 depicts total OAET annual crew IVA requirements, including experiment set-up, operations, servicing, configuration changes, tear-down, and EVA support. As can be seen in the figure, OAET annual crew time requirements are anticipated to grow from 0.75 manyears in 1996 to nearly 2 manyears by AC. By comparison, the overall U.S. allocated crew time for the same time period will grow from 0.75 manyears to 3.8 manyears.

Power Requirements

Figure 6 depicts the build up of OAET payload power requirements over the course of Station assembly. Typical Station power levels available to OAET (both 10% and 20% allocations) are superimposed on the figure.

Figures 7 through 12 illustrate daily power profiles for 1996 through AC. Since OAET payloads are projected to be launched in July of the traffic model year and Station power resources vary by year, each figure depicts one half of a year. The profiles represent one 24-hour period in which all OAET 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 the typical power available for both attached and pressurized payloads in that period.

For 1996 (Figure 7), typical power available to all U.S. users is 20 kW. For this time period, OAET's 10% allocation is not quite sufficient. Peaks in the In-Situ Trace Contaminants Analysis and Manned Observation Techniques experiments cause the requirement to exceed the 2 kW limit. An allocation of 15% (3 kW) would be adequate, with a margin.

Up to mid-1997 (PMC and launch of 1997 payloads), there will be only 12 kW available to U.S. users, as station-keeping power requirements increase. (See Figure 8.) OAET would require 20% of this power level (2.4 kW) to operate the 1996 payloads.

OAET's post-PMC payload launch and return schedule will include the joint NASA/DoD Advanced Sensor Development payload. The power required by this payload causes the OAET requirements to go above the 20% (2.4 kW) level (Figure 9). In September, when additional power modules are integrated into the Station, the Station may be able to produce 46 kW above housekeeping load requirements. OAET could use 12% of the 46 kW level (5.5 kW) for peak power needs and 10% for nominal operating conditions. However, the current U.S. Lab Module design does not provide for distribution of power at the 46 kW level.

In early 1998 (Figure 10), OAET is still operating the 1997 payloads, and 31 kW is available for U.S. use. At this level, 20% would be sufficient, even for peak loads. OAET will change out payloads in mid-1998, and the JEM and Columbus modules will be brought to orbit. At that time, the housekeeping loads and the power required by the international experiments will decrease the power available to U.S. users to 23 kW. The power requirements for OAET will exceed even 30% (6.9 kW). (See Figure 11.) The picture in early 1999 (Figure 12) is almost identical to late 1998, although the power available has decreased slightly.

Data Requirements

OAET payloads are not drivers for the data systems of the Space Station Freedom. Their requirements are several orders of magnitude less than the available resources. Therefore, OAET should not have trouble obtaining the data resources required for its payloads.

Optical Window Requirements

During the Space Station Freedom Configuration Budget Review, three optical windows were removed from the U.S. Lab. Since that time, OAET has been coordinating an effort to have these windows reinstated in the Station program. The proposed optical windows would have the optical properties needed for Earth or celestial viewing. 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. Also, if attached payload sites are not available on the truss, viewing payloads could be located in the pressurized volume with viewing through the windows. It is 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 and port optical windows located in the U.S. Lab, and the Station operational windows should be shared with the users as windows of opportunity. At present, Space Station Freedom meets none of the OAET or DoD optical window requirements.

Discussion

The Space Station Freedom program provides an excellent opportunity for OAET 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 spacecraft.

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 MOUs; however, the allocations among the U.S. users have not been defined. 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. In order for the U.S. users to accurately plan for the long term, these resource allocations must be determined in a timely fashion. The primary purposes of this paper are to review the currently projected OAET Space Station Freedom resource requirements and to determine if proposed resource allocations are sufficient to support the technology development program. If OAET does not acquire the needed resources up front, planning will be difficult, and execution may be impossible.

With a 10% allocation of rack space, OAET will have extreme difficulty maintaining its in-space technology development program as described in OAET's Space Station Utilization Traffic Model. A 20% allocation would allow for a more aggressive early program; however, it would be only marginally adequate for the post-PMC period. If a 20% allocation of rack space cannot be obtained, rephasing gloveboxes and workbenches, which are not required in the early years of the Station, may provide increased rack space for technology payloads.

On-orbit crew time has always been recognized as a limited and precious resource; however, with only a 10% allocation of crew time, crew activities for OAET payloads will be severely limited. Experiments such as Flight Crew Health and Manned Observation Techniques may be eliminated altogether. As was shown in the MUS, OAET payloads continue to be crew intensive. Certain experiments will require the use of two crew members for almost an entire operations shift. While it may be possible, through careful payload manifesting, for OAET crew time requirements to be satisfied during an increment, this cannot be done on an annual basis. If OAET is allocated only 20% of this resource, at no time will the annual requirements prior to AC 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.

If the 1 October 1990 resource allocations are considered, a 10% power allocation may be sufficient in 1996, particularly if a power reduction effort is undertaken by OAET payload developers. However, after that time, at least a 20% power allocation is needed. During the "Turbo" activity, four 6.25 kW DC-to-DC power conversion units (DDCUs) were relocated into the pressurized volume. The limitations on their size and numbers 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 10% allocation at this level will be inadequate.

At present, Space Station Freedom does not meet the requirements for optical windows. OAET should continue with its effort to have them returned to the Station program. Data requirements for technology, however, appear to be well within the 10% resource allocation.

Bartering is a recognized user option in the Station program and is a viable option for obtaining resources insufficient for user program needs. Bartering was shown in the MUS and Joint Science Utilization Study 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 OAET 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, OAET 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. OAET should also accept OSSA's offer to participate in discussions of SARR hardware/Station resource exchanges with the international partners through the SARR Steering Committee.

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 OAET. In the past, 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. If OAET opts to utilize OSSA integration facilities, rather than develop their own payload integration infrastructure, the decision must be made soon, and the request conveyed to OSSA.

Conclusions

The following are the conclusions reached from this study:

1. In order to accommodate OAET Space Station Freedom utilization planning, the need for a nominal 20% resource allocation must again be brought to the Station program's attention. Proper development, budget, and increment planning will require that OAET understands clearly the allocations. A 10% allocation is simply insufficient for RT&E payload requirements as they are currently understood. If future OAET budgets do not allow the realization of 20% resource utilization, then increased emphasis on SARR payloads may be needed.

2. OAET 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.

3. OAET should recommend to OSF that bartering between international partners become a formal process.

4. As it is becoming apparent that operations planning will likely be performed in detail, OAET 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.

5. In view of the crew time problem, OAET should consider enhancing the automation and robotics program to include work on teleoperations. This should include at least one laboratory demonstration.

6. OAET should recommend to its payload developers that automated procedures and controls be incorporated into their equipment as much as is practical. This will be particularly important for payloads with manifested flight dates of 1998 and beyond, when the mismatch between crew time requirements and availability becomes large.

7. Certain aspects of OAET payload planning requires the use of optical windows; OAET should continue to work with the Station program to ensure inclusion of this design feature.

8. OAET needs to ensure that both the SARR-class and distributed sensor-class payloads are included in the program.

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

10. OAET must develop a payload integration infrastructure or start negotiating with OSSA for these services.

11. OAET payload developers should be required to minimize power consumption.

References

1. Space Station In-Space Technology Experiments Model Source Book, March, 1990.

2. Space Station Freedom Program Utilization Sequence Databook, SHQ-373-0001, October 1, 1990.

3. Space Station Freedom Program Design and Requirements Document, SSP 30000.

4. Multilateral Utilization Study, January 30, 1990.

APPENDIX A - OAET 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 geometrics. 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.

TABLE 1.- OAET PAYLOAD TRAFFIC MODEL

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

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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 Special 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

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Table 2.- Experiment Hardware Availability and Launch Dates.			
EXPERIMENT NAME	**PI**	**HWD AVAILABILITY DATE**	**LAUNCH DATE**
MODAL IDENTIFICATION EXPERIMENT	James W. Johnson	Pre-integrated	First element launch
MANNED OBSERVATIONS EXPERIMENT	David L. Amsbury	1/96	7/96
IN-SITU TRACE CONTAMINANTS ANALYSIS	George M. Wood	10/95	7/96
TRANSIENT UPSET PHENOMENA	Felix L. Pitts	1/96	7/96
VHSIC FAULT TOLERANT PROCESSOR	Harry R. Benz	1/96	7/96
SPACECRAFT STRAIN AND ACOUSTIC SENSORS	Robert Rogowski	10/96	7/97
SPACECRAFT MATERIALS AND COATINGS	Wayne S. Slemp	1/97	7/97
MICROELECTRONICS DATA SYSTEMS	Alan R. Johnston	10/96	7/97
ACOUSTIC CONTROL TECHNOLOGY	David A. McCurdy/ David G. Stephans	10/96	7/97
INTERNAL SARR	OAET	3/97	7/97
ADVANCED SENSOR DEVELOPMENT	OAET	1/97	7/97
EXTERNAL SARR	OAET	3/98	7/98
THERMAL INTERFACE TECHNOLOGY	OAET	10/97	7/98
FLIGHT DYNAMICS IDENTIFICATION	George Sevaston	10/97	7/98
POLYMER MATRIX COMPOSITES	R. C. Tennyson	1/98	7/98
RISK-BASED FIRE SAFETY	George E. Apostalakis	1/98	7/98
FLIGHT CREW HEALTH	H. T. Fisher	10/97	7/98

Table 3.- Space Station Freedom Resources

(a).- Prior to PMC Allocation OSSA 70%, OAET 10%, OCP 10%, OSF 10%

STATION PROVIDED RESOURCE	PARTNER ALLOCATIONS						
	NASA				ESA	CSA	NASDA
	OAET	OSSA	OCP	OSF			
POWER (kW)	1.5	10.3	1.5	1.5	0	0.4	0
DATA (kbps)	7E7	4.9E8	7E7	7E7	0	2E7	0
IVA (manhours)	31	217	31	31	0	9.6	0
RACKS	2	15	2	2	0	1	0

(b).- Prior to PMC Allocation OSSA 55%, OAET 20%, OCP 20%, OSF 5%

STATION PROVIDED RESOURCE	PARTNER ALLOCATIONS						
	NASA				ESA	CSA	NASDA
	OAET	OSSA	OCP	OSF			
POWER (kW)	2.9	8.1	2.9	0.8	0	0.4	0
DATA (kbps)	1.3E8	4E8	1.3E8	4E7	0	2E7	0
IVA (manhours)	62	171	62	15	0	9.6	0
RACKS	4	12	4	1	0	1	0

Table 3.- Continued

(c).- AC Allocation OSSA 70%, OAET 10%, OCP 10%, OSF10%

STATION PROVIDED RESOURCE	PARTNER ALLOCATIONS						
	NASA				ESA	CSA	NASDA
	OAET	OSSA	OCP	OSF			
POWER (kW)	2.2	15.4	2.2	2.2	4.0	0.9	4.0
DATA (kbps)	5E7	3.5E8	5E7	5E7	9E7	2E7	9E7
IVA (manhours)	103	720	103	102	184	43	184
RACKS	3.5	26	3.5	3.5	12	2	5.5

(d).- AC Allocation OSSA 55%, OAET 20%, OCP 20%, OSF 5%

STATION PROVIDED RESOURCE	PARTNER ALLOCATIONS						
	NASA				ESA	CSA	NASDA
	OAET	OSSA	OCP	OSF			
POWER (kW)	4.4	12.1	4.4	1.1	4.0	0.9	4.0
DATA (kbps)	10E7	2.8E8	10E7	2E7	9E7	2E7	9E7
IVA (manhours)	206	566	206	50	184	43	184
RACKS	7	20	7	2.5	12	2	5.5

OAET TECHNOLOGY THRUST
TRANSPORTATION TECHNOLOGY Provide technologies for high-design margin transportation systems with high performance, predictable service life and low life cycle costs
SPACE STATION TECHNOLOGY Develop technologies for Space Station Freedom that will increase productivity, safety, and maintainability and decrease life cycle costs
EXPLORATION TECHNOLOGY Provide key technologies for robotic and manned solar system exploration missions including establishment of an outpost on the Moon and exploration of the planet Mars
SCIENCE TECHNOLOGY Provide technologies for space science programs focussed on the planet Earth, the solar system and the universe beyond
BREAKTHROUGH TECHNOLOGY Advance high-payoff, highly-innovative technology concepts that could provide revolutionary improvements in space capability

Figure 1.- OAET technology development thrust.

STUDY DRAFT

UTILIZATION SEQUENCE
SCENARIO 1
PERMANENTLY MANNED AT PMC

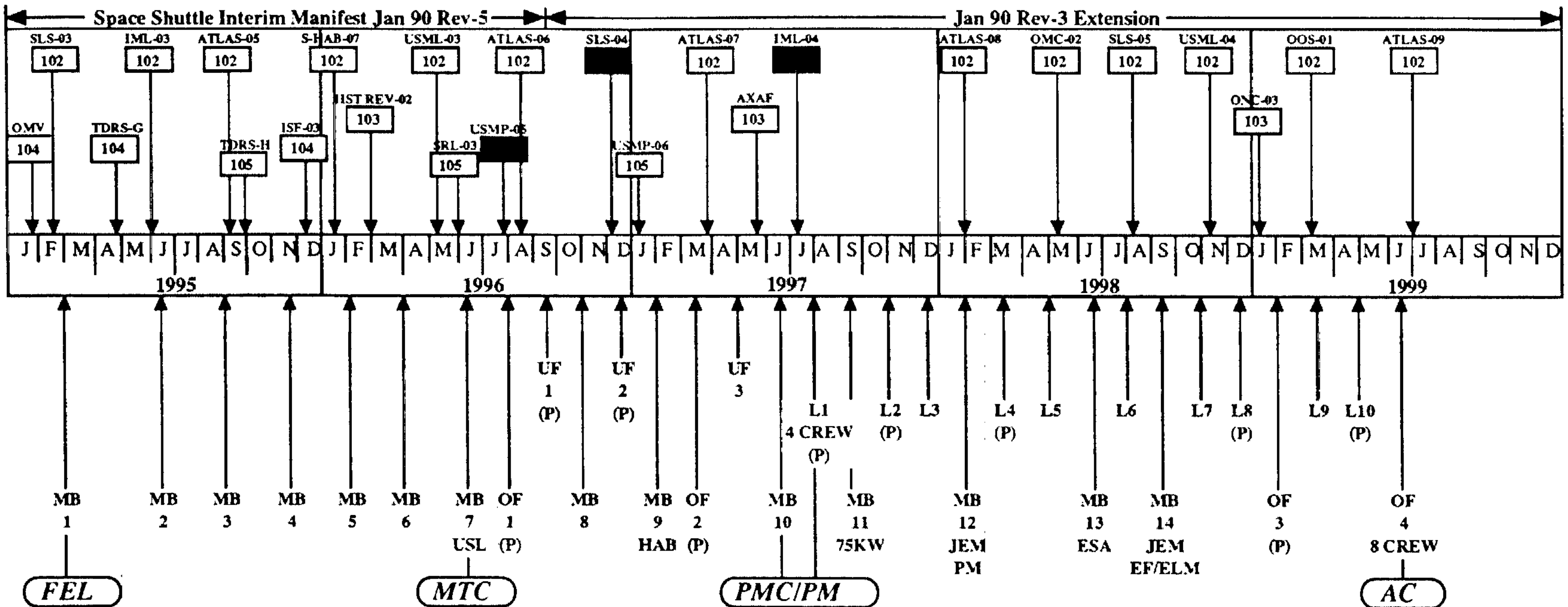
12 September 1990

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

TOTAL = 31

(14 MB, 4 OF, 10 LOG, 3 UF)

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

Figure 2.- Space Station Freedom Assembly Outfitting, Utilization, and Logistics Schedule

SSEIC/mlu.09.12.90

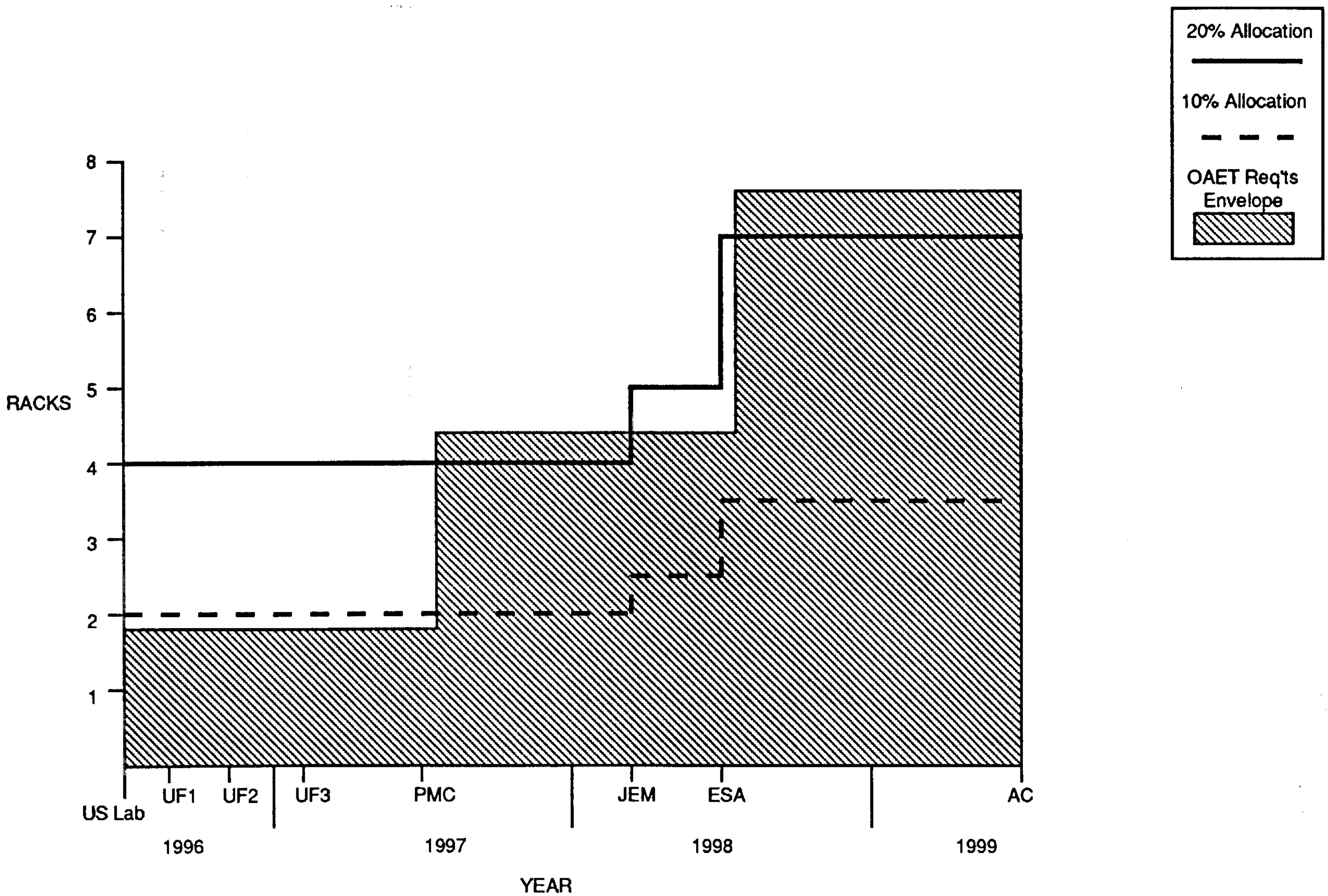


Figure 3.- OAET Rack Requirements

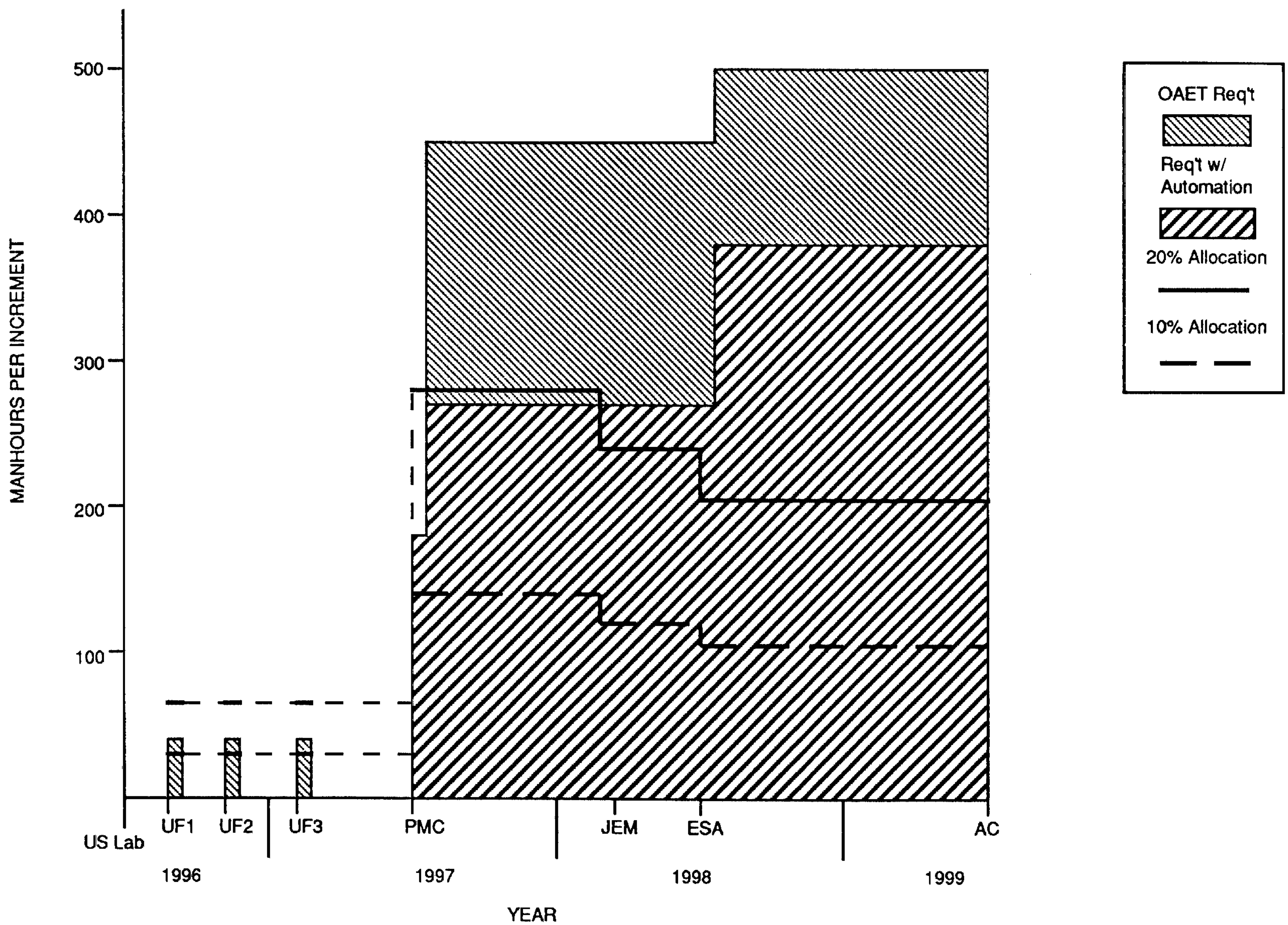


Figure 4.- OAET IVA Requirements

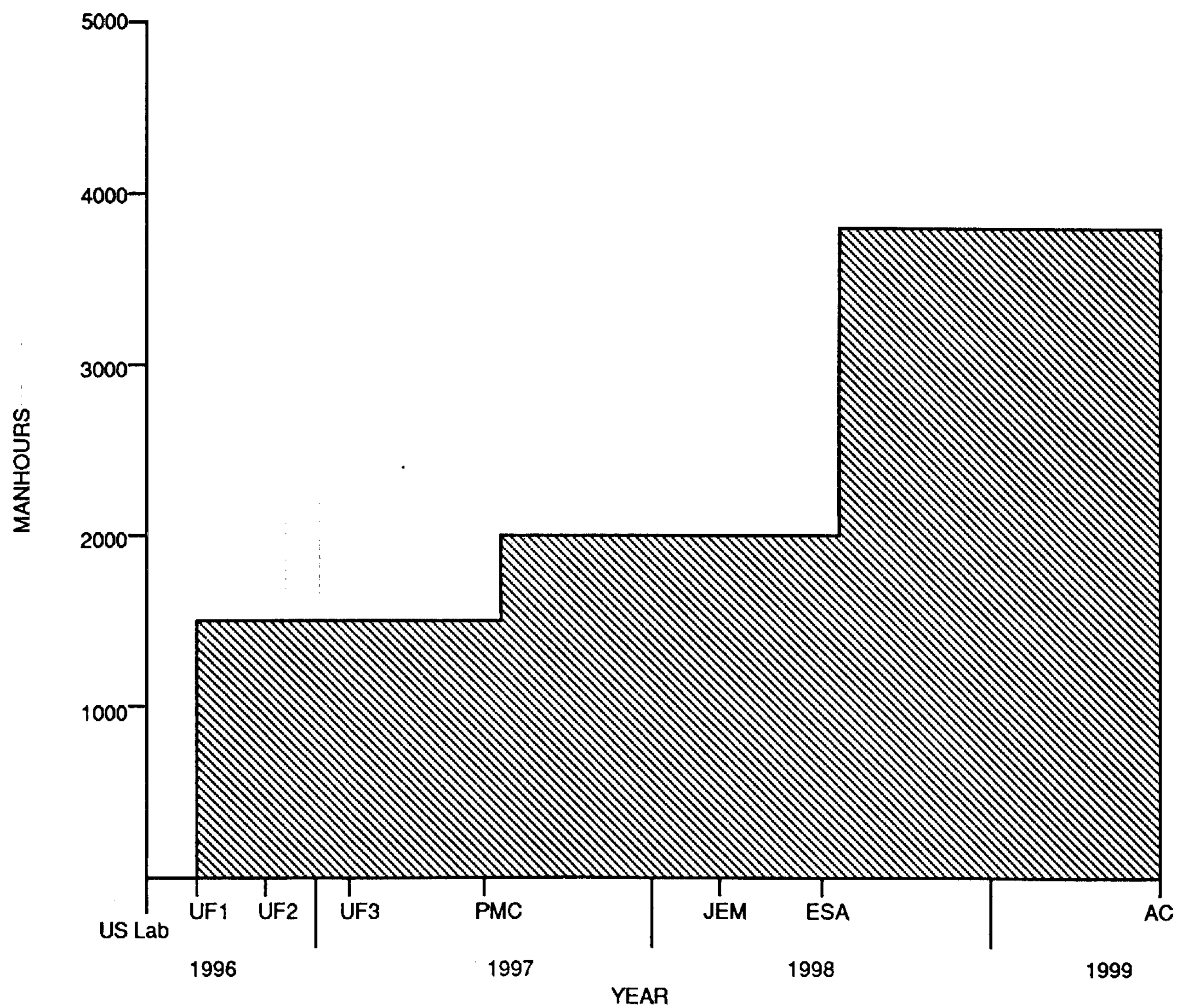


Figure 5.- Total OAET Annual IVA Requirements
Includes Setup Operations, Servicing, Configuration Change, and Tear Down, Plus 6 Hours per EVA

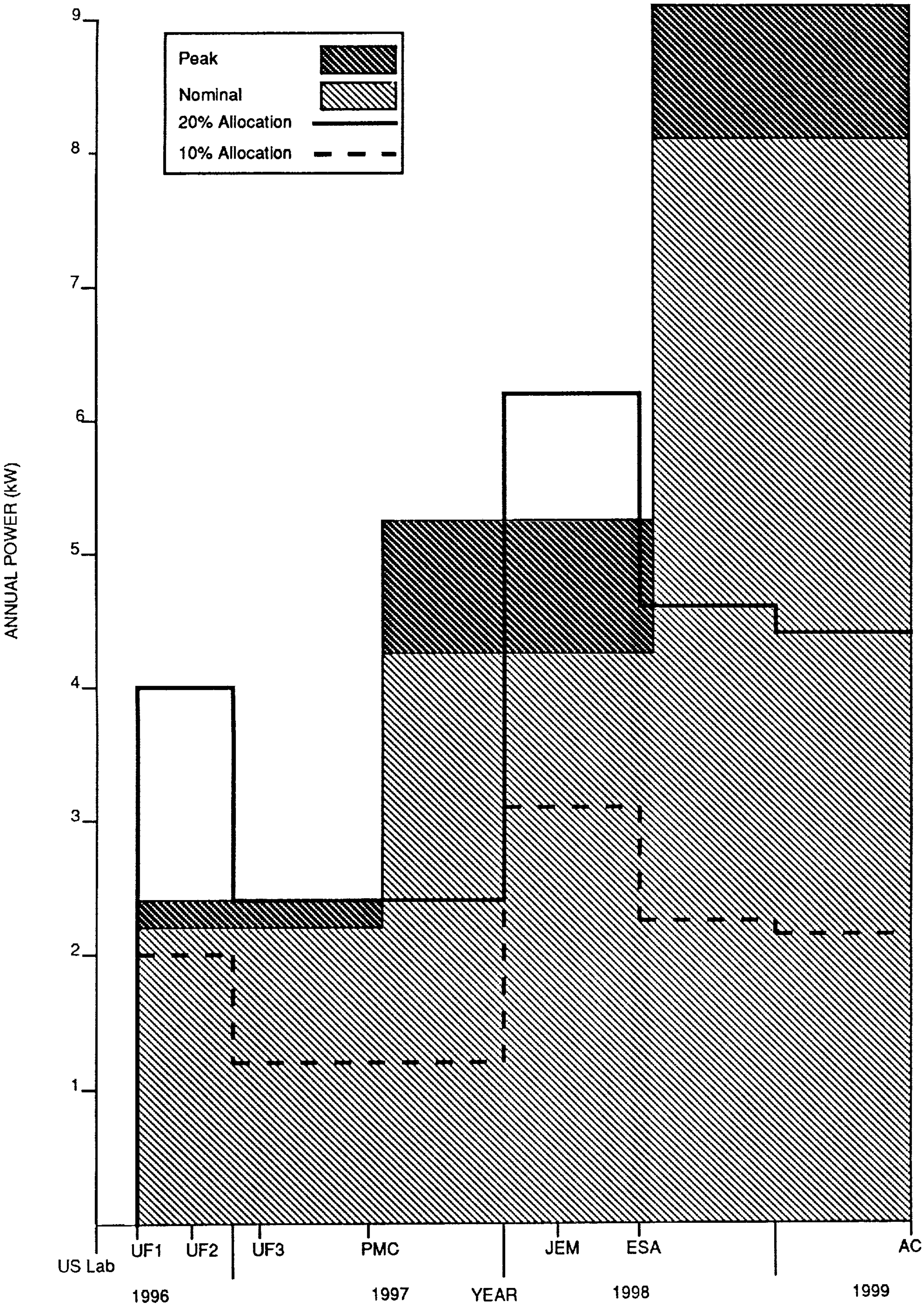


Figure 6.- OAET Overall Power Requirements

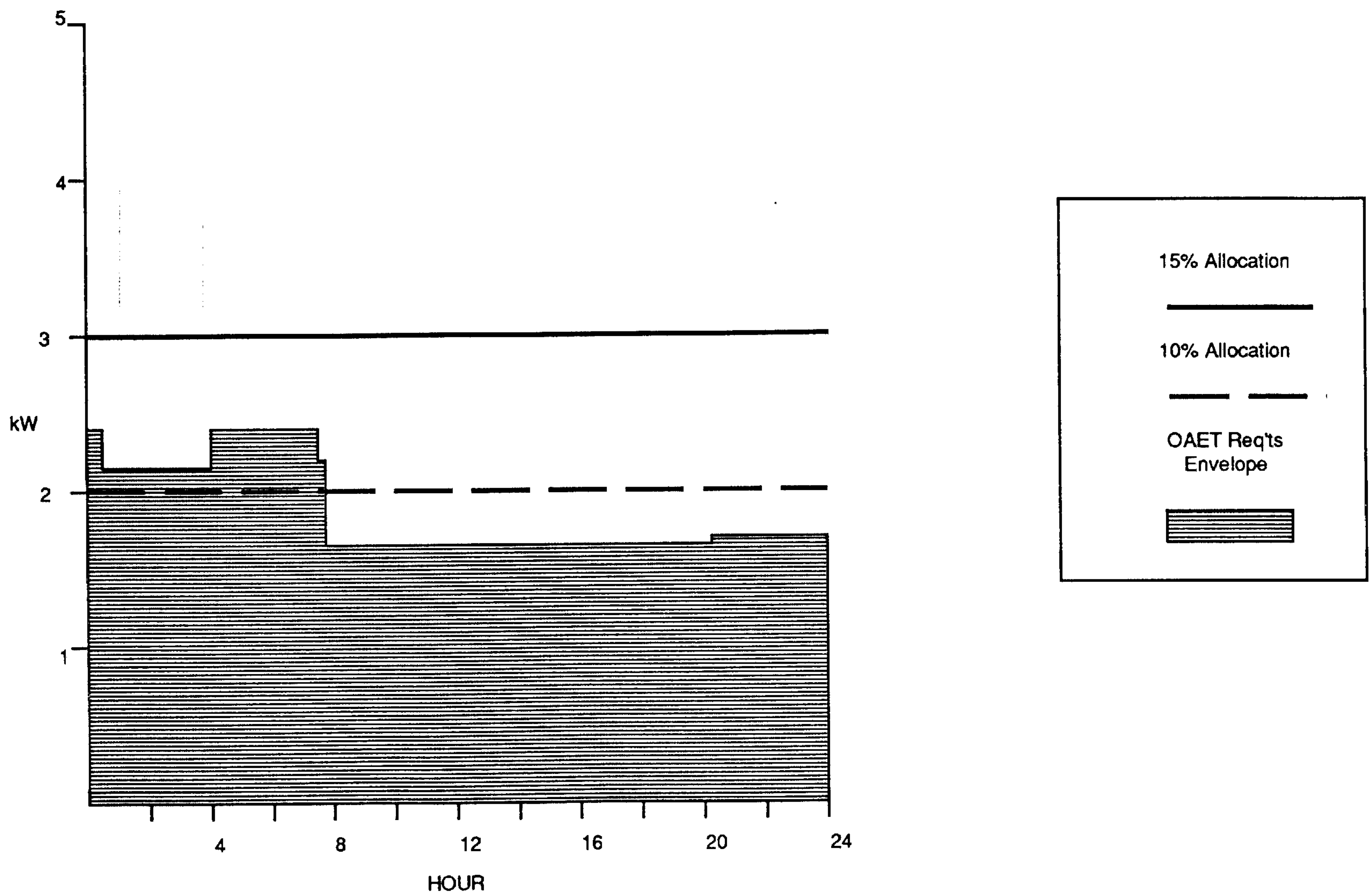


**Figure 7.- Typical OAET Power Consumption Profile
1996 - Manned Portion
20 kW Available To NASA Users**

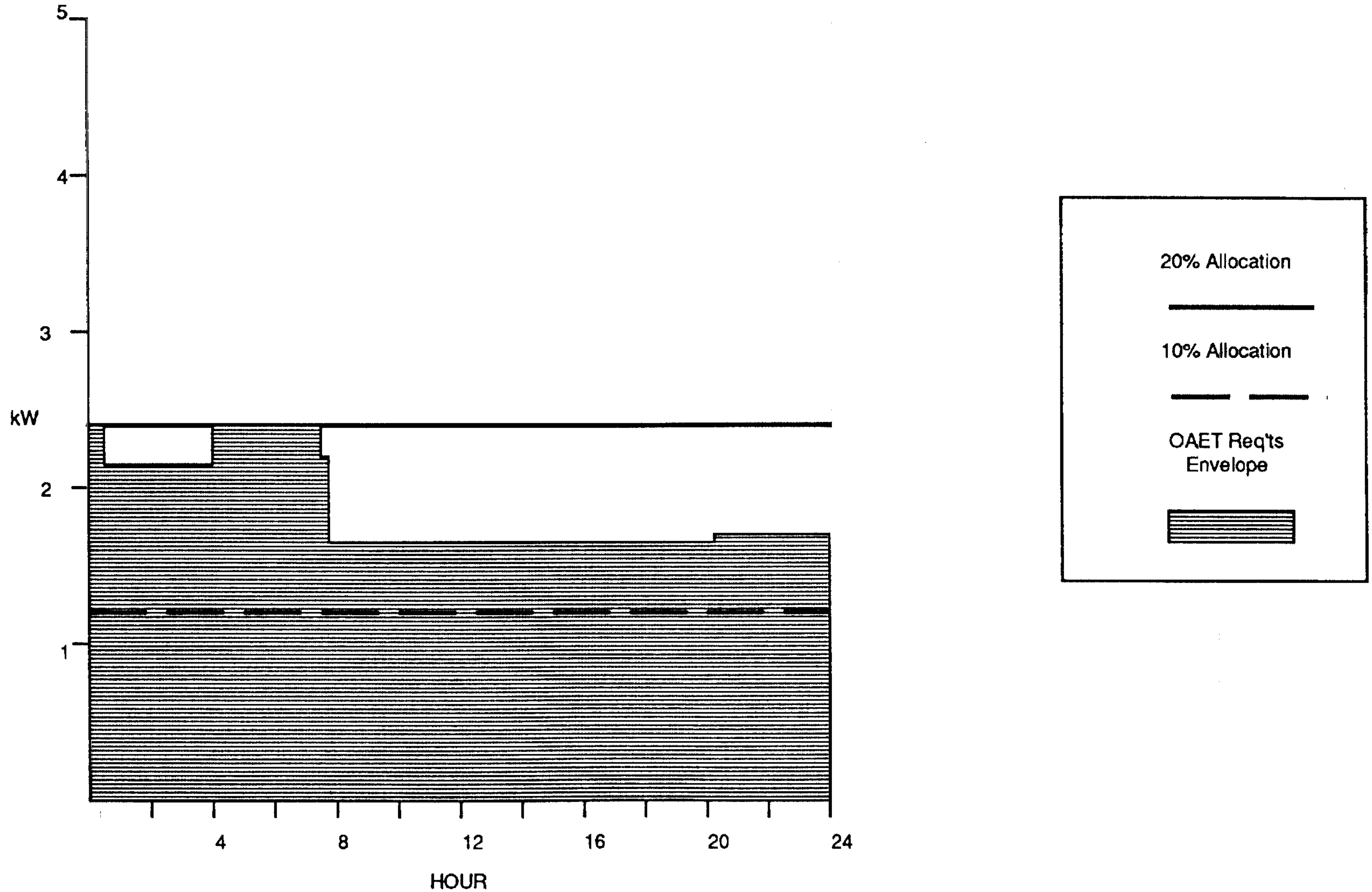


Figure 8.- Typical OAET Power Consumption Profile
1997 - Pre-PMC
12 kW AvailableTo NASA Users

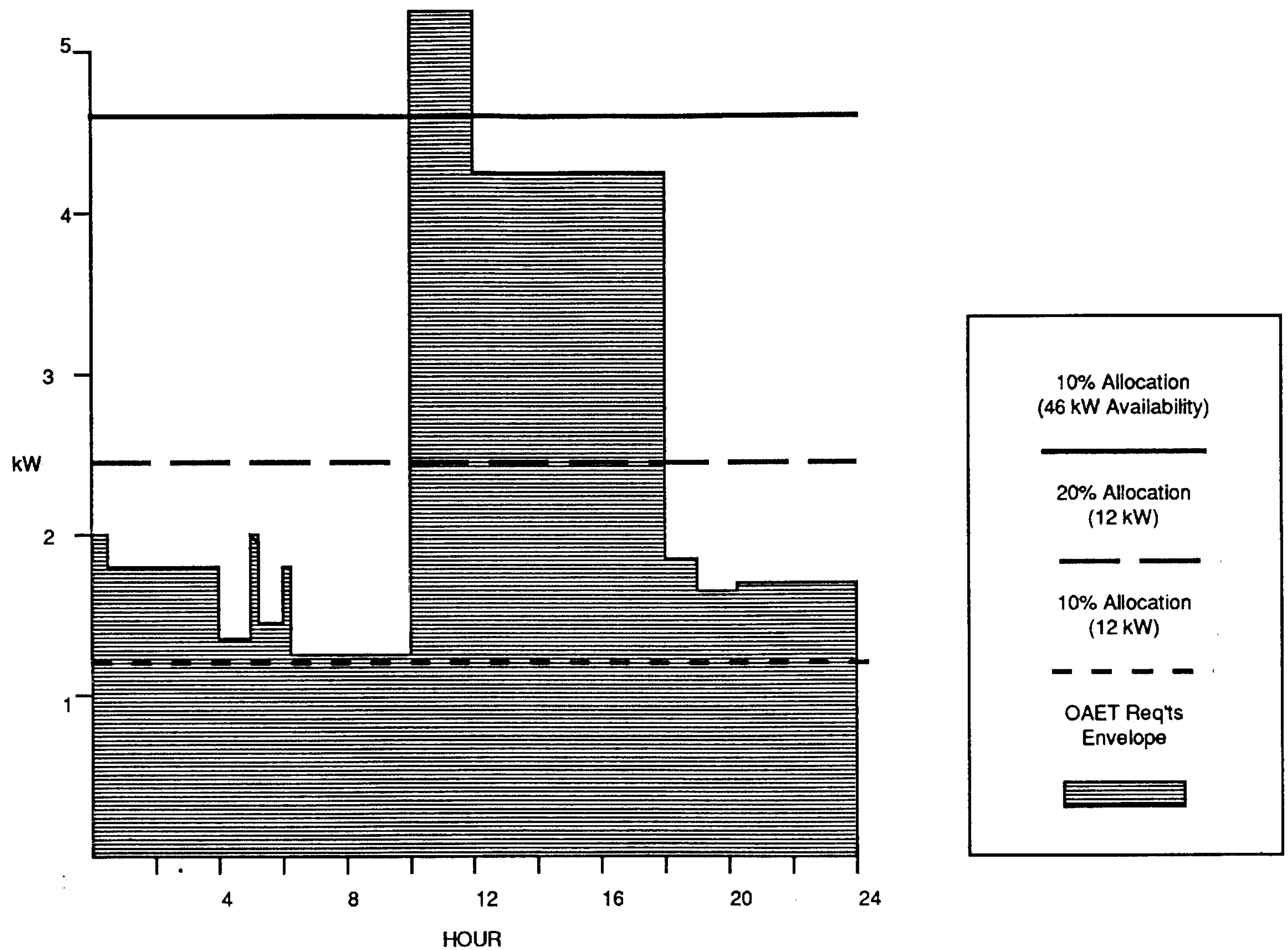


Figure 9.- Typical OAET Power Consumption Profile
1997 - Post-PMC
12 kW Available To NASA Users (46 kW Overall)

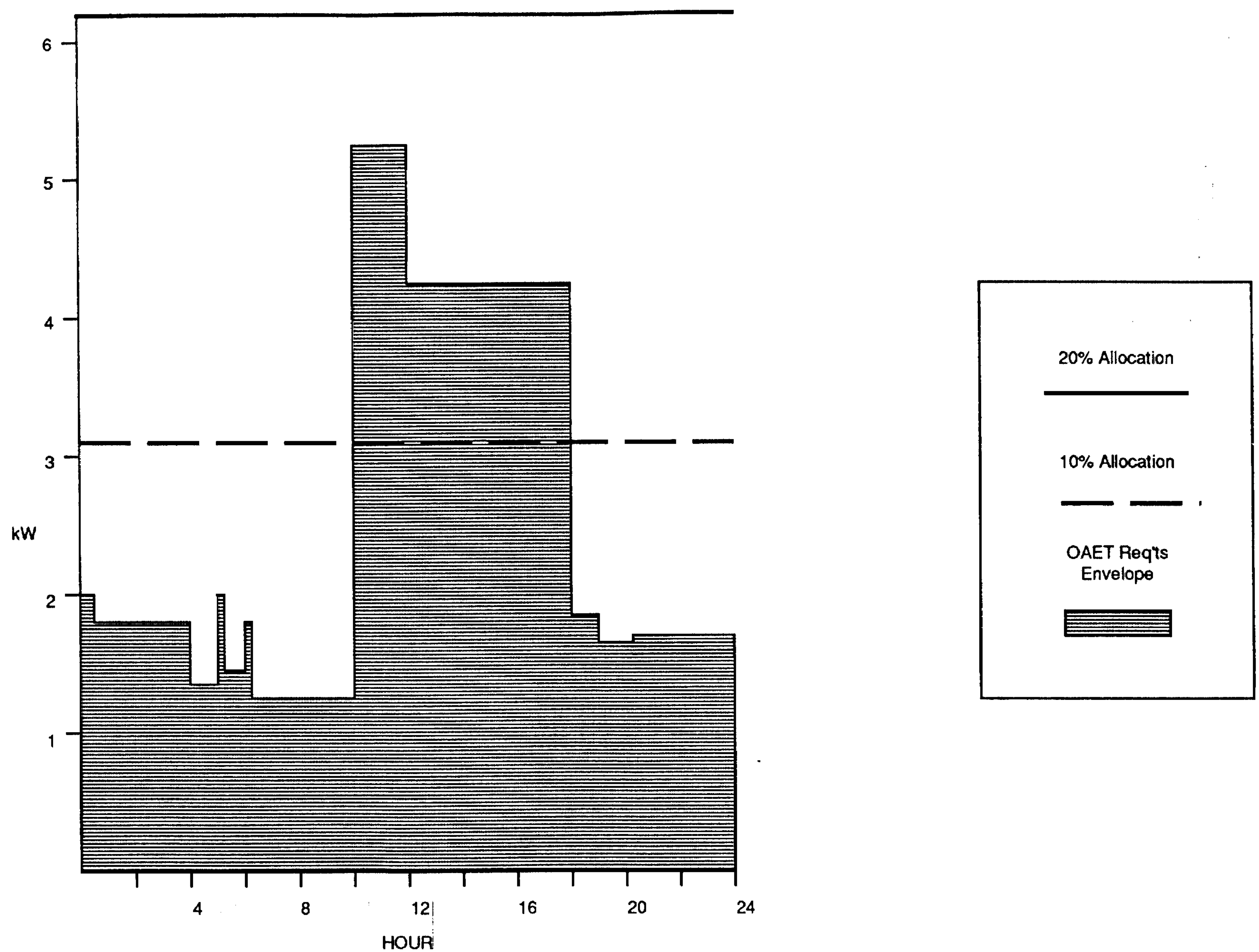


Figure 10.- Typical OAET Power Consumption Profile
1998 - First Half
31 kW Available To NASA Users

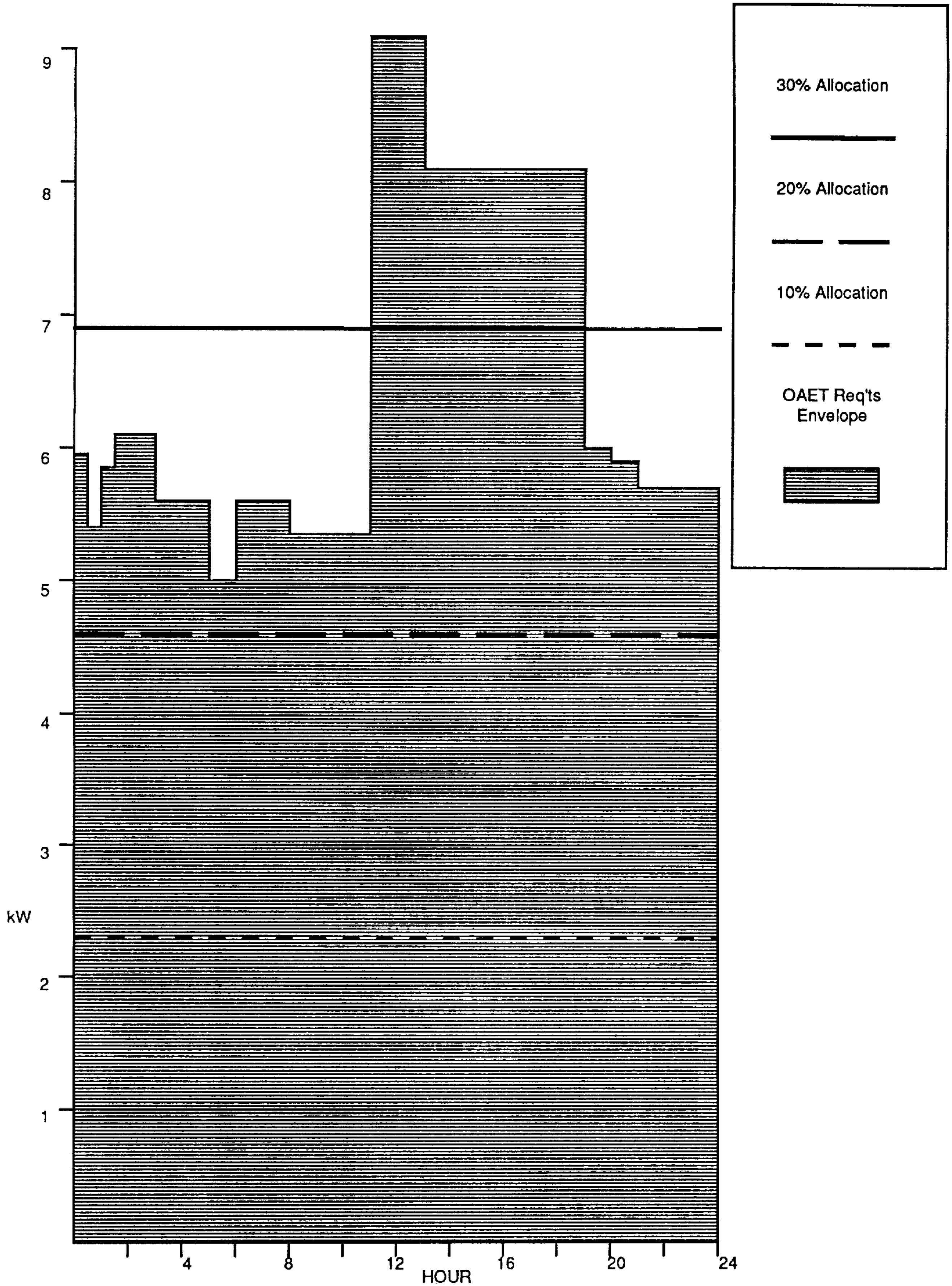


Figure11.- Typical OAET Power Consumption Profile 1998 - Second Half - 23 kW Available To NASA Users

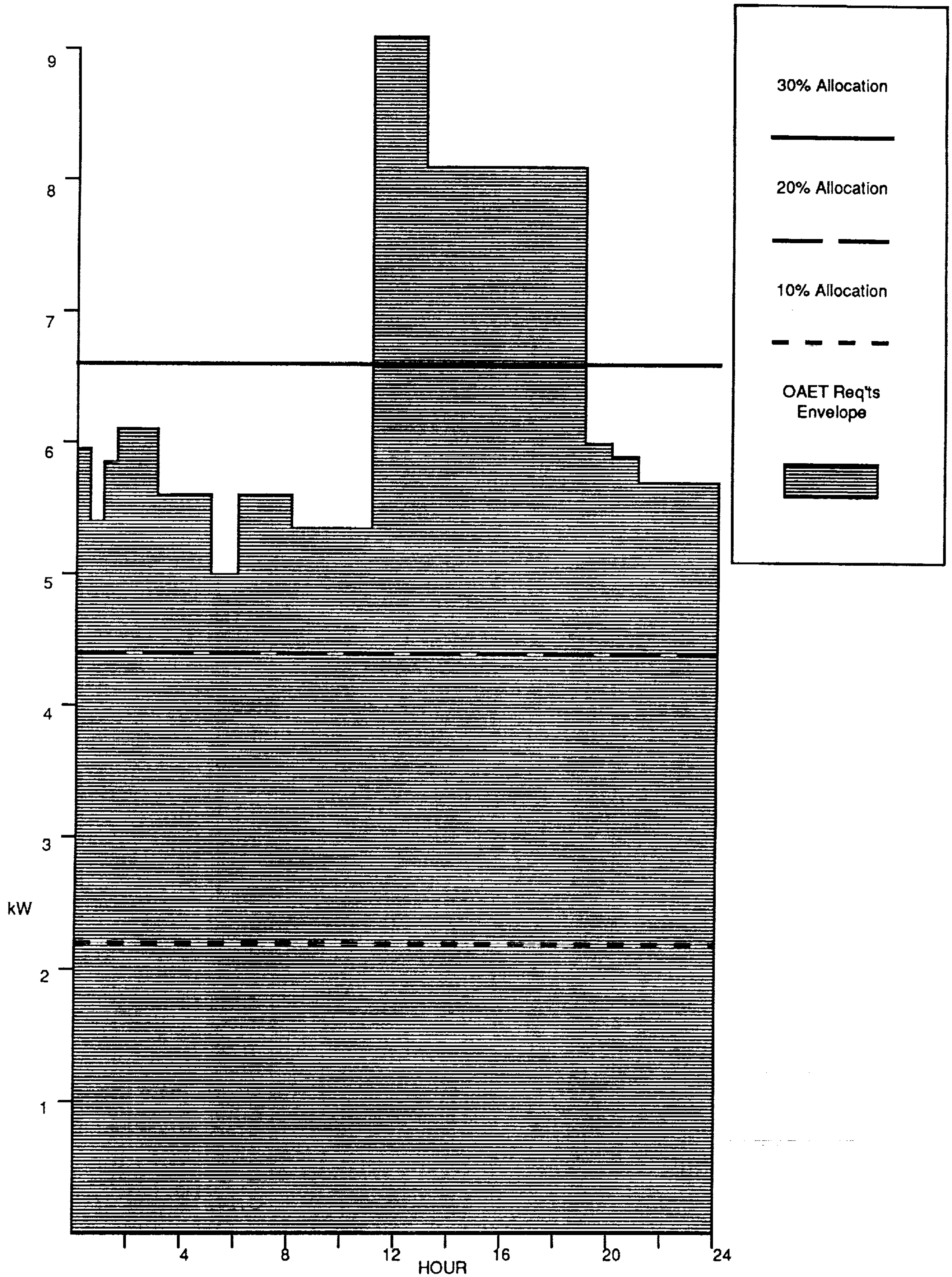


Figure 12.- Typical OAET Power Consumption Profile 1999 - Pre-AC - 22 kW Available To NASA Users

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15. Supplementary Notes

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16. Abstract

This paper provides an overview of the Office of Aeronautics, Exploration, and Technology (OAET) Space Station Freedom technology payload development program, reviews the OAET Station resource requirements, and contrasts the requirements with current proposed resource allocations. A discussion of the issues and conclusions are provided. It is concluded that an overall 20% resource allocation is appropriate to support OAET's technology development program, that some resources are inadequate even at the 20% level, and 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.

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