Evolution User Requirements for the Restructured Space Station

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Abstract

Space Station Freedom (SSF) is designed to be an Earth-orbiting multidisciplinary research and development (R&D) facility capable of evolving to accommodate a variety of potential uses. In order to identify SSF evolution requirements and define potential growth configurations, NASA Langley research Center's Space Station Freedom Office is analyzing user resource requirements for the post-PMC timeframe. The analysis goal is to define resource levels, including crew, power, and volume, which allow full utilization of SSF capabilities commensurate with minimum essential user requirements. Multiple scenarios have been studied including core R&D and combined SEI plus R&D utilization. This paper presents an analysis summary of a core R&D utilization scenario. Included are discussions of resource allocation assumptions for specific R&D disciplines, user requirements trends, and growth resource projections. These preliminary results show total resource requirements of thirteen crew, 150 kW power, and additional laboratory volume equivalent to a second U.S. laboratory module. Additionally, orthogonal growth structure was identified as required to support SSF systems and users.

Discussion Topics

- **Utilization Drivers for Growth / Evolution**
- **Utilization Analysis Summary**
- **SSF Evolution Requirements - Core R&D Utilization**
  - Pressurized Volume
  - Crew
  - Power/Thermal
  - Structure
- **Summary and Conclusions**

Discussion Topics

- Alternative Drivers for Growth Projections

- Utilization Analysis Summary

- SSF Baseline Requirements - Level of Utilization
  - Pressurized Volume
  - Power
  - Crew Time
  - Logistics

Utilization Drivers for Growth / Evolution

Through repeated analyses of user requirements for station resources, it has become apparent that the resources available to the users will need to be increased beyond those available at PMC. In fact, the accommodation of the PMC payload complement identified in the Level II flight-by-flight user payload and resupply cargo model requires sharing of crew and power, and falls short of meeting the volume requirements. In order to permit full operation of user payloads, as well as to accommodate a reasonable percentage of the number of experiments they wish manifested on station, it will be necessary to grow each of these resource capabilities. The preferred manner of growth is such that the available volume, crew, and power balance with user demand in such a way that no large surplus exists in any one resource.

In the course of providing additional user resources, the station will evolve to incorporate new functions for users as well as for station operations. As an example, several large external payloads have been defined by OSSA, but cannot be accommodated on the PMC pre-integrated truss (PIT). Some form of growth structure will, therefore, be required to supply attach locations for these payloads. Additionally, expanded capability will be provided for existing station-provided user services. One area of increased functionality is growth in the data management system (DMS) throughput, storage capacity, and bandwidth. This can be provided as a result of an expandable and upgradeable baseline system design. Another enhancement for station operations could come in the form of an expanded Earth-to-orbit delivery system. To that end, the station will evolve to accommodate cargo delivery via expendable launch vehicles.

New technology provides an avenue by which to maintain a productive research station. Incorporation of new technologies aboard Space Station would serve three main purposes. First, operations costs could be reduced and/or utilization of station could be increased through the use of advanced technologies. As an example, an advanced propulsion system such as Hydrogen - Oxygen propulsion could reduce costs by eliminating a significant number of annual launches to support station reboost. Secondly, crew safety could be enhanced – in this example by removing hydrazine contaminants from the proximity of EVA astronauts. Lastly, but perhaps most importantly for a long duration research facility, is that incorporation of new technologies would postpone obsolescence.

Utilization Drivers for Growth / Evolution

- **Increase resources for users**
  - Reduce time-sharing of critical resources at PMC
  - Increase utilization by expanding user volume
  - Provide balanced resources

- **Provide expanded functionality for users & station**
  - New classes of payloads (e.g., large external payloads)
  - New functionality within station-provided services such as DMS and C&T
  - ELV delivered cargo

- **Incorporate new technologies**
  - Reduce operations costs and/or increase utilization
  - Increase crew safety
  - Avoid obsolescence

Utilization Analysis Summary - Mission Requirements Data Sources

Several data sources were surveyed in assessing user requirements. Of primary importance were the NASA supplied "payload traffic models." Each of the user codes (OSSA, OAET, and OCP) publishes their own traffic model which comprises a list of desired payloads to be flown annually for the early years of station operations.

The Level II User Mission Data Base (UMDB) was the primary source for user mission requirements. This data base specifies the crew, volume, and power requirements for the majority of the missions used in this analysis. It also includes mission frequency, i.e., specifications of nominal, peak, and standby periods. Other data sources included the Space Station Freedom Program Utilization Sequence Databook, which provided general laboratory support facilities and laboratory support equipment (GLSF/LSE) volume requirements, and Change Request #BM010173A, "Laboratory Support Equipment Addback," providing GLSF/LSE power requirements. For the International Partner missions, the Memoranda of Understanding (MOUs) provided laboratory volume allocation specifications.

Lastly, the NASA "90 Day Study on Human Exploration of Moon and Mars" was used to determine requirements for vehicle processing operations and R&D supporting the SEI. Specifically, the OSSA provided inputs on life science requirements, the MSFC lunar vehicle specifications, and the NASA KSC vehicle processing analysis were employed in utilization scenarios assessing SEI plus R&D requirements.

Utilization Analysis Summary
Mission Requirements Data Sources

- **NASA HQ user representatives-supplied traffic models**
  - Office of Space Science and Applications (11/90)
  - Office of Aeronautics, Exploration, and Technology (6/90)
  - Office of Commercial Programs (6/90)

- **Level II Data**
  - User Mission Data Base, Revision 4.2 (9/90)
  - SSFP Utilization Sequence Databook (10/90)
  - CR# BM010173A, Laboratory Support Equipment Addback

- **International MOU's**

- **NASA 90 Day Study on Human Exploration of Moon and Mars**

Utilization Analysis Summary

The purpose of this analysis is to identify resource levels needed to support SSF mature operations in the 2005+ timeframe. Since Program options for long term utilization are currently under study, analysis has been performed to evaluated several potential utilization scenarios. These include core research and development (R&D) and combined R&D and space exploration initiative (SEI) scenarios. By studying various user resource allocation schemes for a "core" R&D program and then for an SEI plus R&D program, it was determined that 150 kW of power, thirteen to fourteen crew, and additional laboratory volume equivalent to a U.S. laboratory module will be required to meet both station and user operational needs.

The results are based on an allocation scheme commensurate with a "minimum essential" user capability. To establish this level of utilization, trend analysis was performed to derive resource relationships within specific user disciplines. These interrelationships were then employed in balancing the resources on the growth station to arrive at the stated growth resource requirements of 150 kW, thirteen to fourteen crew, and two U.S. laboratory modules.

Utilization Analysis Summary

- **Established SSF growth requirements of 150 kW of power, 13 - 14 crew, and the addition of U.S. Lab B**
  - Based on multiple analysis iterations, including Core R&D program and SEI plus R&D support
- **Driver is full utilization of available user resources (i.e., crew, power, volume) commensurate with minimum essential user capability**
  - Resource interrelations established through trend analysis
  - Balanced resources based upon interrelationships

Utilization Analysis Summary - Payload Trend Data

Derivation of an accommodation methodology which would allow for multiple analysis iterations in a reasonable time span was necessary. Also, since this analysis focuses on user requirements in a timeframe later than user traffic model specifications, there was a need to create "generic" missions which represent average requirements for each user discipline. Consequently, user mission requirements were compiled from several data sources with the goal of reducing hundreds of experiment specifications into a manageable set of experiment characteristics.

Each mission was classified according to one of nine research disciplines: Life Sciences, Microgravity Research, Technology Development (internal and external), Observational Sciences, Commercial Materials Processing, Commercial Life Sciences, External Commercial, and GLSF/LSE.

For each of these mission classes, the mission data were reviewed for "trends" in resource consumption (i.e., power use per double rack, crew use per double rack, etc.). Additionally, interrelationships between resource use among users (e.g., power verses crew for pressurized payloads) were derived to aid in balancing resource capabilities. These newly established trend data were then applied to the allocated user volume to determine total user requirements. Through iterative refinement of the allocation scheme, the resources were balanced in accordance with the interrelationships derived in the trend analysis.

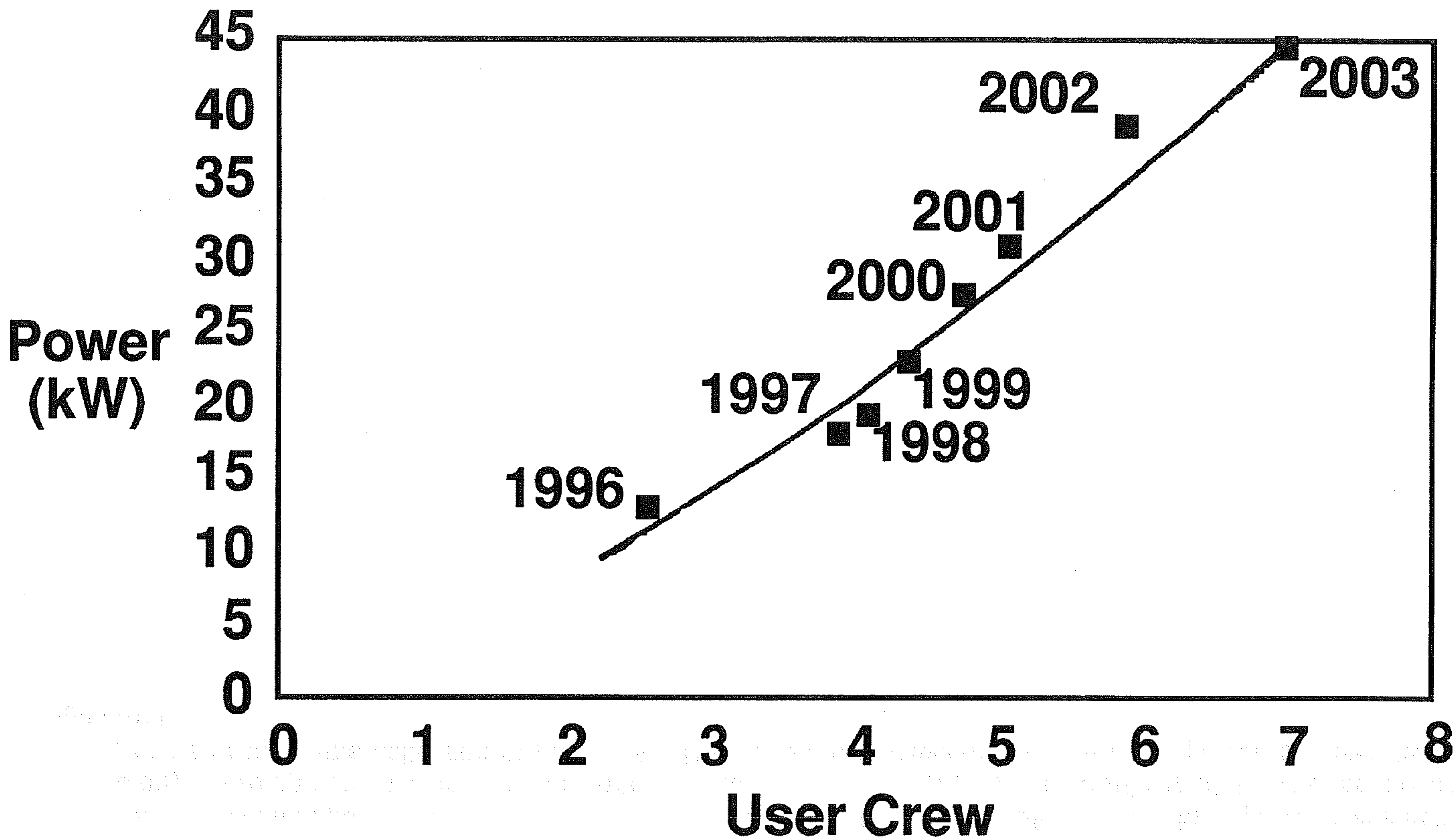
Utilization Analysis Summary
Payload Trend Data

Discipline	Avg cont. Power (kW)	Crew	Annual Logistics (lb)
Per ISPR:			
Life Sci	0.91	0.09	2334
μ-g Research	2.06	0.31	1064
TD (internal)	0.49	0.19	210
Com'l Mat'ls	1.08	0.13	1596
Com'l Life Sci	0.05	0.05	812
GLSF/LSE	0.29	negligible	negligible
Per APAE-equivalent:			
TD (external)	0.31	0.03	338
Obs. Sciences	1.98	negligible	1400
Com'l (external)	0.54	negligible	1465

Utilization Analysis Summary - Power vs Crew Trends

As an example of resource interrelationships, this chart shows the derived user power versus crew trend for a subset of U.S. payloads. Each datum point plots the combined power requirements for all the Life Science, Microgravity Research, and (internal) Technology Development missions manifested in that year of the appropriate traffic model against the combined crew requirements of the same collection of payloads. The correlation between user crew and power is shown by a second order regression.

Utilization Analysis Summary
Power vs Crew Trends*



** Level I Traffic Model missions for internal Life Science, Microgravity Research, and Technology payloads*

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SSF Evolution Requirements - Core R&D Utilization

SSF Evolution Requirements - Core R&D Utilization - Principal Assumptions

This utilization analysis scenario is based on accommodation of core R&D missions as defined in the NASA payload traffic models and mission data bases. No specific SEI utilization such as vehicle processing or augmented life science mission supporting microgravity countermeasures were included. It should be noted, however, that objectives of some of the core life science and technology development missions do support SEI research requirements.

The timeframe assumed is SSF mature operations in the CY2005+ period. The R&D utilization is strongly oriented toward life science and technology development. It is assumed that many of the early microgravity and materials processing missions have either completed their objectives or have moved off station to dedicated free-flying facilities. Also, the International Partner rack allocation is used to emphasize life science and technology development with resources consistent with similar U.S. missions.

SSF Evolution Requirements - Core R&D Utilization

Principal Assumptions

- **Use 1990 Payload Traffic Models as guideline**
- **No dedicated SEI contribution**
- **Allocation scheme**
  - Post 2005 timeframe
  - Strong life sciences and technology development utilization
  - Moderate Microgravity Research accommodation; assumes early microgravity payloads have moved off station
  - Crew and power for international volume consistent with U.S. usage

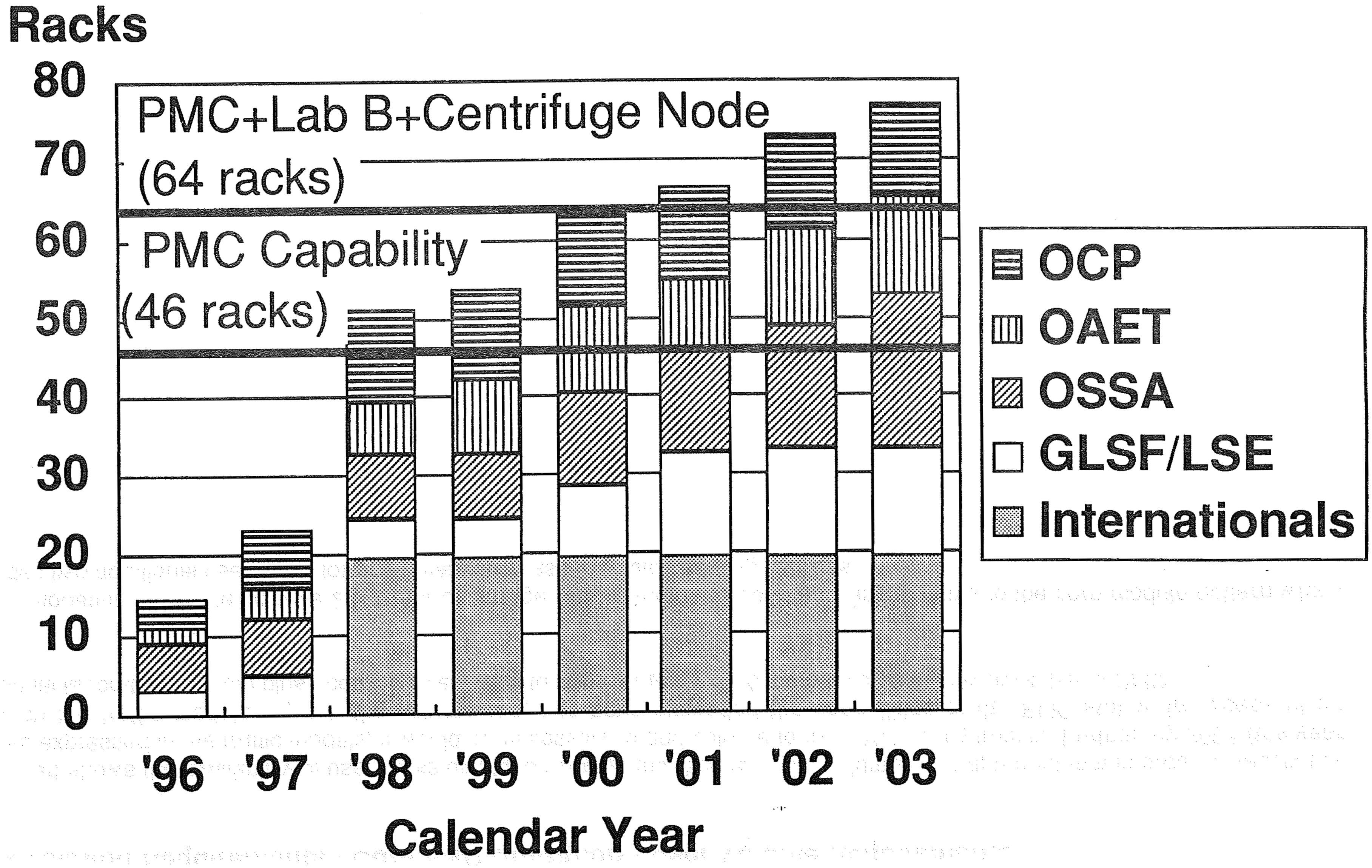
SSF Evolution Requirements - Core R&D Utilization - User Volume Requirements

This chart shows the availability of user racks on station versus the required user volume. It is apparent that in order to satisfy the desires expressed in the traffic models, it would be necessary to add volume to the PMC configuration. Further, by 2003 (the year in which the traffic models expire), the volume requests have exceeded the capabilities of the PMC station in excess of an additional laboratory module plus node. This equates to approximately 67% more volume than is available at PMC.

Accommodation of the life science 2.5 meter centrifuge was assumed to be in a facility external to the core module pattern which provides two additional user racks for equipment such as the habitat holding facilities.

SSF Evolution Requirements - Core R&D Utilization

User Volume Requirements



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SSF Evolution Requirements - Core R&D Utilization - User Volume Allocation Scheme

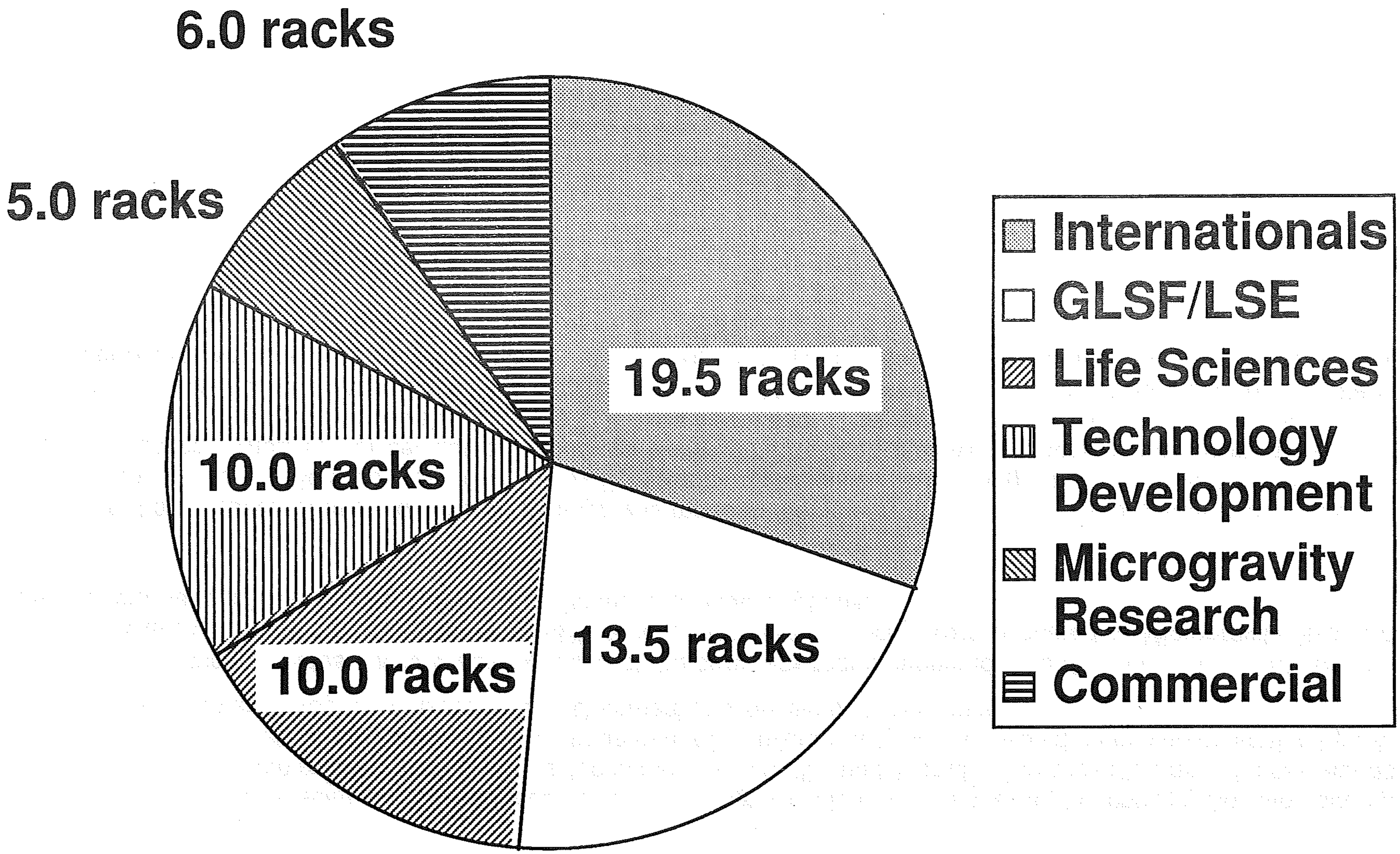
For the Core R&D utilization scenario (Life Sciences and Technology Development emphasis), the chosen allocation attempted to accommodate the maximum number of racks requested in the OSSA traffic model for Life Sciences (10), and of racks requested in the OAET traffic model (12). It was assumed that fifty percent of all microgravity science would be moved off station by this time, so the racks allocated to Microgravity Research and Commercial users were roughly one-half of their traffic model requests.

The resultant allocation provides 100% accommodation of the core rack requirements for Life Sciences (10 racks), and an equal number of racks for Technology Development (83% of request). Eleven racks were allocated to Microgravity Research and Commercial payloads (50% of request) in keeping with the above assumptions.

In addition to the allocation of user volume, an attempt was made to identify an attached payload program appropriate to a core R&D utilization. Since Life Sciences and Technology Development disciplines were being emphasized, and since Life Sciences sponsor no attached payloads, four dedicated Technology Development attach sites were allocated to accommodate an attached program at least as robust at that developed in the OAET traffic model. (This assumed some attach sites can support multiple small payloads). It was further assumed that the large proposed OSSA attached payloads that could not be accommodated earlier in station operations would also be accommodated. To this end, three attach sites were allocated for Astromag-class payloads.

SSF Evolution Requirements - Core R&D Utilization

User Volume Allocation Scheme*



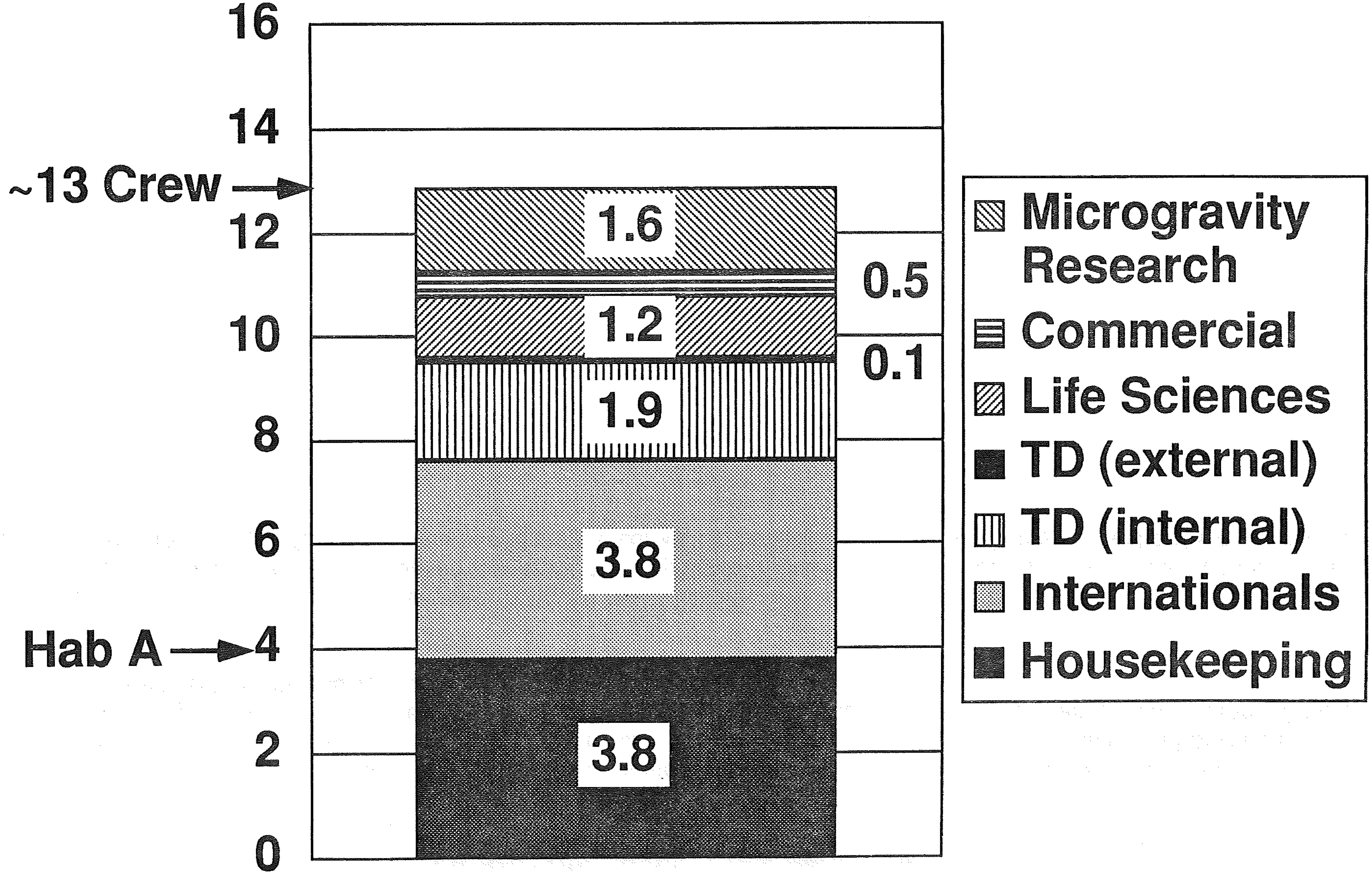
*64 user racks

SSF Evolution Requirements - Core R&D Utilization - Crew Requirements

Thirteen crew are required to meet this allocation of payloads, with over 20% of the user crew attributable to Technology Development payloads. Crew requirements for specific user disciplines are shown as segments within the bar graph. The crew housekeeping specification of 3.8 crew is the result of a first order estimate based on total pressurized volume. Studies are currently underway to refine this estimate.

Growth habitation modules will be required to house the additional nine crew required by this core R&D utilization scenario. Assuming each habitation module houses four crew, this implies four total habitation modules. The actual number of habitation modules required is dependant upon system and crew accommodation facility requirements in the growth habitation modules.

SSF Evolution Requirements - Core R&D Utilization
Crew Requirements

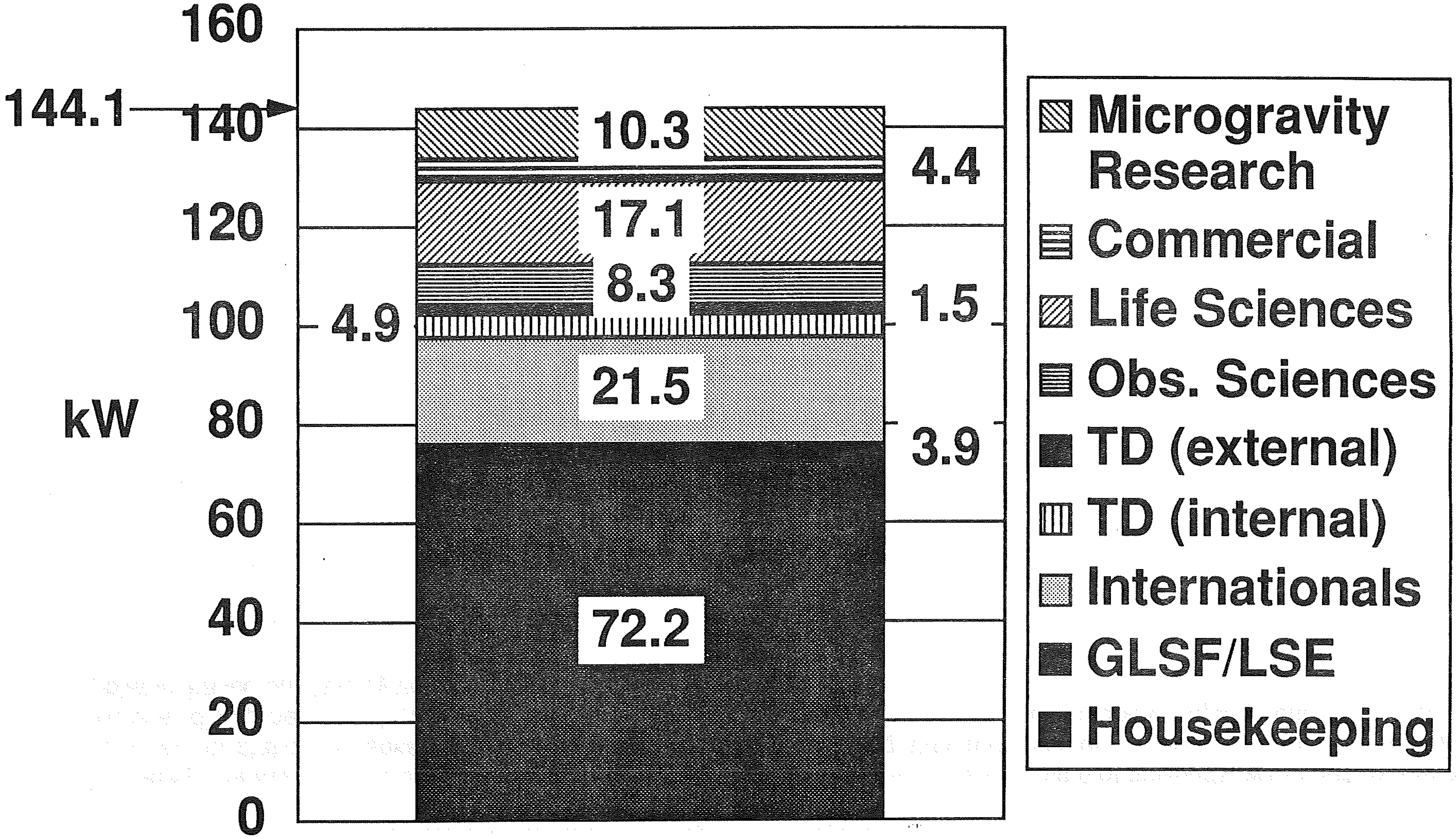


SSF Evolution Requirements - Core R&D Utilization - Power Requirements

Approximately 144 kW average power generation capability is required to meet this allocation of payloads, with ~50% of the power load required for station housekeeping, i.e., non-user equipment including station distributed systems. Power requirements for specific user disciplines are shown as segments within the bar graph. The power housekeeping requirement of 72.2 kW is an extrapolation based on PMC system requirements.

SSF Evolution Requirements - Core R&D Utilization

Power Requirements



SSF Evolution Requirements - Core R&D Utilization - Growth Structure Requirements

This utilization analysis has driven out growth structure requirements for several purposes. Growth structure is required to extend the solar power booms so that additional power generation equipment may be added outboard of the solar alpha joints. Also, growth structure which is orthogonal to the pre-integrated truss transverse boom is required to provide additional external attach locations. This external volume is necessary for user attached payloads and is also required to support equipment associated with growth systems, e.g., equipment needed for an advanced propulsion system. Also, the additional external attach volume will provide valuable storage locations for spare hardware and EVA equipment.

An important additional aspect of the orthogonal growth structure is the flexibility it would provide in the growth plan for Freedom. For example, the growth structure could allow for cargo transfer vehicle storage (required by ELV cargo delivery system), for servicing of contamination sensitive free flyers, and/or for SEI vehicle processing and hangaring. (In fact, the SEI vehicle processing and hangaring were assumed to be accomplished in this very manner in the SEI plus R&D utilization scenario).

SSF Evolution Requirements - Core R&D Utilization

Growth Structure Requirements

- **Ability to add structure to the baseline PIT is required for**
  - Extension of the power booms to support growth power
  - Accommodation of orthogonal structure

- **Orthogonal growth structure provides necessary attach locations and volume for**
  - External attached payloads
  - Growth distributed system components such as H_2 - O_2 propulsion ORUs, growth TCS ORUs, etc.
  - Storage of external equipment and spares

- **Also provides flexibility in the growth path, i.e., may accommodate facilities for**
  - CTV storage
  - Servicing of contamination sensitive free flyers
  - SEI vehicle processing/hangaring

Summary & Conclusions

- **SSF user growth requirements have been assessed through multiple analyses, using sanctioned user inputs**
  - User resource trends established
  - "Core R&D" and "SEI plus R&D" scenarios
  - Varying allocation assumptions

- **Analysis approach is based on balancing resources (i.e., crew, power, volume) commensurate with minimum essential user capability**

- **Key SSF evolution requirements have been derived**
  - Pressurized volume (user and crew habitat)
  - Power/Thermal
  - Structure