PLANNING FOR SPACE STATION FREEDOM LABORATORY PAYLOAD INTEGRATION

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Space Station Freedom is being developed to support extensive missions involving microgravity research and applications. Experiments are being planned by many diverse investigators, with varying degrees of space systems integration experience. Requirements for on-orbit payload integration and the simultaneous payload integration of multiple mission increments will provide the stimulus to develop new streamlined integration procedures in order to take advantage of the increased capabilities offered by Freedom. The United States Laboratory and its user accommodations are described here. The process of integrating users' experiments and equipment into the United States Laboratory and the Pressurized Logistics Modules is described. This process includes the strategic and tactical phases of Space Station utilization planning. The support that the Work Package 01 Utilization office will provide to the users and hardware developers, in the form of Experiment Integration Engineers, early accommodation assessments, and physical integration of experiment

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equipment, will be described. Plans for integrated payload analytical integration will also be described.

Introduction: Space Station Freedom is being designed with three pressurized laboratory modules, which are being developed by the United States, Europe, and Japan, respectively. Each module will be capable of accommodating experiments in a broad range of laboratory sciences, including basic microgravity physics and chemistry phenomena, materials sciences, and biological and biomedical science. A family of logistics modules is also under development by the USA, including Pressurized Logistics Modules to carry pressurized cargo, experiments, and crew supplies to the space station, and Unpressurized Logistics Carriers to carry unpressurized cargo, experiments, fluids, and propellants. A smaller Experiment Logistics Module is being built by Japan to carry experiment equipment and supplies. The logistics modules and crew are to be transported round trip between Earth and Space Station Freedom by the Space Transportation System, or Space Shuttle.

The United States Laboratory (USL) is a pressurized cylinder capped by endcones which are equipped with hatches and berthing mechanisms to permit connection between the USL and the adjacent resource nodes. The interior has a volume of 173 m3 and consists of racks and four utility standoffs along the length of the module. This configuration is illustrated in Figure 1.

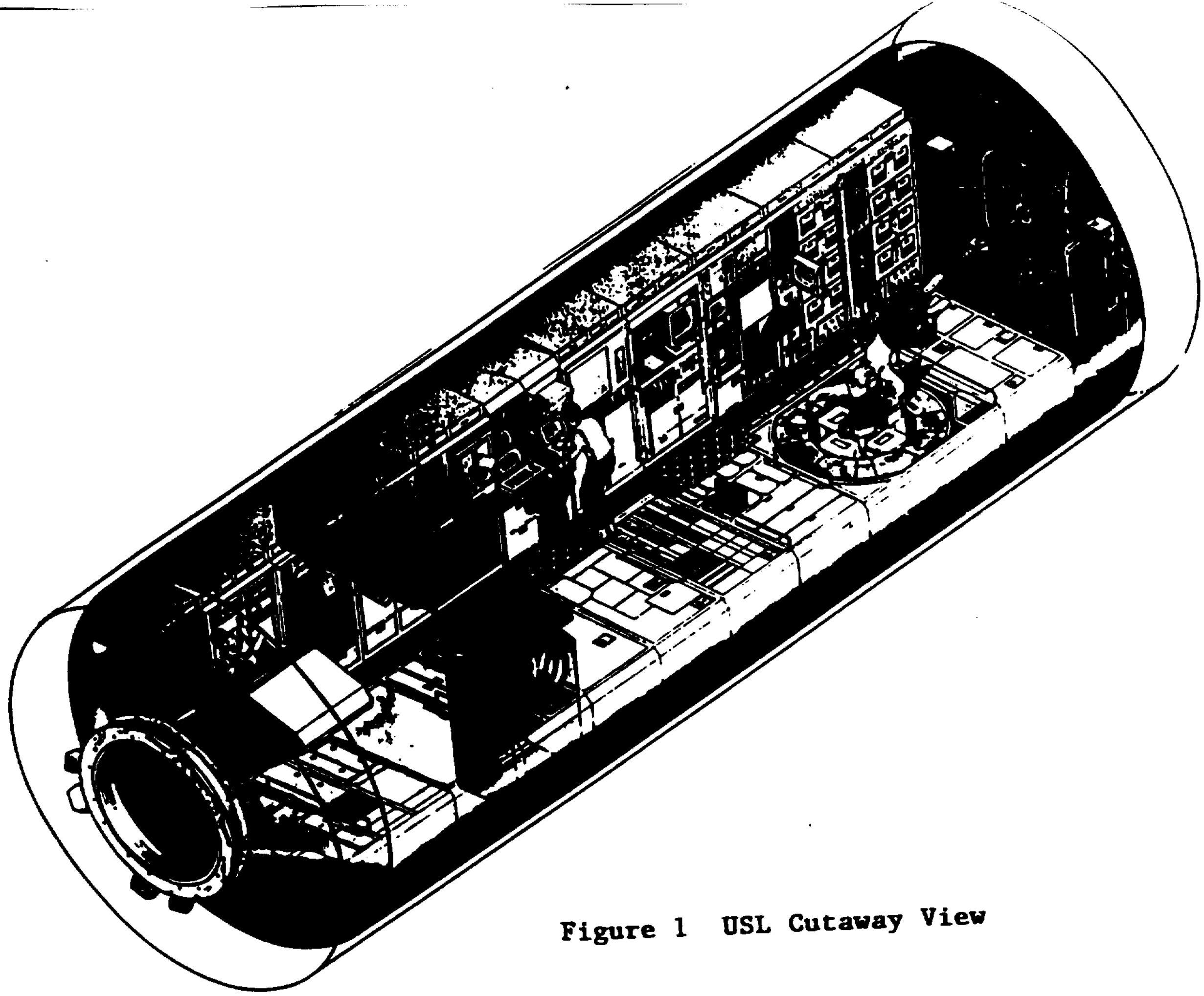

Figure 1 USL Cutaway View

The USL can accommodate a complement of 44 standard racks. Current designs have allocated 9 of these racks to core subsystems, including equipment for the vital functions of life support, hygiene and potable water supply, thermal control, data management, and human waste processing. Five more racks have been allocated to man systems, including an element control work station, emergency shower, waste management, hand and eye wash, and stowage for skip cycle resupply and critical orbital replacement units. Three more racks are allocated to laboratory-unque systems, including acceleration mapping, process fluids and ultrapure water distribution, vacuum vent, experiment fluids waste management. The remaining 27 racks are dedicated to users. The rack allocation by function is illustrated in Figure 2.

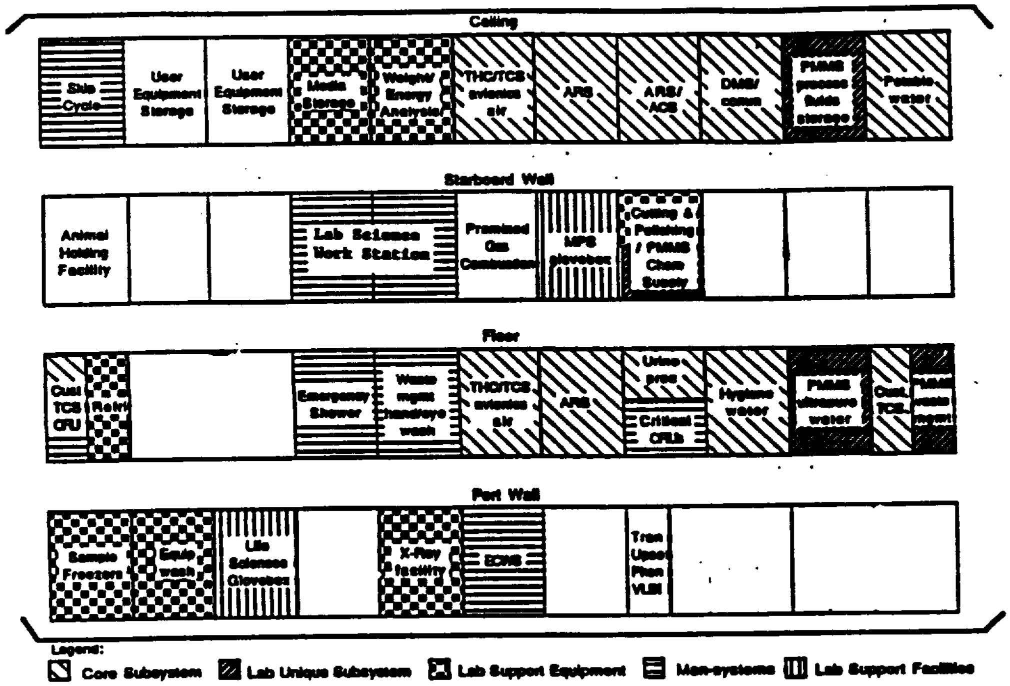

Figure 2 USL Rack Allocation by Function

Allocation of the user racks in the USL will be performed by NASA, operating in coordination with an international user panel. It is currently anticipated that four of the remaining racks will be more or less permanently located within the USL as general laboratory support facilities. These include a maintenance work station and two separate gloveboxes: one for materials processing and one for life sciences. A complement of thirty items of laboratory support equipment, summarized in Table 1, is being developed by Boeing and its subcontractors for use in the USL. The lab support equipment that will

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TABLE 1

LABORATORY SUPPORT EQUIPMENT

Autoclave
Battery Charger
Camera
Camera Locker
Cleaning Equipment
Cutting/Polishing System
Digital Multimeter
Digital Recording Oscilloscope
Digital Thermometers
Dosimeter, Passive
Electrical Conductivity Probe
EM-Shielded Storage Locker
Equipment Washer/Sanitizer
Etching Equipment
Film Locker
Fluid Handling Tools
Freeze Drier
Freezer
Freezer, Cryogenic
General Purpose Hand Tools
Incubator
Mass Measurement Device, Micro
Mass Measurement Device, Small
Microscope System
pH Meter
Refrigerator
Specimen Labeling Device
Surgery/Dissecting Tools
Ultraviolet Sterilization Unit
X-Ray System

actually be located in the laboratory on orbit at any given time is dependent upon the payload complement selected by the users. All the lab support equipment under development in the USA is expected to occupy six racks. If all the lab support equipment is located within the USL, 17 racks would still be available for customer payloads, stowage, and user supplied equipment. If some of this equipment is either not manifested for flight, or is manifested in one of the other laboratories, as much as 23 racks would be available in addition to the general laboratory support facilities.

Although some provisions are being made to allow installation of user equipment directly to the USL structure, user equipment is expected to be installed primarily in standard racks. These racks, shown in Figure 3, are designed to use standardized attachments and

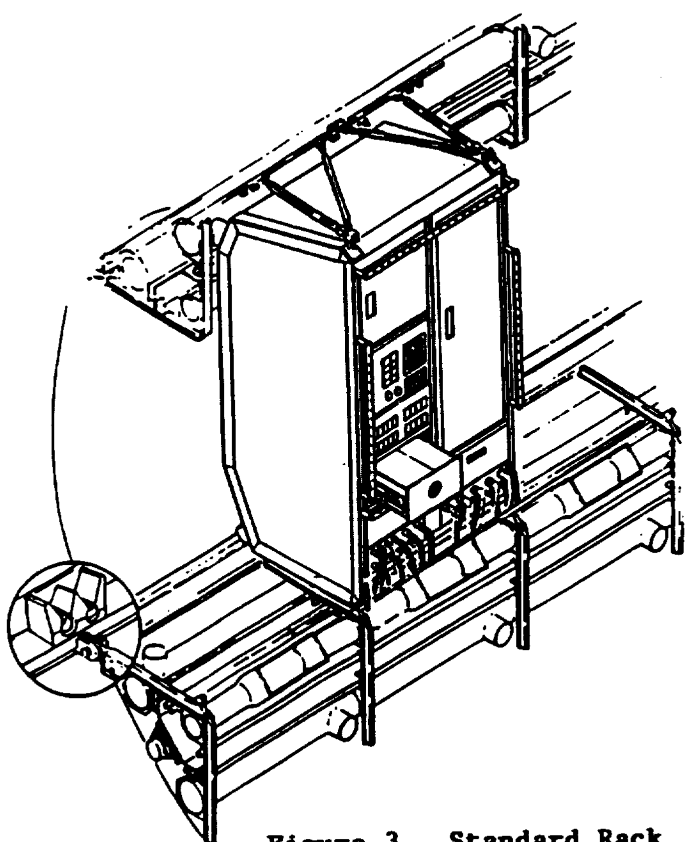


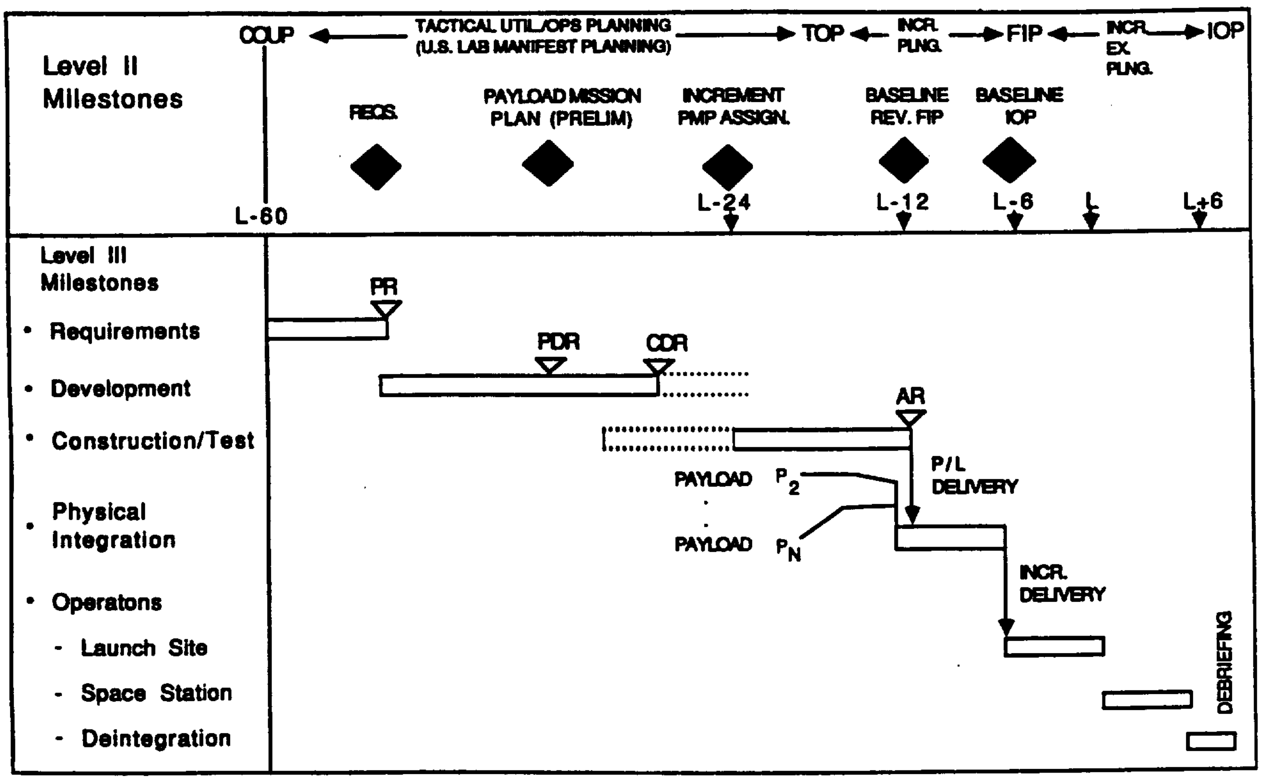
Figure 3 Standard Rack

provide standard utility interfaces to allow attachment of user equipment to any location within the USL, and allow interchangeability of equipment between the three international laboratories. This will allow straightforward reconfiguration of the laboratories, so that equipment can routinely be integrated and de-integrated on orbit as user requirements change. The utility interfaces provided at the rack level include electrical power, thermal control by air and water heat rejection, data management, internal audio and video systems, process fluids, waste management, and vacuum vent.

The payload integration process is being developed to allow Space Station Freedom users to follow a well-defined process of payload design, safety and interface documentation, operations planning, and integration into the Logistics Modules and the USL. NASA, Boeing, and its subcontractors continue to define the payload integration processes and to identify how and when we can assist the payload developers to facilitate the integration process, which is described below.

Payload Integration Process: The payload integration process begins with allocation of Freedom's resources among the international partners. This is done by a Multilateral Coordination Board (MCB), consisting of senior representatives from each of the four international partners (U. S., Europe, Japan, Canada), acting in accordance with the international agreements. Through a users' board acting in support of the MCB, each of the partners proposes candidate payload complements which fit roughly within the partner's resource allocations. This is to be done for a five-year planning horizon, where mission increment details are still unresolved. The reason for the five-year plan is to allow flexibility in assigning payloads to a specific mission increment to ensure integrated payload compatibility and time-averaged consistency with international resource allocations, while also providing sufficient time to provide modifications to Freedom's design and resource capabilities to fit within the payload requirements envelopes when desired.

The MCB will meet semiannually to review payloads proposed by the users' boards and prepare a Consolidated Operations and Utilization Plan (COUP). The COUP then officially approves a payload for flight in an approximate time frame. It is assumed that acceptance into the COUP will then initiate whatever activities are necessary to get the payload funded, developed, and ready for flight. For a USL-assigned payload, this is the signal for Boeing to assign technical support to the payload developer. A schedule of payload integration activities leading from the COUP to flight and return to Earth is shown in Figure 4.



COUP - CONSOLIDATED OPERATIONS & UTILIZATION PLAN
TOP - TACTICAL OPERATION PLAN
FIP - FLIGHT INCREMENT PLAN
IOP - INCREMENT OPERATION PLAN

RR - REQUIREMENTS REVIEW
PDR - PRELIMINARY DESIGN REVIEW
CDR - CRITICAL DESIGN REVIEW
AR- ACCEPTANCE REVIEW

Figure 4 Schedule of PL Integration Activity from COUP to Flight to Return

Once a payload is assigned to the COUP, the payload developer, or mission scientist, becomes a member of the Space Station Users' Working Group (SSUWG). For United States payloads, the Space Station Utilization Board (SSUB) assigns a NASA Payload Accommodations Manager (PAM) to the ~~furnace~~ payload. or Payload Developer. As this payload will be located in the USL (a WP01 element), a WP01 Experiment Integration Engineer (EIE) and an Operations Integration Engineer (OIE) are assigned by WP01 management to this payload to support the mission scientist (MS, who represents the payload sponsor), PAM, and WP01 through the integration and operations processes.

The EIE and MS begin their relationship with a process of mutual education. The MS educates the EIE in the payload concept, preliminary design (if available), research goals, and payload functional, resource, and operational requirements. The EIE guides the MS in understanding Space Station Freedom, logistics elements, and USL accommodations, resources, facilities, and operational concepts, utilizing a WP01 Elements Accommodations Handbook and a Users' Guide as reference documents and guides. From this process, the MS, with EIE support, will develop and document the payload requirements in the Payload Requirements Document (PRD). The EIE will also assist the MS in the planning activities of the SSUWG. The MS may act as the single point of contact to the users for the facility, or the users may be involved to some level in this planning process at the MS and sponsors option.

Upon approval and placement of the payload in the COUP, it is assumed that the payload sponsor begins the process of selecting a hardware developer to build the payload, including releasing an announcement of opportunity, evaluation of the competitive proposals received, and final selection of a hardware developer. The EIE will work closely with the MS and selected hardware developer to identify all user requirements for the payload and development of the payload design. During this payload development phase, the MS and EIE will prepare the Experiment Interface Agreement (EIA) and Integration Requirement Document (IRD), documents which clearly define the payload and uses requirements of the USL, and the agreement (contract) between the SSP and uses to accommodate these requirements). The prior payload experience of all principals involved in the payload design and development phase will expedite this activity significantly.

In parallel with the payload design phase, the payload operations planning phase occurs, with the EIE assisting the MS and OIE in developing the payload Operations and Integration Agreement (O&IA). Input from the users supplying specimens (including live specimens) will be necessary, and the MS will decide the level of direct participation by the users in this process. This phase will also benefit from the principals' prior experience, resulting in a smoother, faster completion of this phase than would occur with less experience.

Prior to the payload Preliminary Design Review (PDR), the EIE and MS will begin preparation of the Payload Mission Plan (PMP), which defines the SSP resource requirements for the payload. At payload PDR, this PMP is submitted to the SSP Utilization and Operations Integration Office (UOIO), which integrates this PMP with other payloads' PMPs, which are in the COUP with the same flight window, as part of the tactical planning activities of the SSP. This payload will be assigned to a specific flight increment at this point and is placed in the Tactical Operations Plan (TOP) which is developed for each flight increment two years before the increment launch. The MS, with continuing EIE support, becomes a member of the Increment Working Group (IWG) for the particular flight increment the payload has been assigned. Again, the MS will decide the level of participation of the users, possibly by designating a representative team of users together to support the MS in the training and operations phases.

NASA assigns an Increment Change Manager (ICM) to prepare the Flight Increment Plan (FIP) and act as overall manager for this specific flight increment. The MS and EIE will be responsible for coordinating with the users, ICM, IWG, and PAM to support development of the FIP. At nine months prior to launch, the FIP is baselined, and a number of associated activities begin or may already be underway. These activities include both MS/users and crew training. The MS (and other user representatives as determined by the sponsoring organization and the MS) will be familiarized with the SSP user support facilities, protocols, and functions, with EIE support and guidance. The ground and flight crews selected by NASA for this flight increment will be trained on the payload handling and operations by the MS/users at the SSP ~~POIC~~ PTC and at selected user sites.

For the initial USL payload complement, the WP01 analytical integration task is expected to begin two years before the initial TOP and be essentially completed by six months prior to launch. The EIE and MS will provide input to the analytical integration task, which will be utilized to perform payload interface and safety verification, analysis to demonstrate compatibility of the payload requirements with the space station accommodations, and prepare and document input to guide the physical integration task activities. The WP01 physical integration task activities will be closely monitored by the EIE, who will work closely with the WP01 Manufacturing Engineer (ME) on all aspects of the physical integration process, with MS support and guidance as required. Upon completion of the physical integration of the payload into the USL, the EIE will track the payload through delivery to the KSC launch site, and will continue to support the MS and PAM during the KSC handling, prelaunch, and launch activities.

Payloads which are integrated into the USL on the ground will be integrated at Marshall Space Flight Center (MSFC) approximately one year before launch, or within six to nine months before the USL is delivered to Kennedy Space Center (KSC) for launch. Payloads which are integrated into the Pressurized Logistics Modules (PLM) for on-orbit integration will be integrated at MSFC six to nine months prior to the first PIM launch, and at KSC three to six months prior to all subsequent PIM launches. Payload-to-rack integration and checkout facilities will be in place at MSFC for rack integration. Boeing and its WP01 subcontractors will be available to assist the user in his payload integration, and is responsible for ensuring the interface verification testing is performed and that safety requirements are met. The users are responsible for the functional test and checkout, and the maintainability and reliability, of their own equipment.

Payload integration and installation into flight racks can also be performed by the user at other sites, designated by NASA as Science and Technology Centers (S&TCs). Boeing provides portable rack interface simulators for test and checkout of payload to be integrated at S&TCs, and will deliver the flight racks to the integration site.

During the on-orbit operations phase, the EIE will remain in close contact with the MS and his selected user team in the user operations facility previously selected (ROC, DOC, UOF, S&TC). While the MS will be responsible for monitoring on-orbit operations of his payload and the disposition of the user specimens, the EIE will be available to coordinate any on-orbit payload or payload operations changes, and work the resolution of any issues that arise.

Summary: The permanently-manned Station Freedom will be a constantly evolving facility based in low earth orbit with the capability to support a wide variety of space-based research, production, and development activities. NASA and the Work Package 01 contractors will provide the necessary support services to the space station users to achieve these space-based activities and will be responsible for integrating the various users of WP01 elements, such as the U.S. Laboratory, in an effective, safe, and timely manner.