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Space Station Freedom Pressurized Element Interior Design Process

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Abstract

The process used to develop the on orbit working and living environment of the Space Station Freedom has some very unique constraints and conditions to satisfy. The goal is to provide maximum efficiency and utilization of the available space, in on–orbit, zero–g conditions that establishes a comfortable, productive, and safe working environment for the crew. The Space Station Freedom on orbit living and working space can be divided into support for three major functions: 1) Operations, maintenance, and management of the station; 2) conduct of experiments, both directly in the laboratories and remotely for experiments outside the pressurized environment; and 3) crew related functions for food preparation, housekeeping, storage, personal hygiene, health maintenance, zero G environment conditioning, and individual privacy, and rest. The process used to implement these functions, the major requirements driving the design, unique considerations and constraints that influence the design, and summaries of the analysis performed to establish the current configurations are described. Sketches and pictures showing the layout and internal arrangement of the Nodes, US Laboratory and Habitation modules identify the current design relationships of the common and unique station housekeeping subsystems. The crew facilities, work

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stations, food preparation and eating areas (galley and wardroom), and exercise/health maintenance configurations, waste management and personal hygiene area configurations will be shown. US Laboratory experiment facilities and maintenance work areas planned to support the wide variety and mixture of life sciences and materials processing payloads will be described.

Design Process for SSF Pressurized Modules

The overall process used to define and develop the living and working environment in the Space Station Freedom pressurized modules shown in figure 1 is not significantly different than that used for any new system. The basic mission criteria for the Space Station were identified through the development of the Program Documentation that has been incrementally developed by a long term system engineering process. The total SSF program requirements were established by analysis of the activities to be accommodated in the pressurized volumes and definition of the integrated operations planned for Space Station Freedom complex. The process used for evolution of these mission requirements into system level requirements, subsystem design requirements, and the early design process to incrementally develop the required key subsystems is the primary subject of this paper.

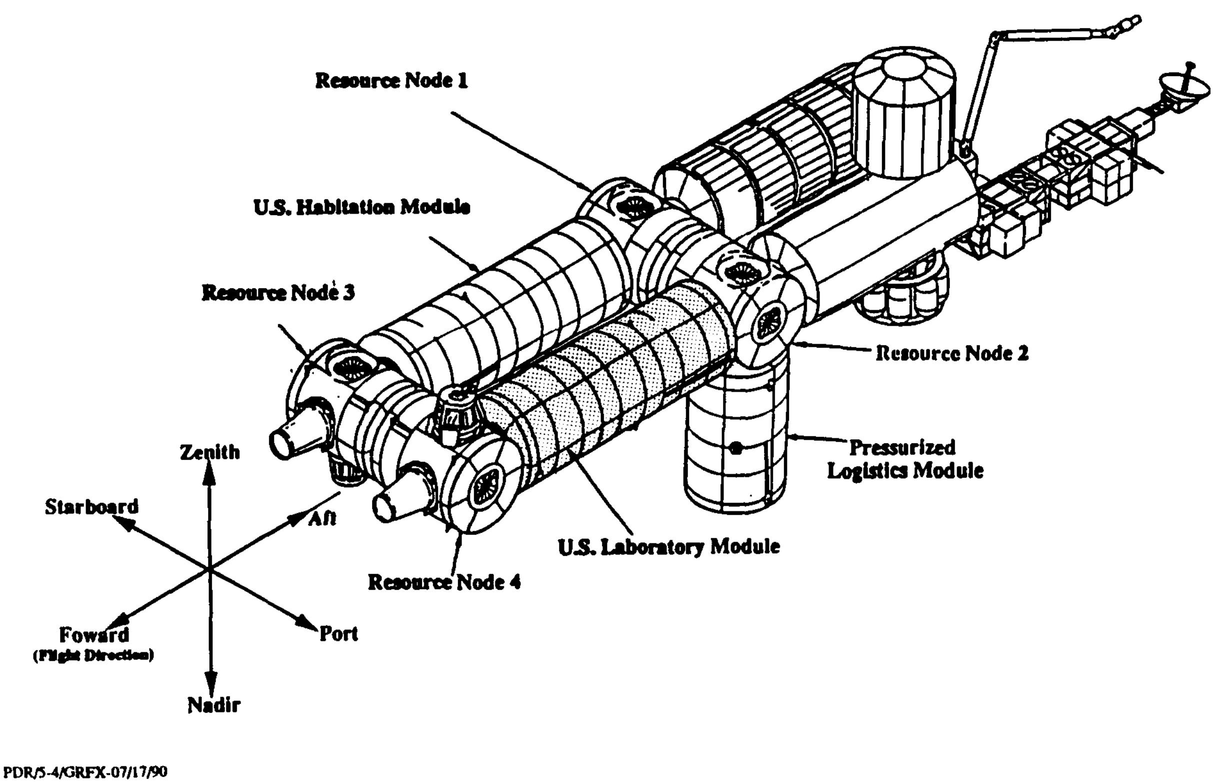


Fig. 1 Space Station Freedom Pressurized Modules

Product Development Team (PDT) Approach. The definition and design process used to develop the SSF module configuration is based on a Product Development Team (PDT) approach. A PDT consists of representatives from all the organizations or technical descriptions directly or indirectly involved in the development process. The PDTs were initially established at the module level and then evolved into logical subsets as dictated by complexity of the developing configuration. They function as a mini program for their area of responsibility with schedule, budgetary and decision authority. Functional and technical disagreements are taken back by team members to their parent organization, reviewed, and briefed back to the PDT for resolution. Each of the PDTs report bimonthly to the Boeing SSF Chief Engineer for approval of planned actions. Each PDT changes emphasis as the program moves through the major development phases to allow focus during each phase of the disciplines, skills and experience of the personnel involved. The major program phases and the emphasis provided by the PDT structure is shown in figure 2.

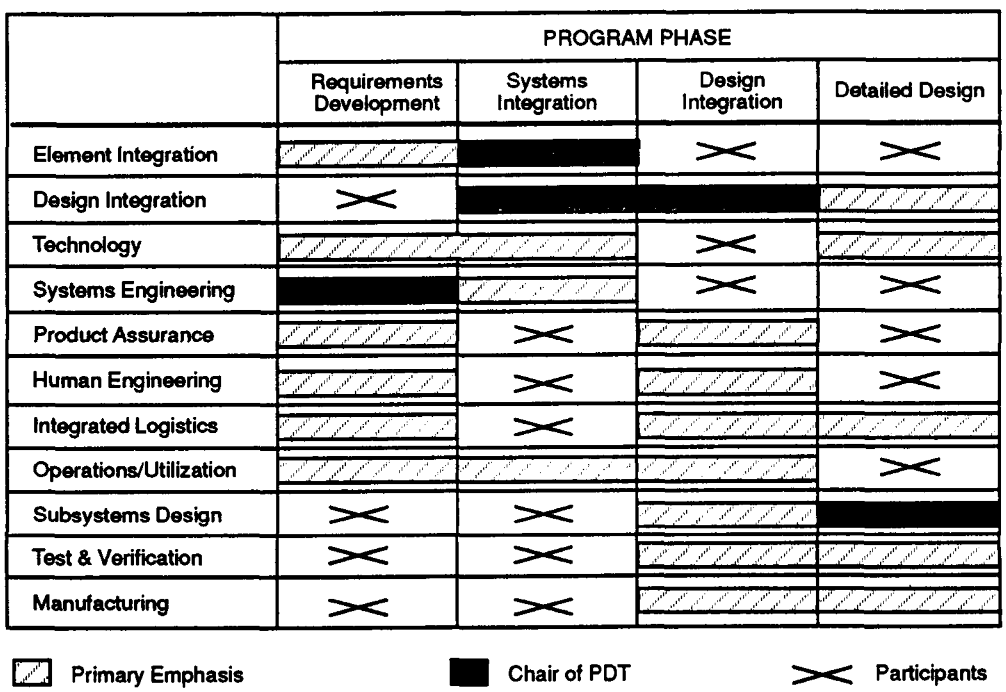


Fig. 2 PDT Phasing Emphasis

Requirements Definition and Development. Early emphasis in the design process is towards development of real, clear and traceable engineering requirements. As a result the PDT was chaired by a Systems Engineering representative. The major disciplines involved are those that are key to defining, deriving, validating and documenting the design requirements. As part of this responsibility a comprehensive plan identifying trade studies, analysis, and concept development for their area was developed and assigned. The functional organizations implemented these actions and reported back to the team through their representatives on the PDT. Selected system level studies and analyses were conducted by team members to provide integration of the detail trades results. During this process the baseline configuration established during the early phase of the program was re-evaluated and concepts updated accordingly. The major features and configurations of each element were reassessed to ensure maximum capability and utility were being provided, and all crew and safety considerations were addressed. These were developed into clear requirements statements and incorporated into released and controlled engineering documentation. The PDT team structure and focus on requirements definition continued through the formal Program Requirements Review (PRR), resolution of PRR actions and update of the specifications and release of the design requirements for implementation. Phasing of the PDT's in relationship to the program schedule milestones is shown in figure 3.

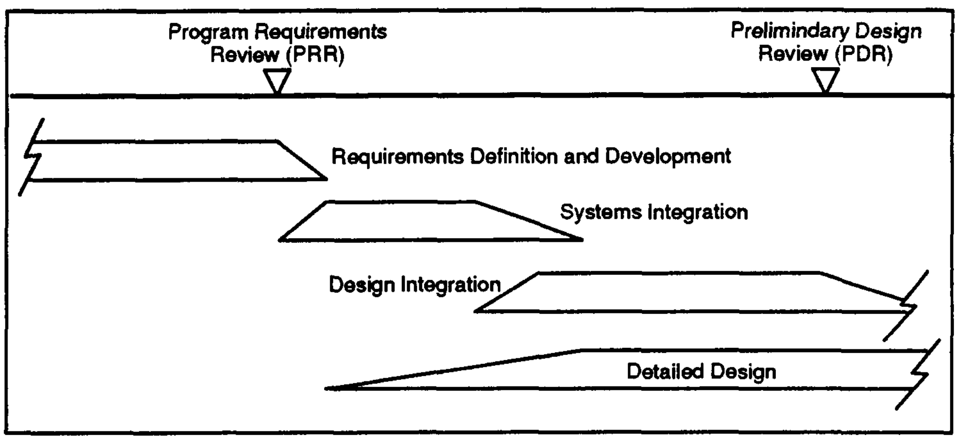


Fig. 3 PDT Phases Related to SSF Program Milestones

In the Habitation module for example, the crew privacy zoning was revisited to ensure a quiet area could be implemented in the same module where the galley and health maintenance and exercise areas functions were performed. Additional studies were completed to evaluate and refine the planned approach with emphasis placed on establishing acceptable noise levels, lighting levels, and crew accommodations. The experience and background of the Human Engineering personnel in Man Systems (MS) at MSFC and JSC were tapped by MS PDT members to support these studies. Formal crew reviews were jointly held by JSC and MSFC MS personnel involving NSTS crew members, and Spacelab crew and personnel to obtain their comments on the proposed configurations as they were incorporated into the mockups. Early involvement of the crew was essential in developing a realistic and clear definition of their unique support and operational requirements rather than possible misinterpretation and as a result, high cost/low return implementation.

In the US Laboratory the emphasis was on maximizing the payload/science return. The original layout of payload types/locations was reassessed and it was determined that moving Life Sciences experiments to one end and Material Sciences experiments to the other with "common use items in between" provided a better layout. Not only was it more efficient from a subsystems, distribution and resource standpoint, but considered more desirable by the crew and the payload users. Numerous reviews, working groups, and seminars were conducted and coordinated by MSFC and JSC Operations personnel to develop both crew and users inputs. These were input through Utilization PDT members to refining the overall US Lab layout. These reviews provided the first real opportunity to coordinate, work with, and as a result understand and develop a more concise definition of the real users requirements. The results became the foundation of the initial set of derived users requirements that were input into the US Laboratory design requirements.

JSC is responsible for the definition and documentation of the requirements and configurations for the Nodes. They provided inputs to MSFC defining the primary interface and structural design requirements. The design and development of the primary structure is a MSFC responsibility. MSFC hardware (ECLSS, TCS, etc.) to be installed in the Nodes was established, coordinated and data provided to JSC. Internal, secondary structure, and the layout and installation of the hardware in the Node interior is a JSC responsibility. Close coordination between JSC and MSFC have resulted in a clear understanding and definition of the Node configuration and all associated internal and external interfaces.

Systems Integration.. After PRR the emphasis of the PDT shifted to implementing the defined design requirements. Design concepts and configuration trades and analysis were revisited and sensitivity analysis completed. These used the new requirements baseline to update analysis and confirm previous decisions.

The team co-chairmen were from the Element Integration/Design Integration organizations to provide an element level advocate emphasis on the continuing definition process. PDT membership emphasis and participation changed to concentrate on establishing an element or major system with integrated architecture and subsystem concepts that provided optimum response to the system requirements. In parallel the PDTs also helped evolve the final more detailed level of subsystems design requirements. These were documented by element and subsystem in a fully traceable, parent/child requirements database. This provided the designer a complete definition of all design requirements for his subsystem, in one place, including all associated design to "standards" requirements that must be met or could influence his design.

An example of a major decision out of this process was confirming a utility of the four quadrant layout with subsystems installed in standard rack envelopes. This provided standard interface definitions, both physical and functional, and drove a rack oriented packaging of the majority of subsystems and outfitting hardware. The associated issues of redundancy, fault isolation subsystems architecture, etc., now had a baseline for evaluation, definition, and final accommodation. Overall operational utility and flexibility of the modules continued to be emphasized and the resulting systems trades resolved issues on module depressurization/repressurization, crew emergency egress, safe haven, critical storage location of ORU's, windows, berthing interfaces, floor orientation, etc. These system level decisions on modular element internal arrangements resulted in a design that provides for easy reconfiguration of the modules over their life span of 30 years.

Design Integration. The transition of PDT emphasis from Systems level Integration to a more detailed Design Integration process did not have a sharp demarcation point. Packaging of the subsystems into racks and into the modules was an iterative process as the DMS and EPS architectures evolved between the work packages. The PDT team chairmen were now beginning to focus on integration of detailed hardware design and packaging into the elements and the racks. As part of the packaging process it was found that some hardware items, e.g., the EPS PDCUs utilized the end cone area better than a rack, both from a volume and distribution layout standpoint. Routing of utilities in the limited space in the standoffs is compounded by the redundancy requirements and the size of the air ducting for both avionics and cabin air systems and for the additional vacuum and waste gas lines in the US Lab. The density of endcone packaging is illustrated in figure 4 along with

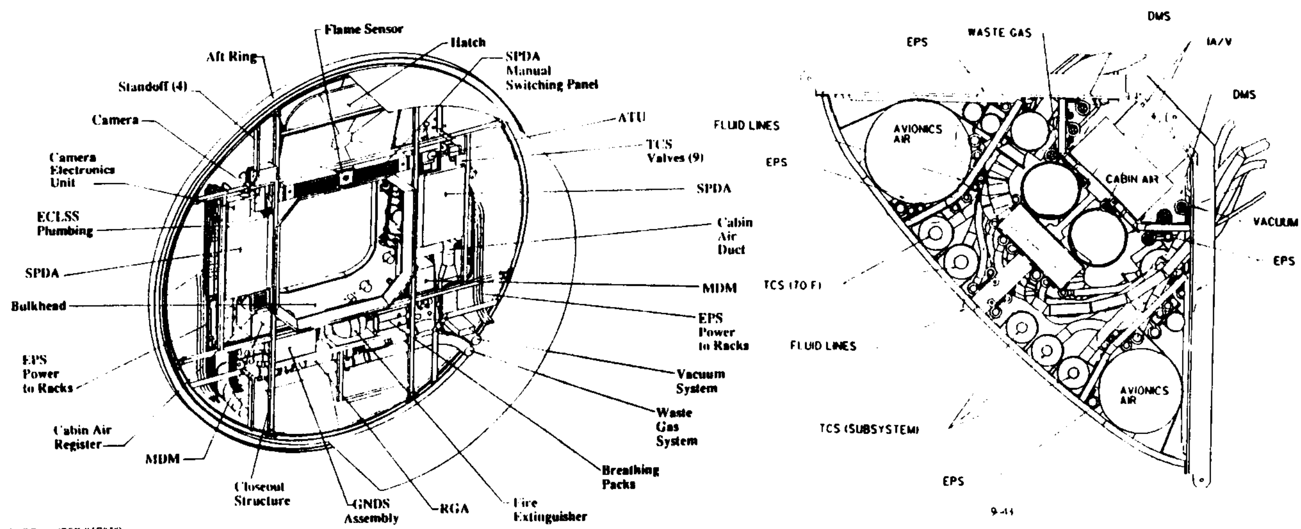


Fig. 4 Typical Endcone and Standoff Packaging

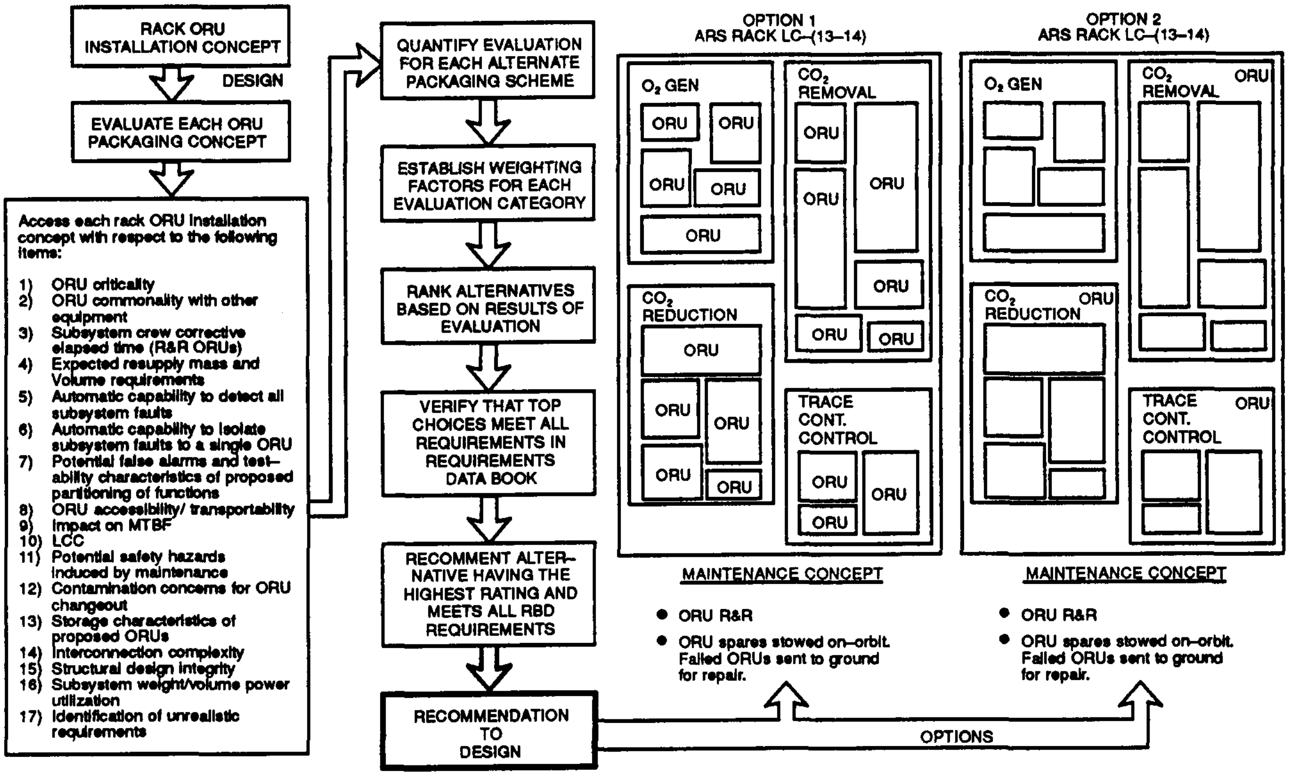


Fig. 5 ORU Priority/Access Matrix

requirements. This capability has been increased from 48% to 96% without impact on the station requirements. These changes were the results of a series of trade studies by PDT members on: payload locations; interrelationship of payloads; standardizing categories of interfaces and resources required; user water quality requirements; vacuum requirements, FMS considerations, vent and waste gas consolidations, etc. The significance of these results is illustrated in figure 7.

Common Element Configuration. The element configurations evolved are based upon a common physical architecture and dimensions that are constrained by the Space Shuttle Orbiter payload bay envelope. The USL, Hab, PLM, and the four Resource Nodes are cylinders of approximately 4.4M diameter, capped by endcones and hatches. The common core primary structure consists of a pressure shell complete with rings, skins, endcones, penetrations and Orbiter attachment hardware. It provides for loads transmission during launch, pressure retention on orbit, and micrometeoroid, debris, and radiation protection. Secondary structure consists of external truss attachment hard points, and an outer shield which completes the meteoroid/debris protection, and internal set of attachments and standoffs for attaching racks, utilities, etc.. Internal outfitting is packaged primarily in racks that are located in the four quadrants. Utility provisions are distributed to the racks through the standoffs and additional outfitting and utility connections are located at the module endcones.

and a typical standoff cross section. Producibility analysis were accomplished and input to influence the design concepts and minimize downstream redesign. As these packaging concepts evolved development tests were established and conducted to provide data supporting final design configuration decisions. Tests were conducted to establish airflow patterns in the modules with various combinations of flow rates, diffusers, and outlet locations. These tests helped establish the duct sizes, expected losses, requirements, etc., for the ECLSS cabin air and avionics air system distribution. Development tests were also conducted to establish lighting fixture configurations, locations, evaluate candidate fixture characteristics, and fixture envelope limitations. The quality, color characteristics (spectrum) and quantity of light are shown to have pronounced physiological impact and were carefully considered during the tests. Architectural and lighting consultants and subcontractors were used to develop these tests. Human Engineering and Man systems personnel from MSFC and JSC and astronauts were used to provide inputs to the evaluation process. Candidate configurations were developed by the subcontractors and evaluated in both the lighting test areas and the mockups of the US Laboratory and the Hab. Technical and crew response results were analyzed, requirements refined, and a final configuration selected that provided an excellent response to all requirements and visual assessments. In conjunction with the lighting tests, internal color schemes, and textures were also evaluated as they are closely coupled. The primary color and texture considerations were to develop a pleasing and comfortable atmosphere and ease of changeout, maintenance and cleaning.

During the packaging process it became apparent that new tools, techniques and approaches were needed to assist in the rack packaging and integration process. The SSF requirements state that an "ORU may not require removal for access to another ORU" and this provides a difficult series of decisions for the designer. To help this process the Integrated Logistics PDT members devised an approach of establishing an ORU priority matrix to provide the designer early insight into the real access requirements for each ORU. This allowed packaging arrangements and locations based on replacement probability of various combinations of ORU size selection. A sample of this approach and how it is applied is shown in figure 5. Automation through CAD CAM in two and three dimensions and associated analysis have become essential tools in the packaging and integration process and reduced mockup requirements. Examples of use of 3D layouts are shown in figure 6. As needed, additional PDTs were established to work on specific products such as mechanisms, hatches, racks, windows, cupolas, etc. Their results were integrated into the element PDT's to maintain maximum commonality and ensure desired flexibility was retained.

The Design Integration process has implemented significant changes to the initial US Laboratory layout that have improved capability to handle a large cross section of sample payloads

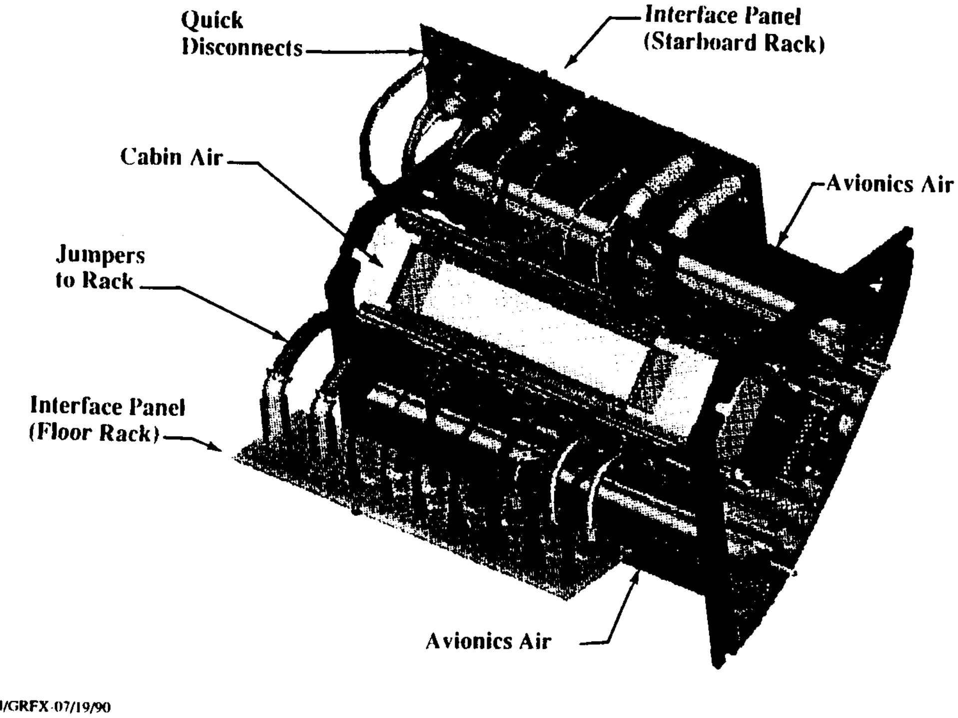


Fig. 6 Packaging Layouts Using CAD CAM

All the elements are configured to provide a consistent internal orientation for the crew which is similar to the one they would have on Earth e.g., the wall racks have a consistent orientation and always pivot down.

The USL and Hab modules are each approximately 13.4 meters long and contain forty four rack positions (eleven in each of the four quadrants) and two axial berthing ports. The PLM is approximately 5.4 meters long, and two axial contains twenty rack positions and one axial berthing port. Each of the four Resource Nodes are approximately 5.2 meters long and contain four radial berthing ports and four rack positions. Common structure is used for berthing mechanisms and hatches used to connect the pressurized elements.

US Laboratory Description. The United States Laboratory (USL) module is used to provide a "shirt sleeve" environment for the conduct of basic microgravity materials processing research and production, and life sciences research. The interior outfitting can be represented in two categories, each performing a function required of the USL: (1) common and unique housekeeping systems, and (2) payloads consisting of experimental facilities, materials processing science experiments, life sciences experiments, and associated supporting hardware. The common housekeeping systems perform all functions required to maintain a liveable environment, communicate, support crew

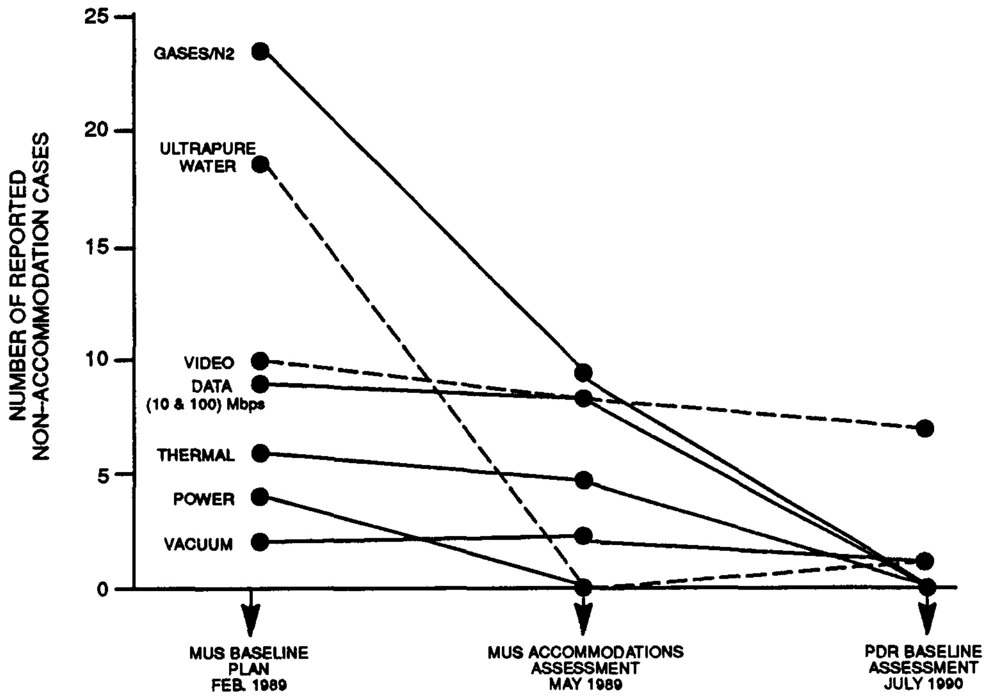
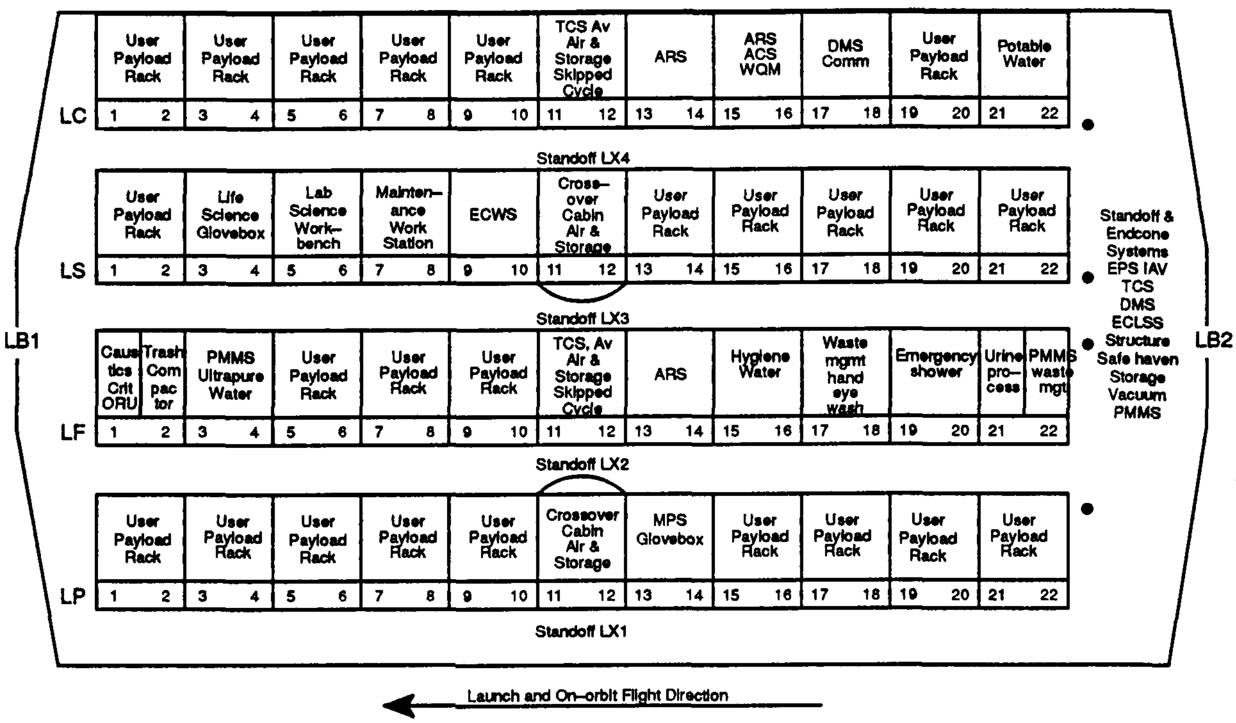


Fig. 7 Payload Accommodations Capability Improvements

hygiene and safety, and control the station. Unique housekeeping systems provide additional power and thermal resources needed by the payloads. These are located primarily in the ceiling and floor due to the low access requirements and automated nature of these racks. Racks performing the common functions also maintain the same location in the Habitation module. The module is zoned into two halves. The forward half is used primarily for life sciences studies involving plants and animals. The aft half of the module is used primarily for materials processing. Common use equipment and facilities are generally located in the middle and the most frequently accessed racks are mounted along the port and starboard walls. The standoffs are also plumbed with laboratory unique subsystems that provide ultrapure water, nitrogen gas, vacuum, and waste gas disposal. Layout of the US Laboratory module is shown in Figure 8.

Habitation Module Description. The Habitation module provides the living quarters for the crew where eating, sleeping, recreation, hygiene, and medical activities are performed. The crew quarters, which are located in the low traffic quiet zone in the forward part of the module are placed radially about all four walls and are comprised of the crew compartment, with storage and sleeping arrangements, core systems which provide air distribution, and an electronics base for audio, video, and control functions. Each can be tailored in color and texture by replaceable coverings brought on board by the crew. A buffer zone is located in the middle and contains mostly passive and storage

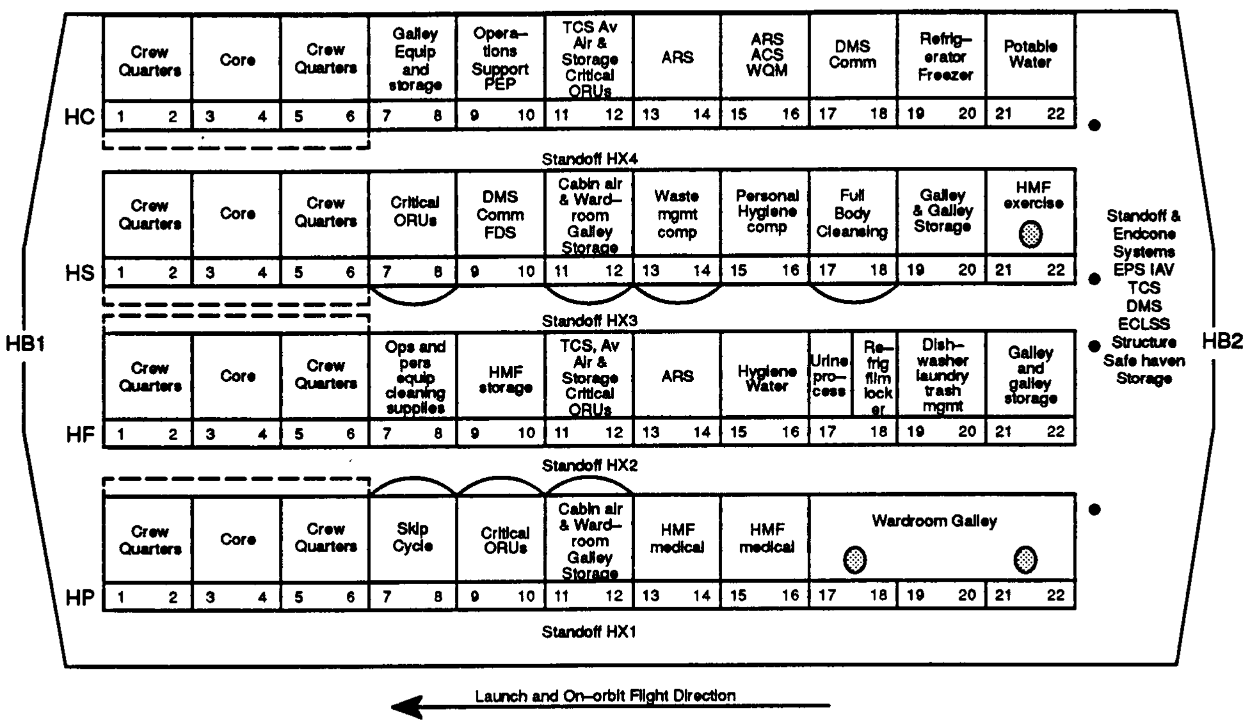


LC = Ceiling, LF = Floor, LP = Port, LS = Starboard

Fig. 8 US Laboratory Module Layout

racks and serves to dampen noises generated elsewhere in the module pattern. The active zone is located at the aft end and contains the module unique systems, the galley, wardroom, exercise facility, personal hygiene facility, and other housekeeping functional equipment. The active zone also contains windows for terrestrial and celestial viewing. Location of common housekeeping racks are the same as described for the USL. Placing the subsystem racks in the floor and ceiling towards the aft end of the module helps maintain quiet–active zones, with the subsystem racks located away from the crew quarters. Tasks such as laundry, trash compacting, food preparation, eating, general crew conferencing, and viewing are performed in the wardroom area. Also located in the active zone is the crew health maintenance facility that includes provisions for exercise, clinical and medical equipment, and environmental monitoring. Layout of the Habitation module is shown in Figure 9.

Pressurized Logistics Module Description. The Pressurized Logistics Module (PLM) is used to transport equipment, supplies, and experiments which require a pressurized, protected environment to and from station. The PLM is carried by the Orbiter on regularly scheduled 90 day resupply flights. The PLM is alternately attached to the nadir facing ports of Resource Nodes 1 or 2 (or as a



HC = Ceiling, HF = Floor, HP = Port, HS = Starboard

Fig. 9 Habitation Module Layout

contingency to Node 4) and the two berthing locations provide capability to connect the upcoming PLM prior to the removal of the returning PLM.

The PLM has structure common to the Hab and USL, except the cylinder is only 5.4 meters long, and the endcone/hatch at the aft end is replaced by a large ground access door to support easy rack loading during ground processing. The PLM outfitting consists of common subsystem components installed in endcones and three active racks standoff–mounted utilities. Endcone mounted equipment includes Controller Multiplexer/ Demultiplexers (CMDMs), valves, cables, connectors, and the standard hatch mechanism. Avionics air is routed through the standoffs for ventilation and fire detection purposes along with standoff mounted utilities (thermal, power and data) for the three active racks. The three active racks are located in the PLM starboard wall and include a subsystem rack, a refrigerator/freezer rack and a freezer rack. The 17 other rack locations in the PLM are for resupply cargo and experiment transport and are not powered and have no supporting standoffs. In order to maximize available resupply weight, some of the on orbit PLM equipment is stored in the nodes and added to an arriving PLM. This "drag–on" equipment includes man–system restraints and translation aids, and normal portable emergency breathing system, ECLSS portable fire extinguishers, all IA/V units, and normal EPS light fixtures. The Pressurized Logistics Module layout is shown in Figure 10.

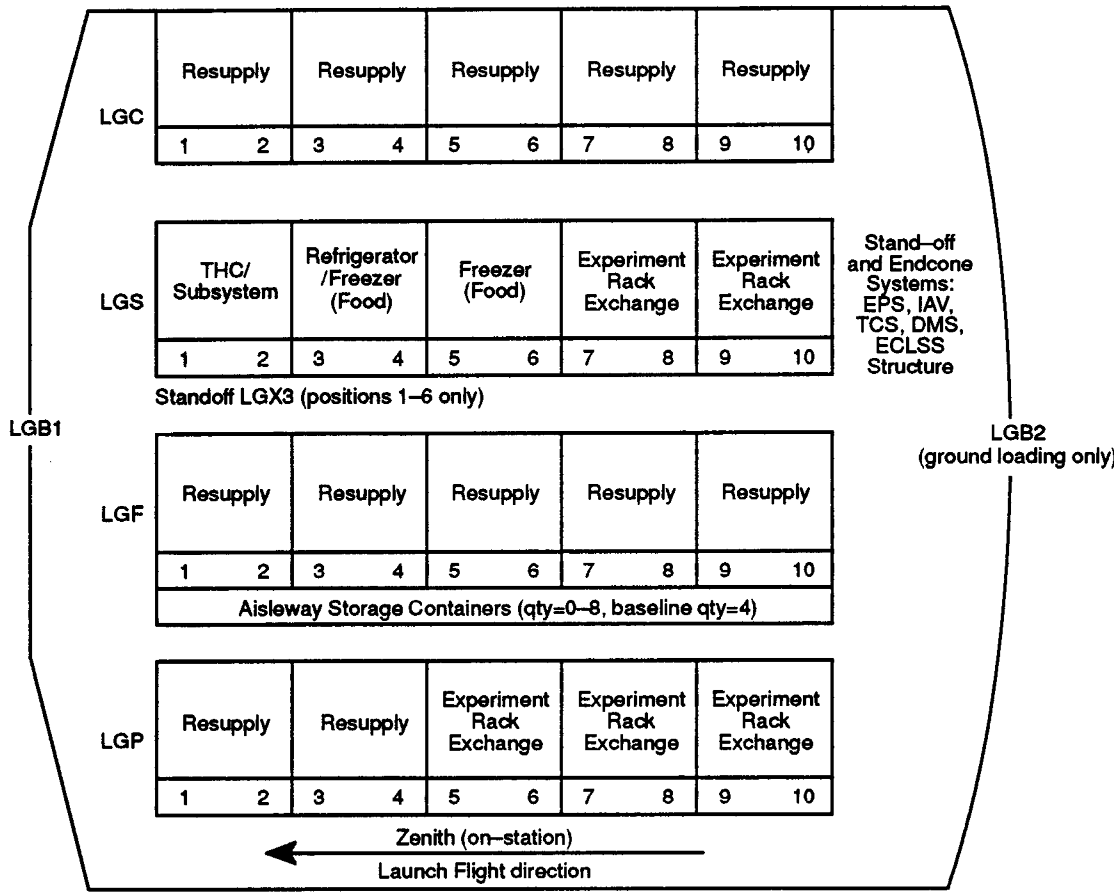


Fig. 10 Pressurized Logistics Module Layout

Resource Node Description. The four pressurized Resource Nodes are located at each end of the USL and Hab. They are used as command and control centers and passageways to other elements. Four nodes are provided for individual manifest during the assembly sequence to support incremental buildup of the SSF and module patterns.

The four radial ports with hatches are set 90 degrees apart and allow the Resource Nodes to be used as the interconnections for all the pressurized elements. The nodes are outfitted with common systems hardware, and unique communications and tracking system, avionics systems, contral workstation and fluids (water) storage. The two forward Resource Nodes (3 and 4) have two attached cupolas which provide 360 degree viewing for station EVA operations, proximity operations, and Shuttle docking and MSC operations. The SSF airlock is attached to the aft starboard Node (Node 1). A layout for each Resource Node is shown in Figure 11. Nodes 3 and 4 also have an Orbiter Attachment

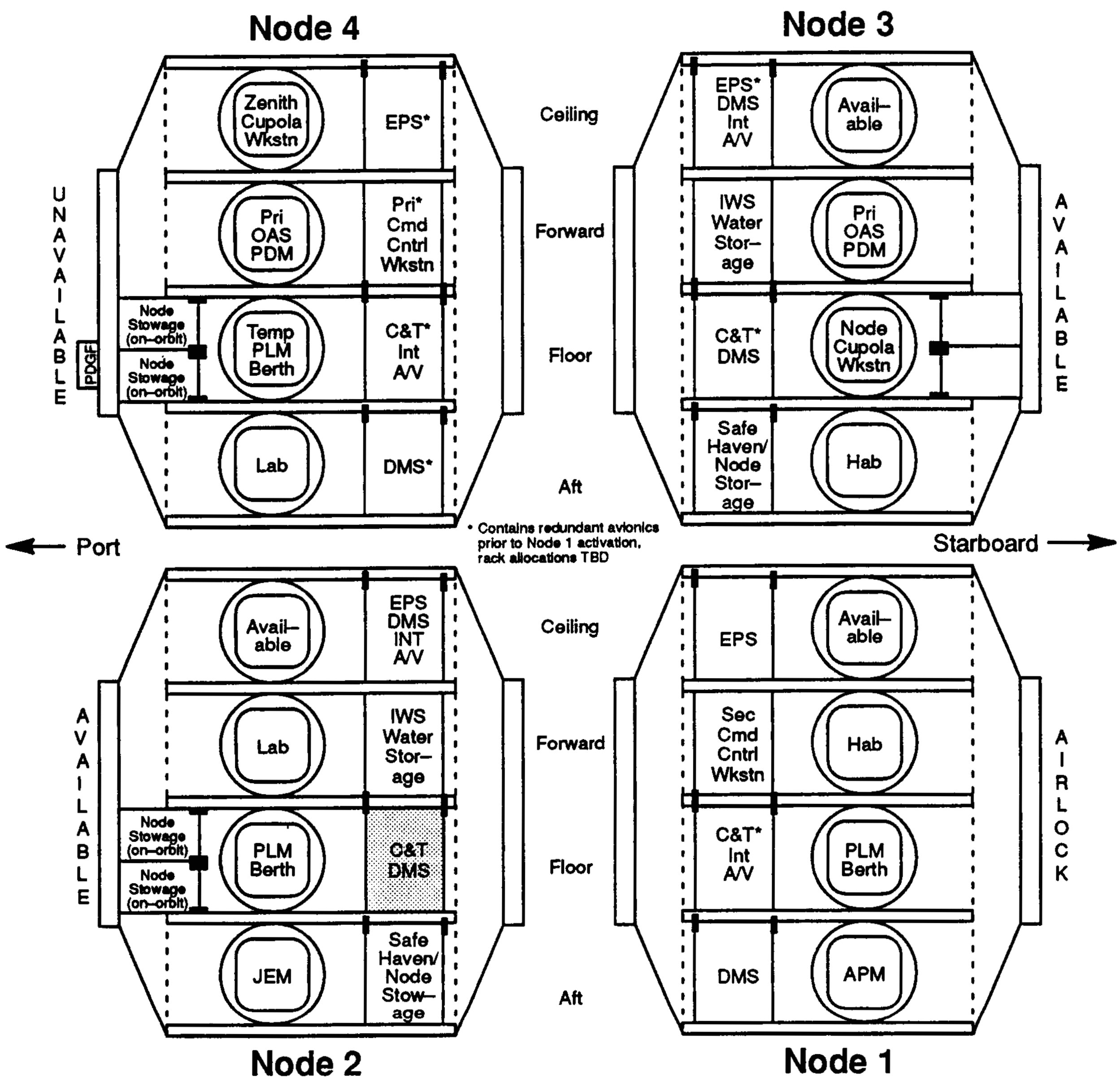


Fig. 11 Resource Node Layouts

System (OAS) located on the forward berthing ports. The OAS includes a pressurized crew transfer tunnel called the Pressurized Docking Mast (PDM) that connects the Orbiter and node pressurized volumes. the OAS also includes a slide track device to capture the Orbiter and bring the Orbiter and Station together to effect a pressurized connection. This system is shown in Figure 12.

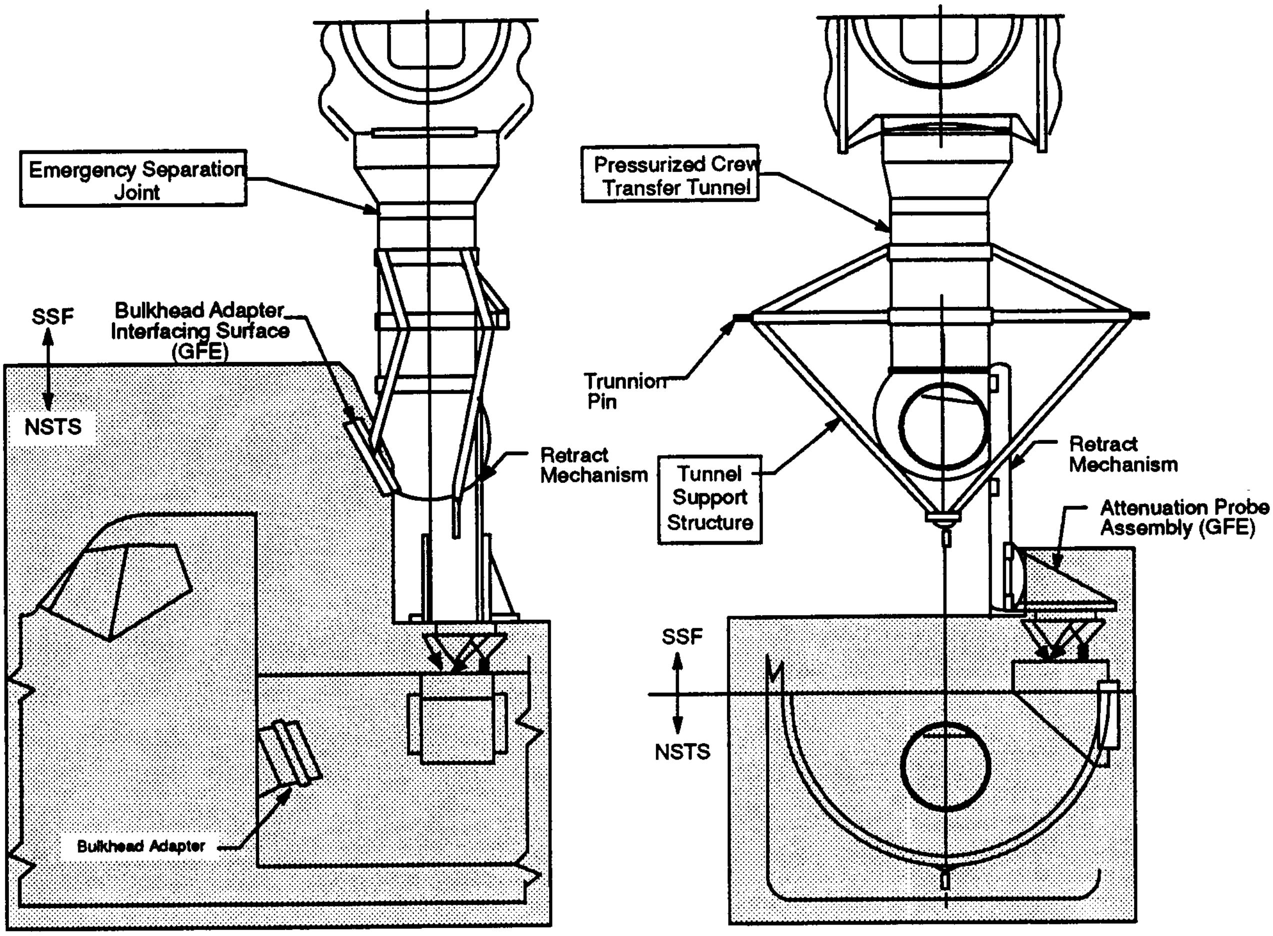


Fig. 12 Pressurized Docking Mast

SSF Modules Subsystems Summary

The subsystems are primarily incorporated into standard racks that interface with the standoffs. There are four separate rack configurations: 80 inch equipment racks, 80 inch storage racks, 74.5 inch standard payload racks, and 80 inch functional units. All racks are 42 inches wide. The envelope for the 74.5 inch standard rack is shown in Figure 13. Once configured on orbit, all racks and functional units have the ability to be tilted out from the wall into the aisle from a pivot point located at the bottom of each rack, which attaches to the standoff structure. This feature is necessary to provide access to the pressure shell and for access into the rack for maintenance. There are four rack attachments to the module cylinder and the standoffs. The rack to module cylinder attachments carry the launch loads and the standoff attachment is for on orbit loads. Once on orbit, three of the four rack to cylinder attachments may be disconnected and the rack held in place by two standoff

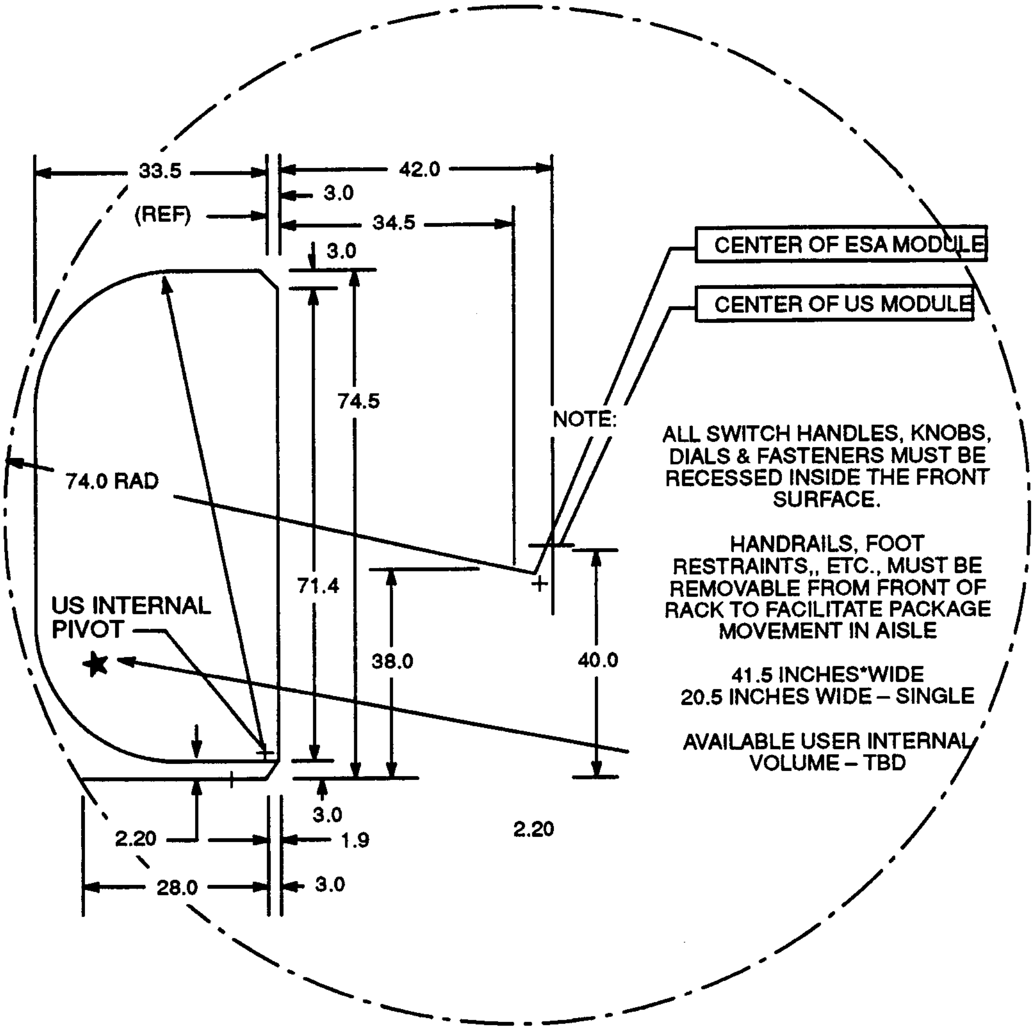


Fig. 13 Standard 74.5" Rack Envelope

pivot point attachments and a single cylinder attachment. The racks have standard interface plates with utility cutouts located at the base of the racks as shown in Figure 14. These plates receive the rack utilities from the standoffs and allows the rack to be tilted out without disconnecting utility lines and therefore remain active.

The internal architecture of the modules results in no racks being fed from standoff X1, the port wall racks being fed from standoff X2, the floor and the starboard racks being fed from standoff X3, and the ceiling racks being fed from standoff X4. As a consequence, standoff X3 is more populated with utility distribution lines than standoffs X2 and X4, while standoff X1 has the least population of utility distribution lines.

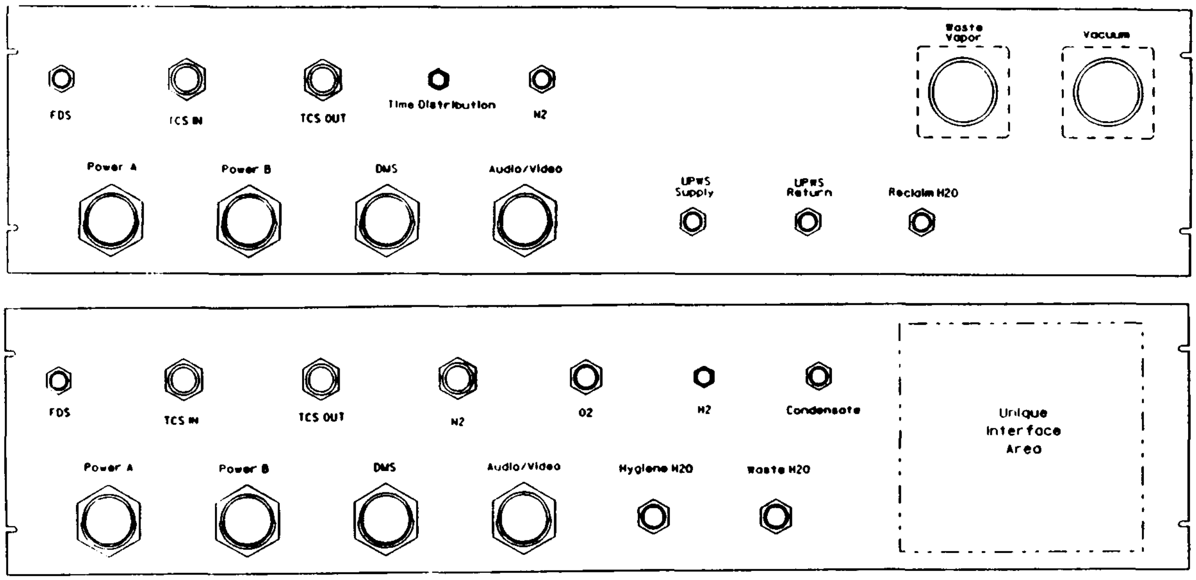


Fig. 14 Standard Interface Plates

Similar utility distribution schemes that functionally connect the racks are common between the USL and Hab modules. This takes the form of physical connection of racks by means of utility plumbing and cabling located in the standoffs and endcones: racks mounted on opposite walls are able to be connected by means of utility routings through the module endcones and by means of utility crossovers located at the middle of each module to allow the systems to be redundant. Figure 15 presents an isometric cross–over view. The crossovers are located at rack positions 11 and 12 of both the USL and Hab modules at a centralized location that allows the greatest efficiency of utility distribution lines, especially for the large air distribution ducts of the Cabin Air and Avionics Air subsystems.

Environmental Control and Life Support System (ECLSS)

The ECLSS maintains a habitable atmosphere within the pressurized modules. ECLSS controls and monitors the atmosphere for temperature, humidity, pressure and composition. Potable and hygiene water are also supplied by the system. ECLSS is responsible for the detection and suppression of fires, the collection, processing, and storage of metabolic wastes, thermally conditioned storage of food, and air cooling for powered equipment racks. Figure 16 provides an overall ECLSS functional block diagram.

ECLSS functions are accomplished through six subsystems: Temperature and Humidity Control (THC), Atmosphere Control and Supply (ACS), Atmosphere Revitalization (AR), Water Recovery and Management (WRM), Waste Management (WM), and Fire Detection and Suppression (FDS). The THC subsystem is responsible for controlling the temperature and humidity of the cabin air,

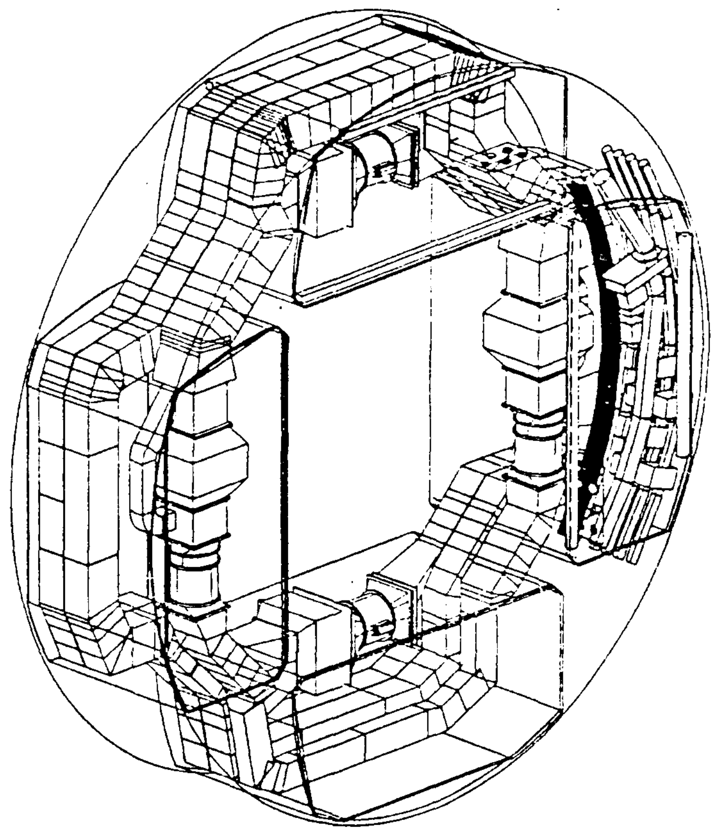


Fig. 15 Crossover

providing equipment air avionics cooling, providing thermally conditioned storage, and ventilating the atmosphere within and between pressurized modules. The ACS subsystem provides total and partial pressure control, atmosphere leakage makeup, and controlled depressurization/ repressurization of the atmosphere in the modules. AR removes CO_2 from the atmosphere, reduces it with hydrogen to form water, and electrolyzes water to form oxygen. Atmosphere composition monitoring and trace contaminant control are also AR functions. WRM recovers and recycles water used for various purposes. WRM takes the condensate from THC and the water produced by the reduction of CO_2 from AR and produces potable water. Hygiene water is reclaimed from waste water from man systems equipment and urine. However, urine must be processed to remove solids and toxic components before the water can be reclaimed. Finally, WRM monitors the quality of the water produced. Waste management is responsible for the collection of urine and feces. The urine is sent to the WRM for reclamation while the feces is stored for return to earth. Lastly, FDS detects fire through the use of flame, smoke, and thermal sensors and suppresses fire through centralized CO_2 distribution and portable fire extinguishers. The functional distribution and location of ECLSS among the pressurized modules is shown in Figure 17.

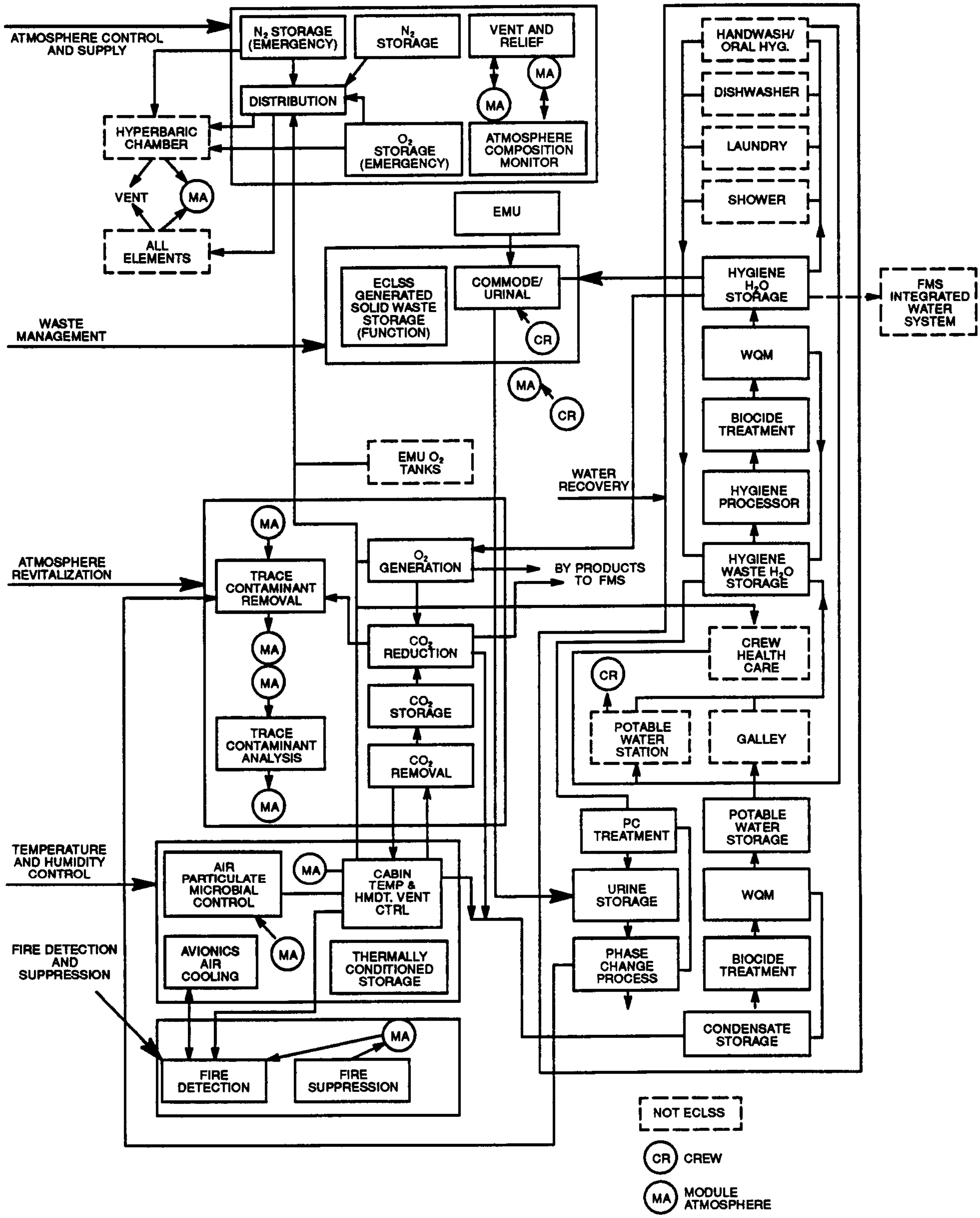


Fig. 16 ECLSS Functional Block Diagram

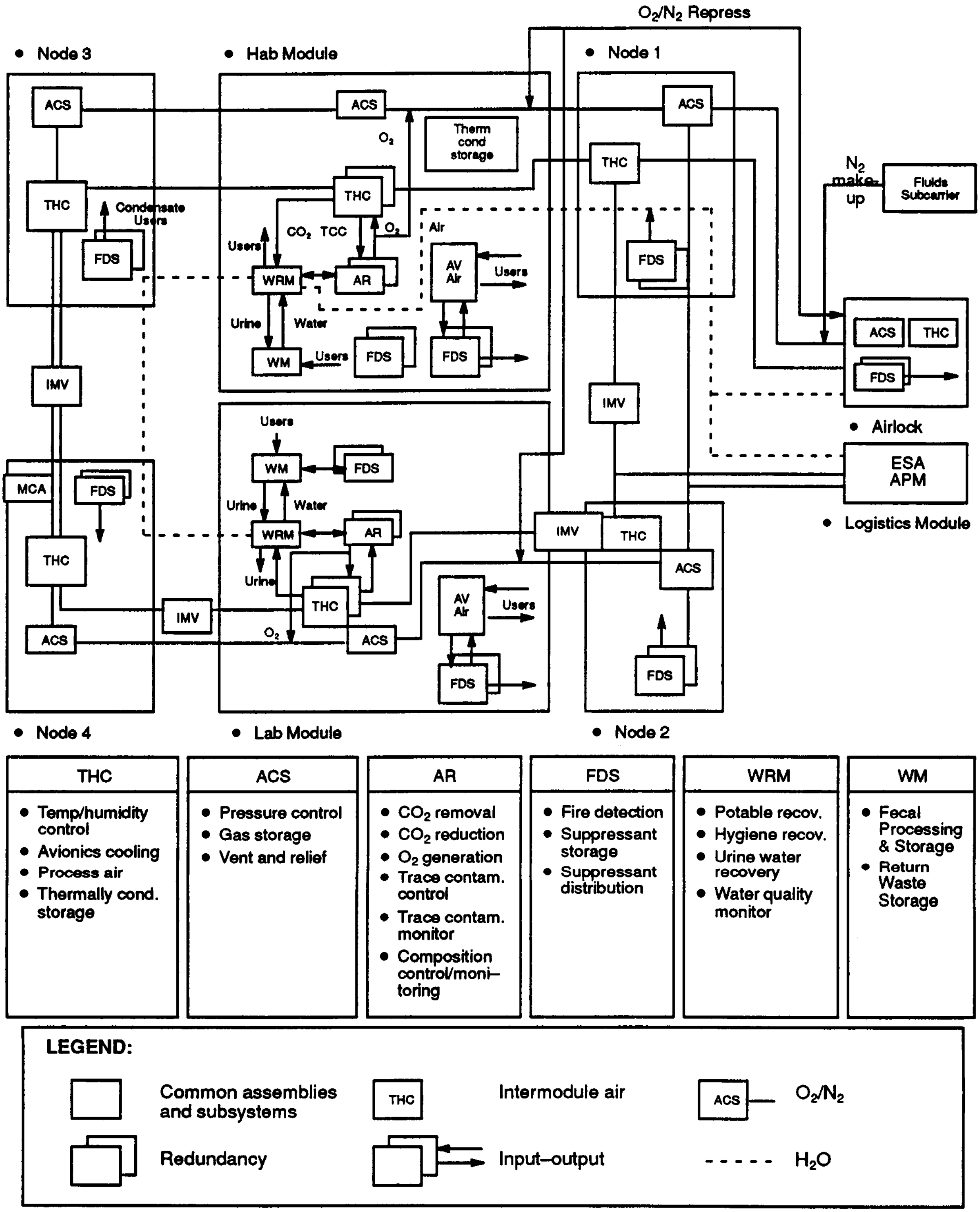


Fig. 17 ECLSS Functional Distribution

Thermal Control System

Thermal Control is divided into two systems: Passive Thermal Control System (PTCS) and internal Active Thermal Control System (ACTS).

The PTCS consists of multilayer insulation (MLI), coatings, thermal isolators and heaters used to maintain structural temperatures based on the local thermal environment. The MLI design consists of 19 layers of ultrasonically–welded, double–aluminized Mylar separated by Dacron net spacers. The Mylar is enclosed in an aluminized Beta cloth outer cover and a Nomex–reinforced, double–aluminized Kapton inner layer. Each blanket is electrically grounded at two locations. The baseline shield thermal coating is S13GLO white paint. The baseline piping insulation is TG15000.

The internal ATCS collects, transports and rejects waste heat via water heat transport loops. The ATCS consists of subsystem loops in the modules and nodes and a customer loop in the USL. The subsystem loop in each of the Habitation and Laboratory modules supports subsystem loads including support to life–critical loads which are essential to crew safety. The subsystem loop in each module consists of two physically separated but cross–strapped fluid coolant circuits. The customer loop in the Laboratory module supports user payloads and general purpose laboratory equipment. The customer loop provides 40–117 F service depending on payload and circuit location. A subsystem loop is provided in each Node. The airlock and on–orbit Pressurized Logistics Module (PLM) heat loads are serviced from the Node loop via the hatch interfaces. The TCS loop in the PLM is also used during ground, ascent and descent operations.

The ATCS loops interface with the Central Thermal Bus heat exchangers located on the module external endcones. The CTB heat exchangers transfer internally generated heat to a two phase ammonia loop which carries heat away to truss mounted radiators. Figure 18 shows the layout of the TCS.

Internal Audio/Video (IA/V)

The Internal Audio/Video (IA/V) System provides communications services within all the SSF Elements. The IA/V consists of 30 Audio Terminal Units (ATUs), a distributed antenna for uninterrupted communications and four audio recorders for record and playback capability. IA/V also provides an interface to the Communications and Tracking (C&T) System for audio communication with the ground, an orbiting or docked Orbiter, Extravehicular Activity (EVA) participants, and suited crewmembers in the Airlock.

The Internal Video Subsystem (IVS) provides generation, switching, fiber optic distribution, and display of all video signals within SSF. The IVS consists of 12 fixed cameras, 2 fixed monitors, 2

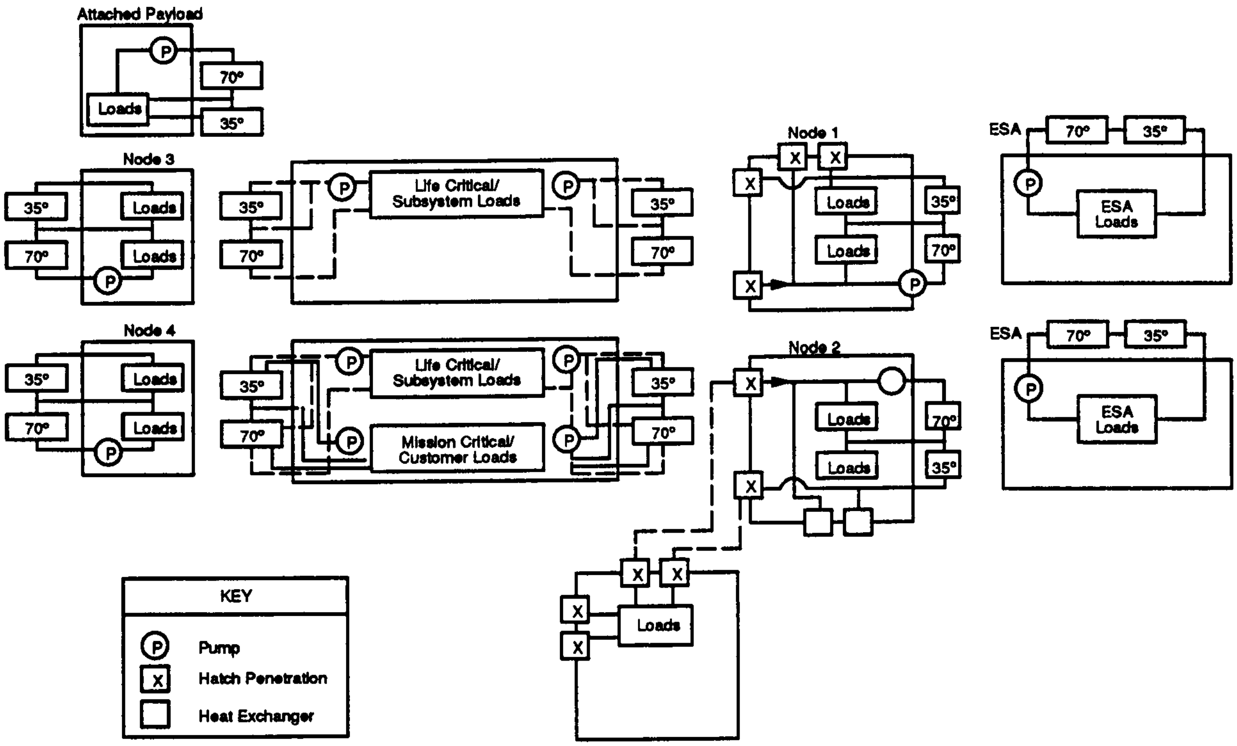


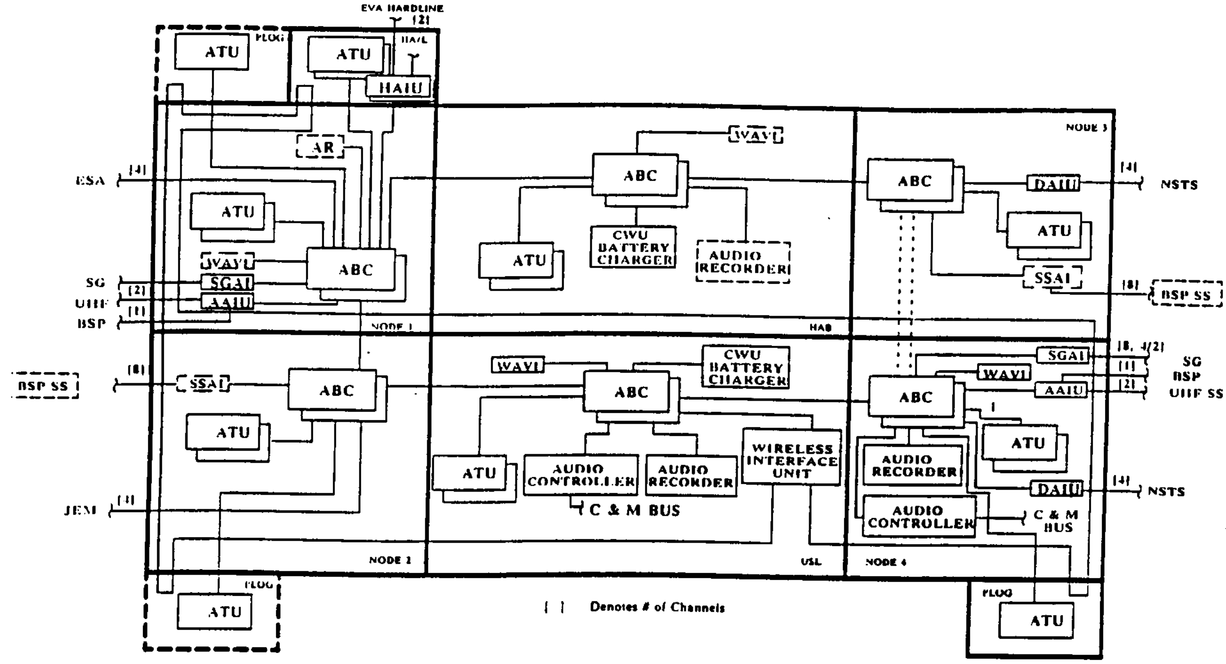
Fig. 18 Thermal Control System

portable (supporting ports are provided throughout SSF) cameras, 4 portable monitors, and 4 recorders. IVS also provides an interface to the C&T system for video communication with external video, with the ground, and with a docked Orbiter. Figures 19 and 20 show the functional relationships of the AV systems.

Data Management System (DMS)

The Data Management System (DMS) consists of hardware and software that provides application processing, process control, data handling, and integration of the operational environment of Freedom. Hardware resources consist of communications processors, mass storage units (MSUs), electronic workstation components, and data acquisition and distribution items. Software resources consist of an operating system and Ada run time environment, acquisition and distribution, communication, data storage and retrieval, time distribution, and crew interface services.

The Multiplexers/Demultiplexers (MDMs) provide the DMS interface to subsystem sensors/effectors and other ORUs. MDMs also send status to the Standard Data Processors (SDPs) upon request. There are three sizes of MDMs: small (4 cards), medium (10 cards), and large (16 cards).



IASTOPACD.APP
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Fig. 19 Internal Audio System

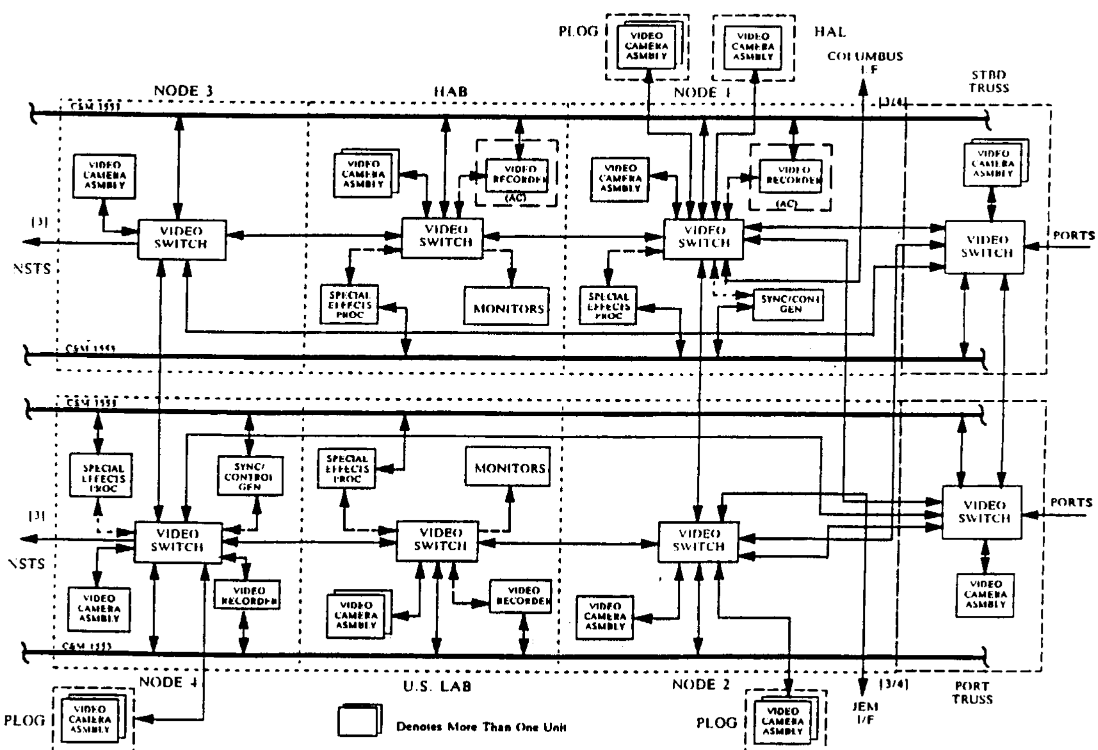

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Fig. 20 Internal Video System

The Multipurpose Applications Console (MPAC) is the hardware core of the crew workstations which provide the human–computer interface to the DMS. MPACs are configured into three different types: Fixed (F–MPAC), Cupola (C–MPAC), and Portable (P–MPAC). Figure 20 shows the functional relationship of DMS items.

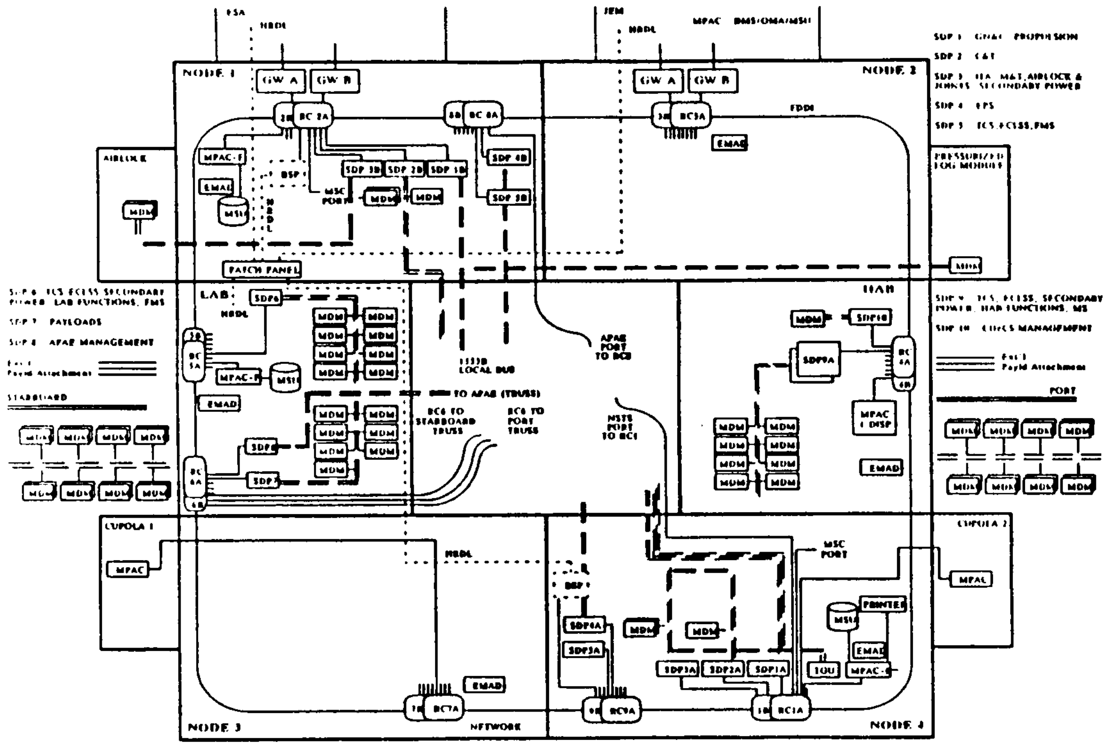

Fig. 21 DMS Functional Diagram

Electrical Power System (EPS)

Primary power from the Truss is provided to the DDCUs externally mounted on the element cylinder. The DDCU converts 160 VDC primary power to 120 VDC secondary power for use within the elements. Within the Hab and USL, secondary power is distributed by the Secondary Power Distribution Assembly (SPDA). Two SPDAs are mounted in each endcone. The SPDA contains Remote Power Controller Modules (RPCMs) which provide EPS protection and monitoring capability. Rack loads are evenly distributed across the four SPDAs. Although a rack is nominally connected to one SPDA, cabling to the rack from a back–up SPDA is provided. Switching from one SPDA to another is performed manually.

The SPDA distributes power to the Tertiary Power Distribution Assemblies (TPDAs) located in the racks and the PLM. The TPDA consists of circuit breakers for tertiary power distribution to the various loads. The Nodes each have a SPDA that distributes power to TPDAs in each active rack.

The PLM receives power from Nodes 1 and 2 for it's 3 powered racks, and is equipped with an endcone–mounted TPDA. Figure 21 shows the internal functional layout of the EPS.

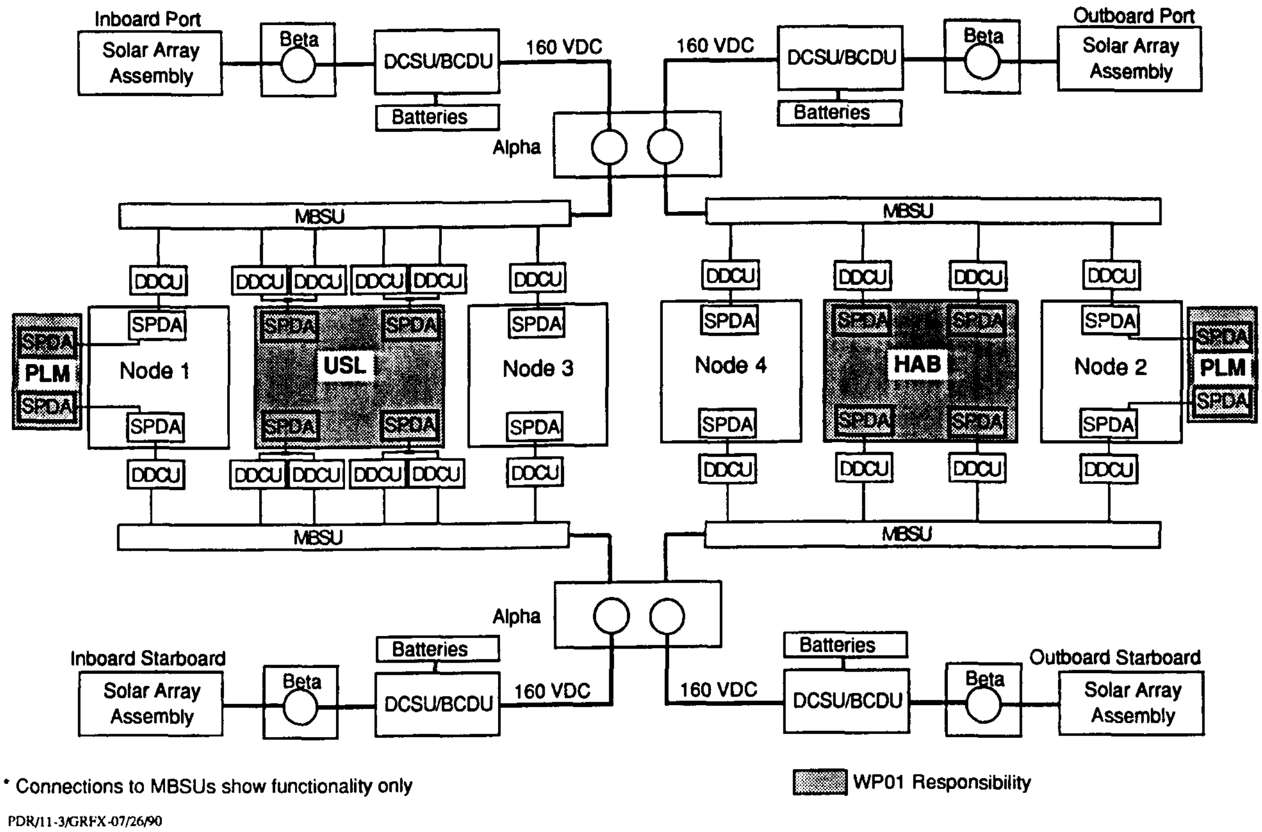

Fig. 22 Internal Functional Layout of EPS

<u>Man Systems (MS)</u>

Man Systems consists of equipment which interfaces with the station crew members. Restraints and Mobility aids are modular and interchangeable crew and equipment restraints provided in all areas of station. Both permanent and portable restraints are provided. Rack faces have slotted seat tracks that allow attachment of handrails and restraints by the crew where desired. Integrated workstations support station operations, payload and experiment operations, crew health maintenance, proximity operations, and maintenance operations. The primary command and control of station is conducted from a Command and Control Workstation (CCWS) located in Node 3 and the C–MPCA in the cupola. An Element Control Workstation (ECWS) is located in the USL and provides primary support for customer and experiment operations. Portable workstations are also available and can be utilized at any of the racks.

The Illumination subsystem provides interior area lighting including fixed, specific task lighting, and portable lighting. Partitions and closeout panels or curtains are provided for the segregation of internal volumes for noise, light and particulate control, for containment of loose items, for aesthetics, and for privacy. Included in this area are rack and equipment closeouts, window shades, curtains, partitions around the exercise area and partitions in the vicinity of the crew quarters. Stowage is provided for short and long term stowage of loose payload, crew supplies and consumables, and ORUs to be placed in WP01 elements. Stowage methods include soft pack bags, stowage racks including drawers and other restraint hardware, and thermally conditioned stowage for food and film. The Housekeeping Trash Management subsystem includes all provisions for nominal cleaning of station habitable interiors and their contents and for the tracking of all loose equipment within the WP01 inventory. The Personal Hygiene System consists of Waste Management (WM), Full Body Cleansing (FBC), and Personal Hygiene (PH) units. WM and FBC functions are duplicated in the USL and Hab; a PH area is provided in the Hab only for personal grooming and dressing. The Portable Emergency Provisions (PEP) provide tools, supplies and equipment for use in an emergency mode. PEP includes portable fire extinguishers, breathing devices and emergency lighting as well as dry food and other equipment.

Fluid Management System (FMS)

The FMS consists primarily of routing of nitrogen as part of the Integrated Nitrogen System (INS) and water and the water tanks in the Nodes. At the element level, the FMS interfaces with the USL and its subsystems, including the Process Materials Management (PMMS) and Ultrapure Water System (UPWS), as well as to each of the Laboratories for nitrogen gas distribution. A functional layout of the FMS INS is shown in Figure 23.

Communications and Tracking (C&T)

The Communications and Tracking System provides for communication internal and external to SSF. Communication to ground is accomplished via Tracking and Data Relay Satellites (TDRSs). Communication within the station modules is provided by the audio and video subsystems. The video subsystem also provides external capability to support experiments, docking, servicing, remote manipulation, and surveillance. Audio communications are fully duplex with the following capabilities: conferencing, recording, paging, listen only, privacy, caution and warning communications, time tagging, playback, wireless, and distribution. The video subsystem will use pulse frequency modulation. It includes cameras, monitors, video switches, recorders, sync and control generators, special effects processors, pan/tilt units, fiber optic/electrical conversion, and a fiber optic distribution network. The C&T architecture is shown in Figure 24.

Guidance, Navigation and Control (GN&C)

The Guidance, Navigation and Control System provides orbital position and attitude knowledge and control. The system also provides data used to point the solar arrays and radiators. It controls

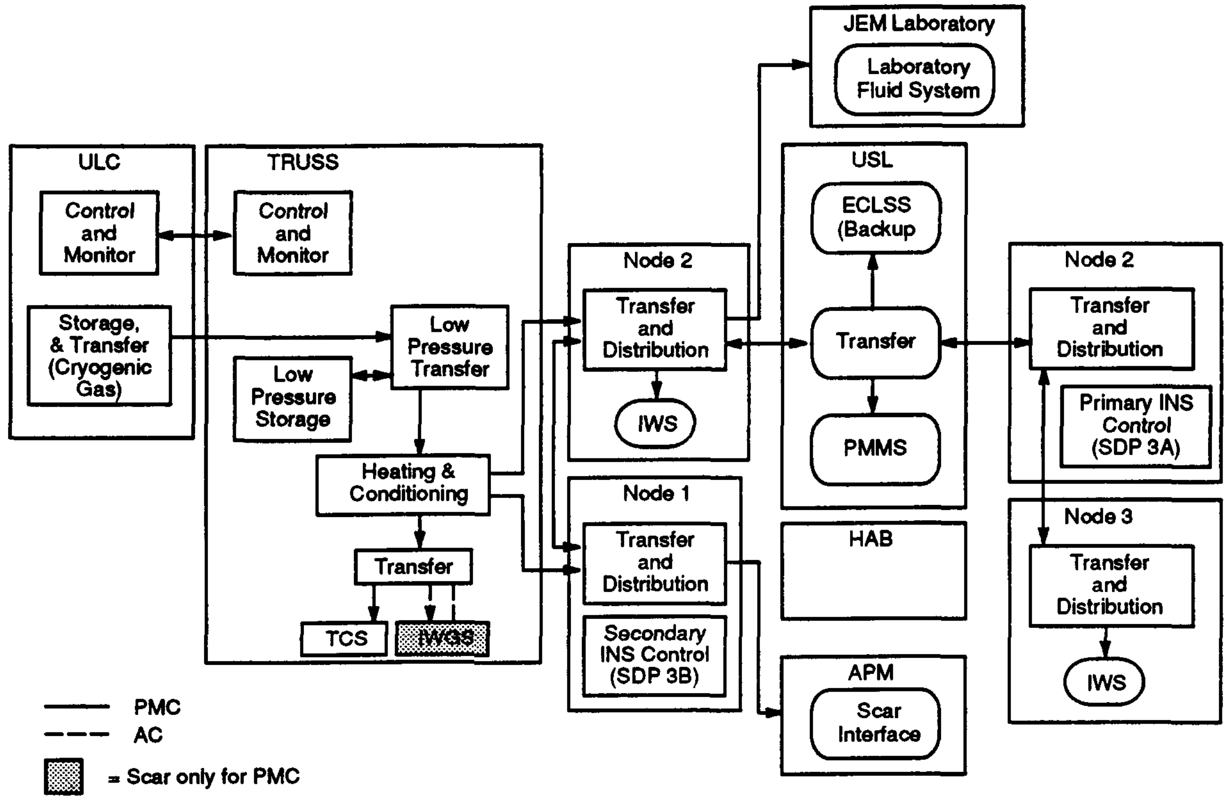

Fig. 23 FMS Functional Diagram

incoming, outgoing, and station–keeping traffic. It will also control docking and berthing operations and monitor trajectories for collision avoidance. There are no GN&C components internal to WP01 elements. The GN&C system is partitioned into two subsystems: the core subsystem and the Traffic Management (TM) subsystem. The core subsystem functionality is provided at PMC and the TM subsystem functionality is provided at AC. The core subsystem controls the attitude and orbit of the SSF. In addition, the core GN&C subsystem supports the pointing of the power system and thermal radiators and provides orbit, attitude state and pointing information to other systems and users. The core subsystem supports inflight verification, checkout, and dynamic stability tests. The subsystem consists of Inertial Sensor Assemblies (ISAs) and star trackers mounted on the navigation base, which is located on the GN&C pallet; Control Moment Gyros (CMGs), also located on the GN&C pallet; Standard Data Processors (SDPs) and software located in the Resource Nodes; the Reaction Control System (RCS) electronics located on the Reaction Control Modules. A dedicated GN&C local bus provides connectivity between the SDPs and the system sensors and effectors. A functional schemtic of the core subsystem is shown in Figure 25.

The GN&C Traffic Management (TM) subsystem provides the functions to control the approach and departure of traffic within the Command and Control Zone (CCZ). These functions are: monitor the

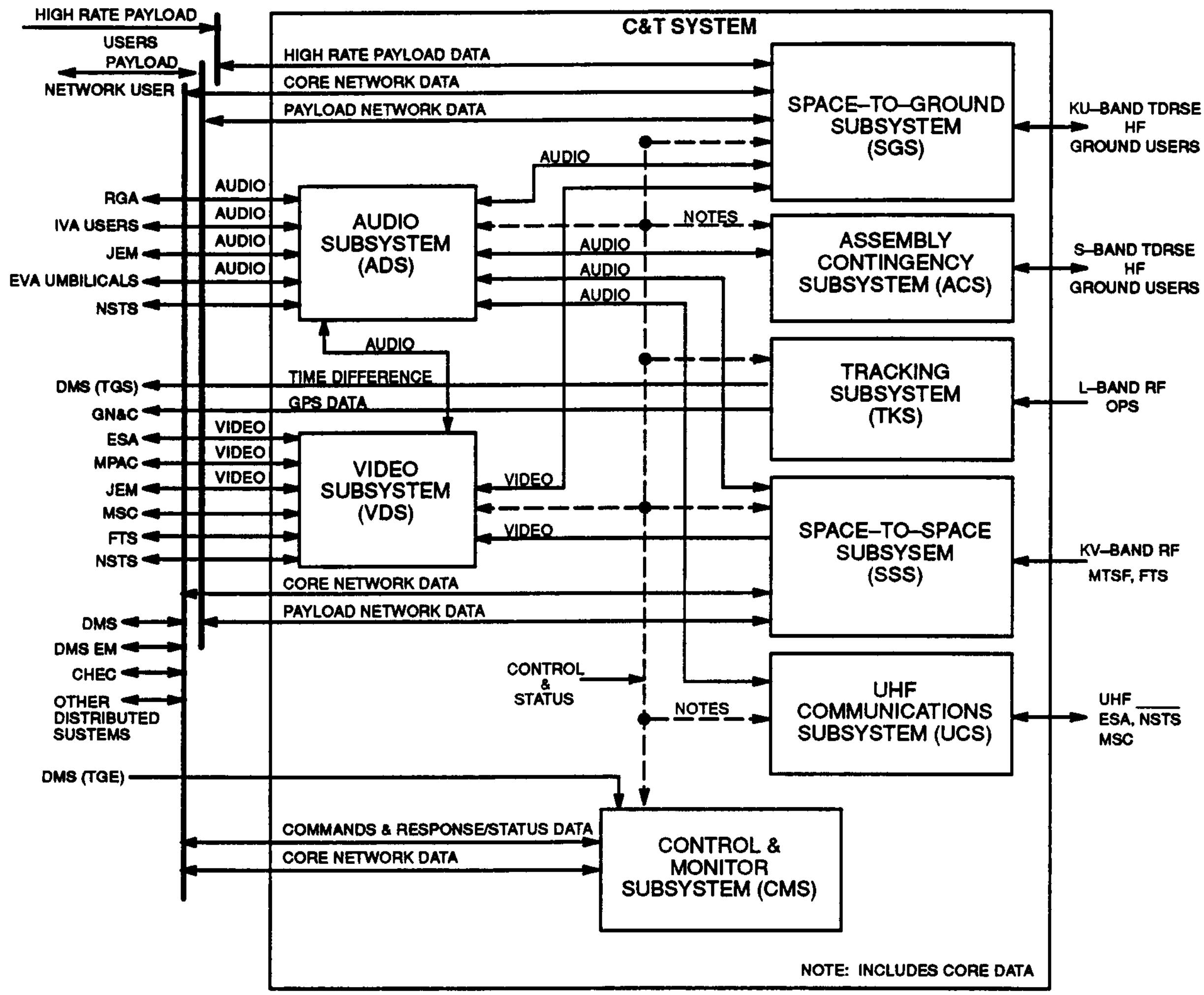

Fig. 24 C&T Architecture

trajectories of vehicles and other objects which intersect the CCZ, support docking and berthing operations, provide rendezvous planning, control incoming, stationkeeping, and outgoing traffic, support collision avoidance maneuvers, and provide status of the TM operations to the crew and mission control for the duration of the mission. The TM subsystem consists of SDPs and software located in the resource nodes. The TM subsystem interfaces with the core GN&C subsystem, DMS, and C&T. The TM functions rely on data transmitted from cooperative maneuvering vehicles and on ground tracking data for noncooperative vehicles and debris. Closed Circuit Television (CCTV) and/or cupola crew observations support close proximity operations for berthing and docking.

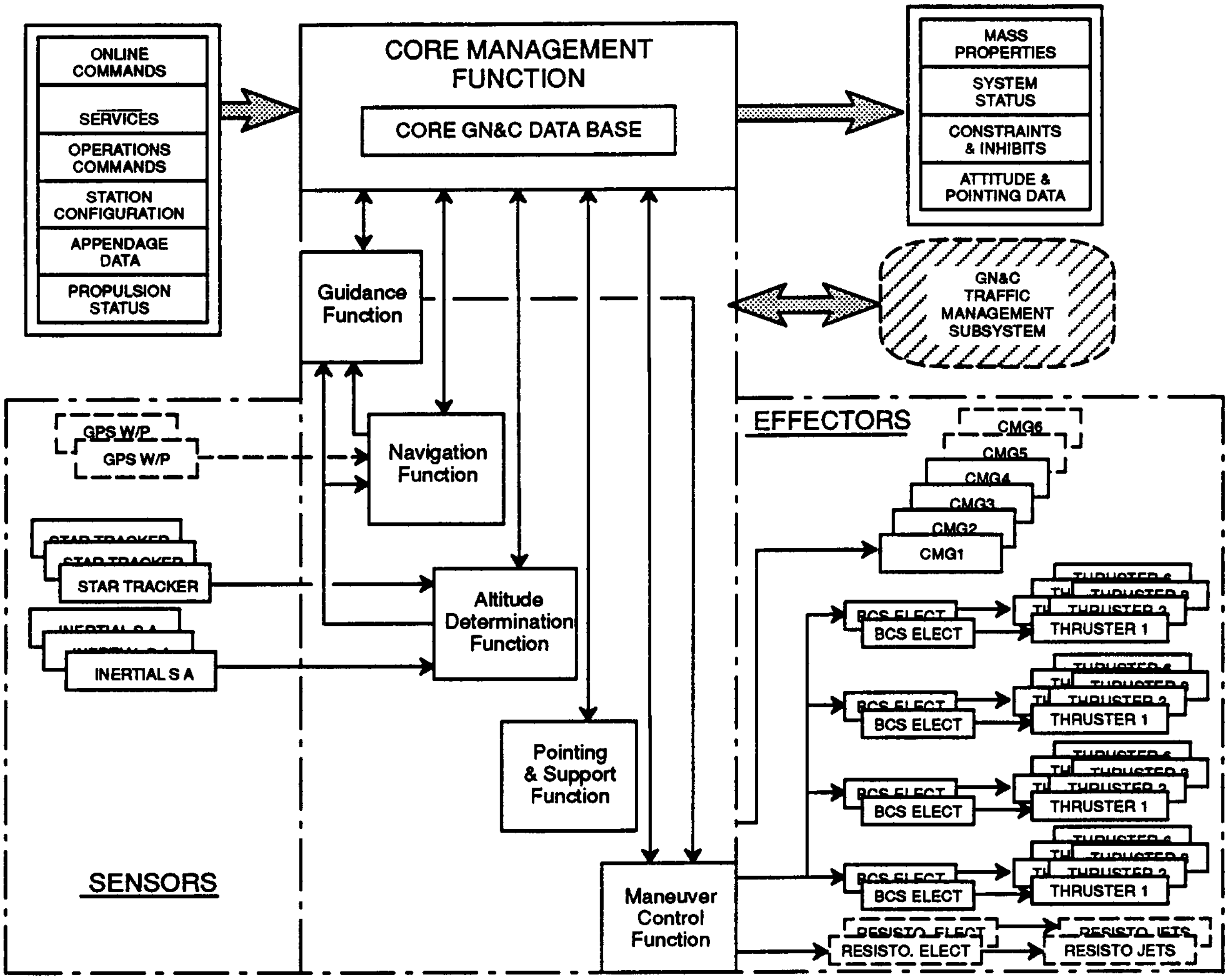

Fig. 25 GN&C Interfaces