An Evolutionary Construction Facility for Space Station Freedom

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Technology for Space Station Evolution - A Workshop
Dallas, Texas

January 16-19, 1990

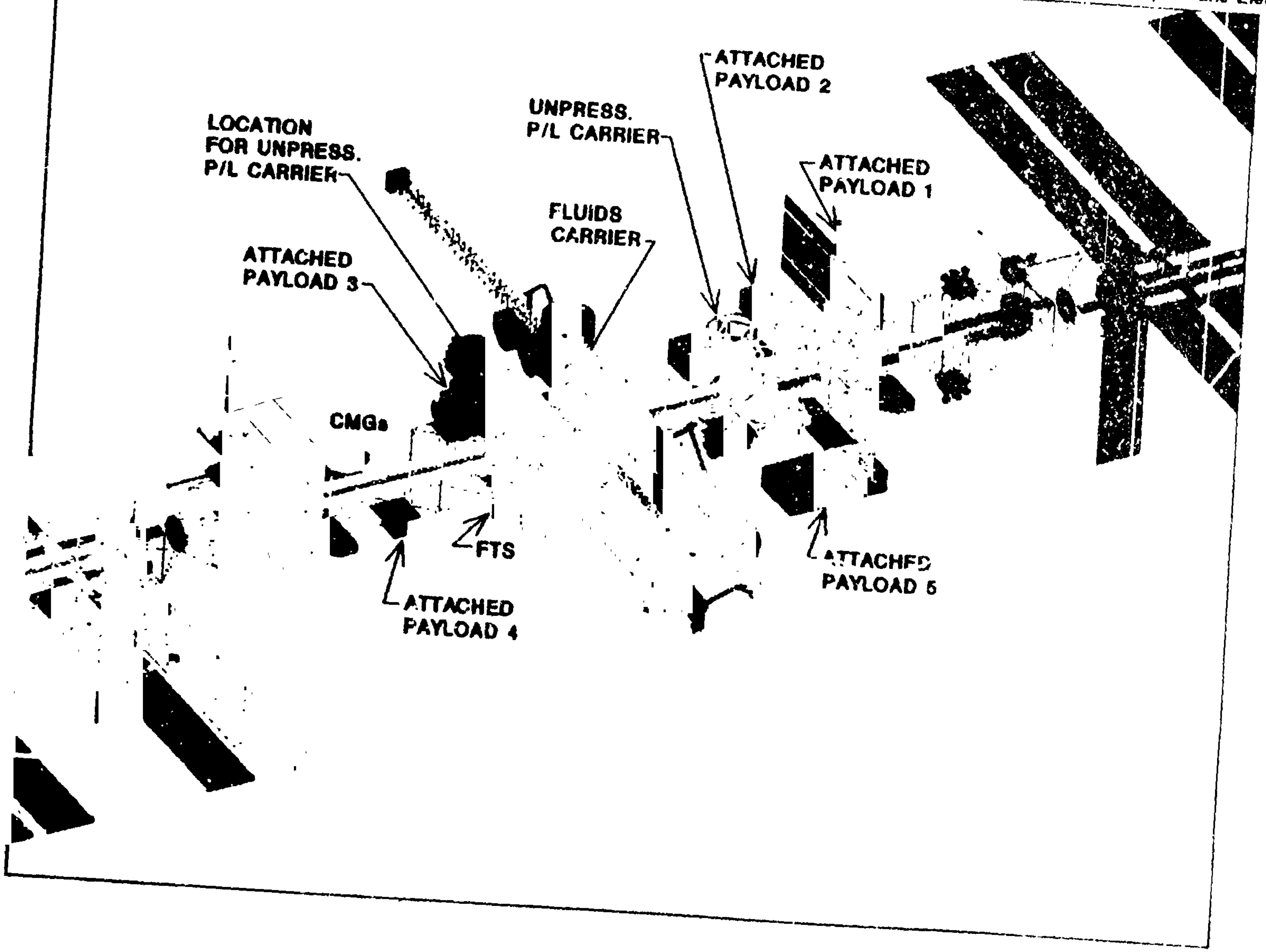
Space Station Freedom

Space Station Freedom (SSF) will support permanent human presence in space and has the potential to enable scientific and exploratory endeavors unequalled in history. Most importantly, it will permit the use of human abilities and interaction to perform tasks, interpret results, and react to contingencies in real time. With larger and more ambitious spacecraft being developed, it will serve as a site for construction, checkout and deployment. However, with the realities of government funding, the Space Station Freedom configuration has been cut back to the point where there is little "real estate" left for scientific instruments, and even less for the development and demonstration of the technologies required for in-space construction.

While it is true that the construction of Space Station Freedom itself will provide valuable experience in some of the techniques necessary for in-space construction, a facility attached to SSF is required to develop and demonstrate the techniques that will enable on-orbit construction of future large spacecraft.

Examples of attached scientific experiments that currently envision in-space construction are: Solar X-Ray Pinhole Occulter Facility, Astromag, and X-Ray Large Array. Examples of large assemblable spacecraft are: Large Deployable Reflector (LDR), Geostationary Platforms, and interplanetary vehicles. Future additions to SSF such as satellite and OTV servicing hangers and solar dynamic power systems will also need to be constructed in space.

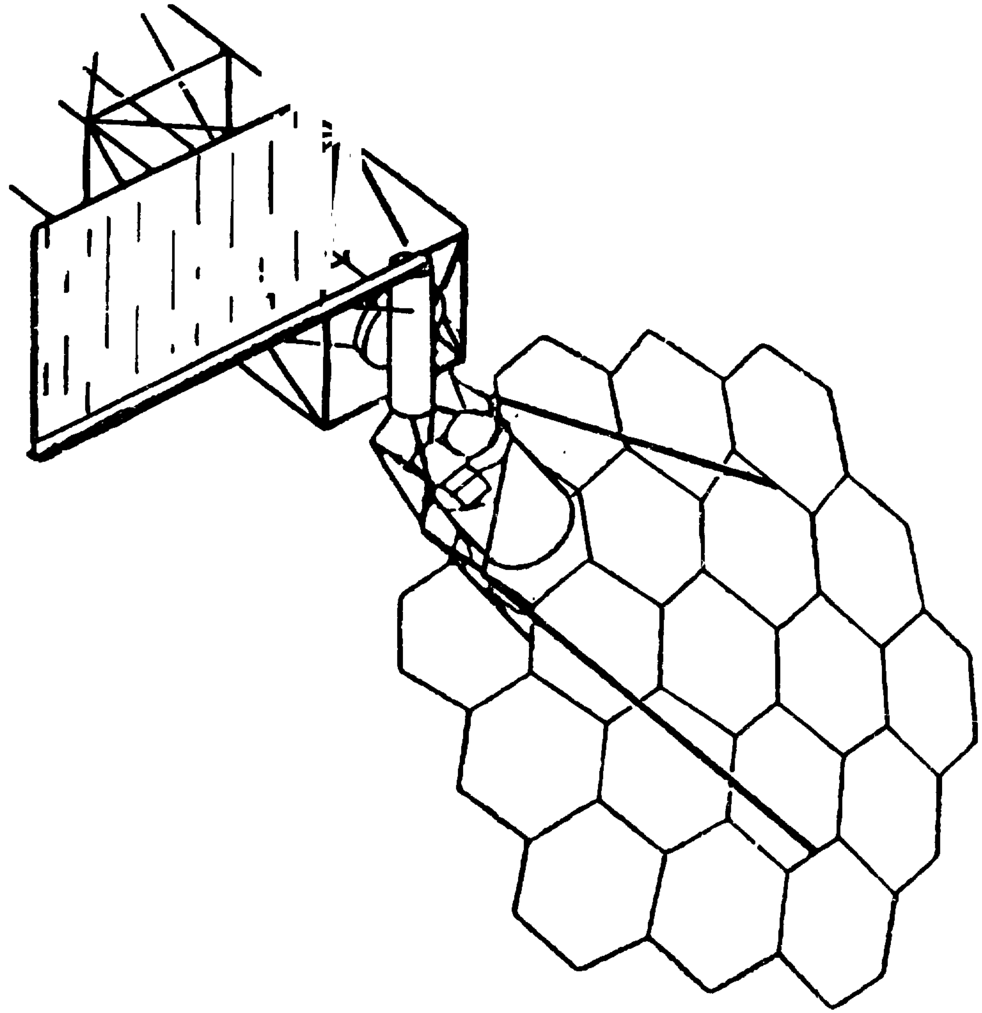
Space Station Freedom



Solar Dynamic Power System

Future growth of Space Station Freedom will use many of the same techniques of construction used for the initial configuration. The addition of solar dynamic power, however will require new techniques because of the use of segmented reflector segments that must be precisely aligned to focus the Sun's energy on the collector. Construction will probably take place near the module cluster to minimize the distance that the individual components must travel during assembly. The complete system will then be transported to its operational position at the end of the power boom.

Solar Dynamic Power System



Solar X-Ray Pinhole Occulter Facility

Although it is designed as a Shuttle experiment, the Solar X-Ray Pinhole Occulter Facility is envisioned as being placed on SSF for long duration operation. As designed, it is an automatically deployed experiment and requires little or no human interaction. Since it must face the Sun, its operational location will be on the space viewing side of SSF.

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Solar X-Ray Pinhole Occulter Facility (SPOF)

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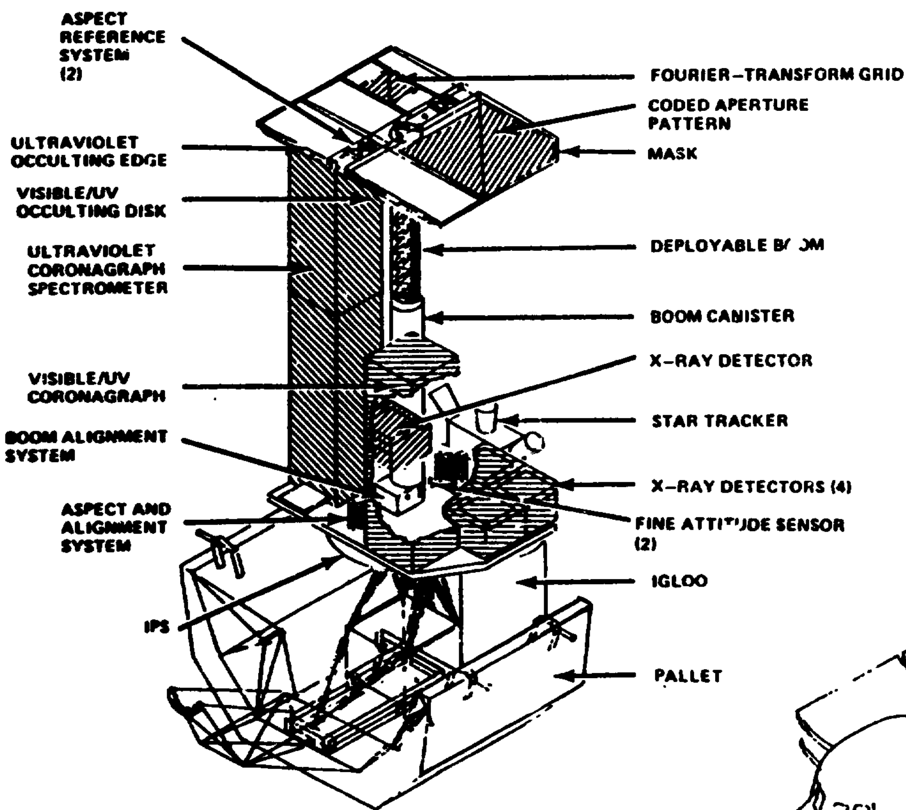
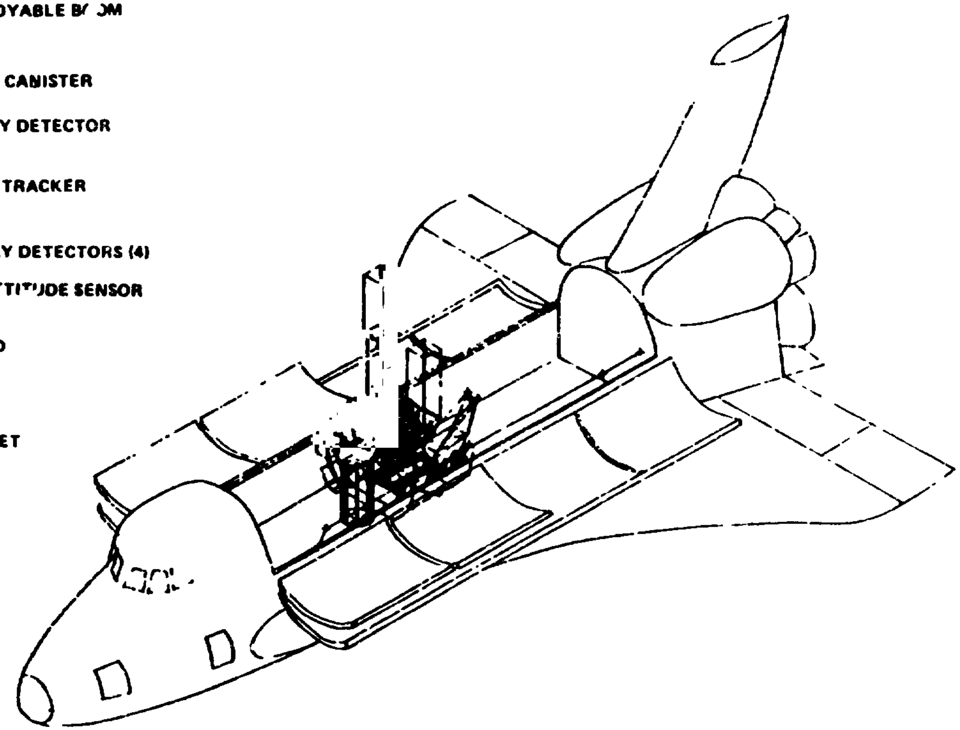
PINHOLE OCCULTER FACILITY
PHASE A CONCEPT



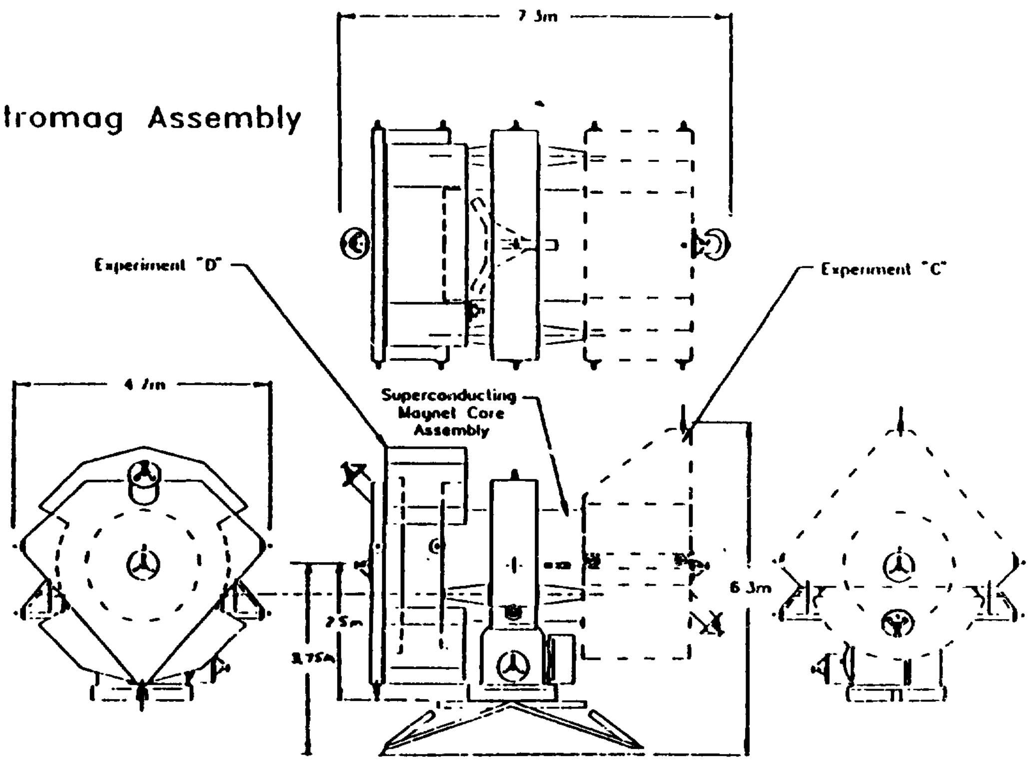


Astromag

The Astromag experiment is an attached experiment whose modules must be assembled in space. It is a space-facing experiment that incorporates a strong superconducting magnet and, therefore, must be separated from SSF by 10-15 meters (two or three truss bays) to minimize its interference with SSF systems. It will most likely be assembled at its operational site on the outward-facing surface of SSF.

ASTROMAG CONFIGURATION

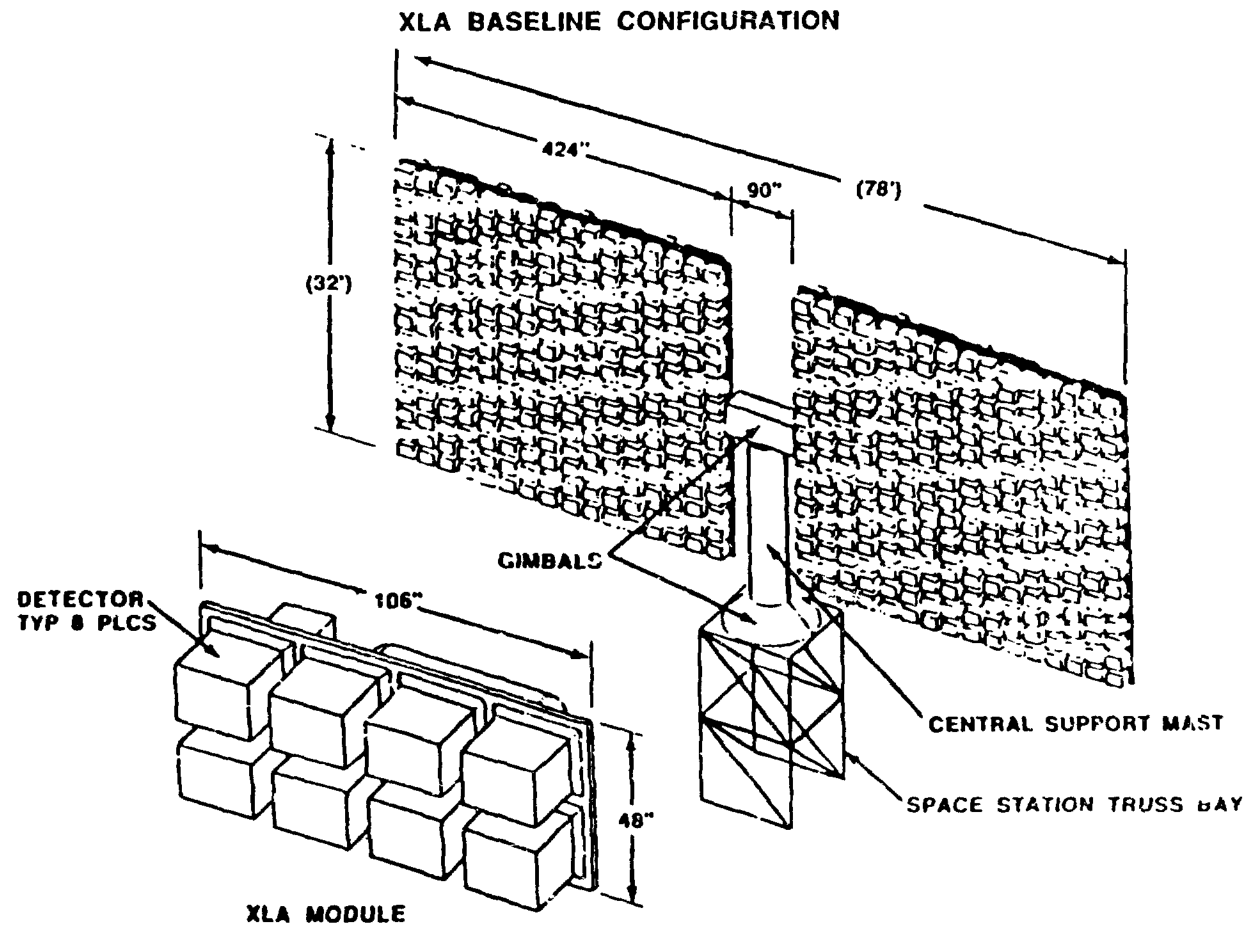
Astromag Assembly



X-Ray Large Array (XLA)

The X-Ray Large Array experiment is characterized by a pair of large planar arrays assembled from 64 individual detector modules. They are mounted to a central support mast and are pointed at a target in space by two gimbals. Its preferred operational location is also on the outward-facing surface of SSF.

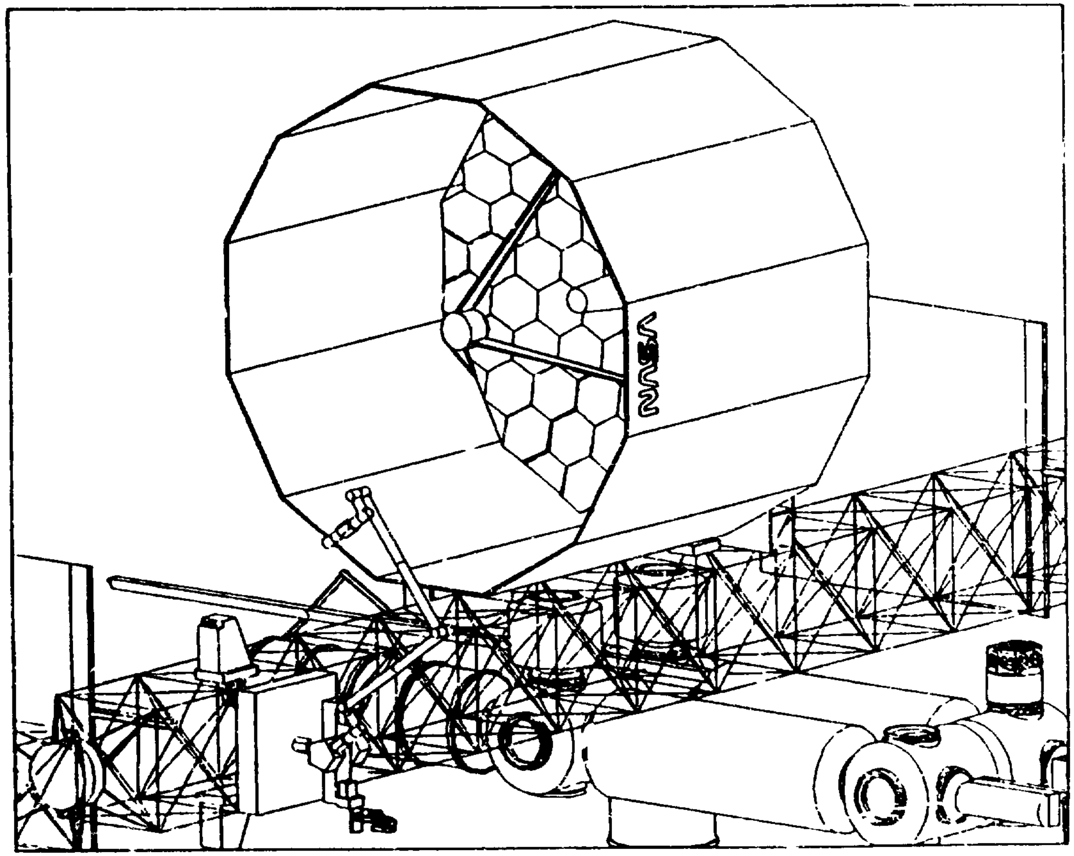
X-Ray Large Array (XLA)



Large Deployable Reflector (LDR)

Precision segmented reflector technology is exemplified by the LDR, a 20 meter diameter, segmented optics, submillimeter telescope. Its size and dimensional precision make on-orbit construction necessary. The proposed construction scenario has been well documented by JPL. It is assembled piece by piece by EVA astronauts with SSF mobile service center (MSC) assistance. Its required orientation relative to SSF is shown in the figure. This is to prevent direct sunlight from striking the reflector surface during construction. Once assembled, it is separated from SSF and transported to its operational orbit.

Large Deployable Reflector (LDR)



Geostationary Platform System

The Geo Platform System shown in the figure consists of a backbone truss structure to which are attached two reflector systems and other experiment modules. During construction, it is attached to SSF using an interface adapter. There are apparently no restrictions on its orientation during assembly. Following assembly, it is transported to geosynchronous orbit.

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Geostationary Platform System

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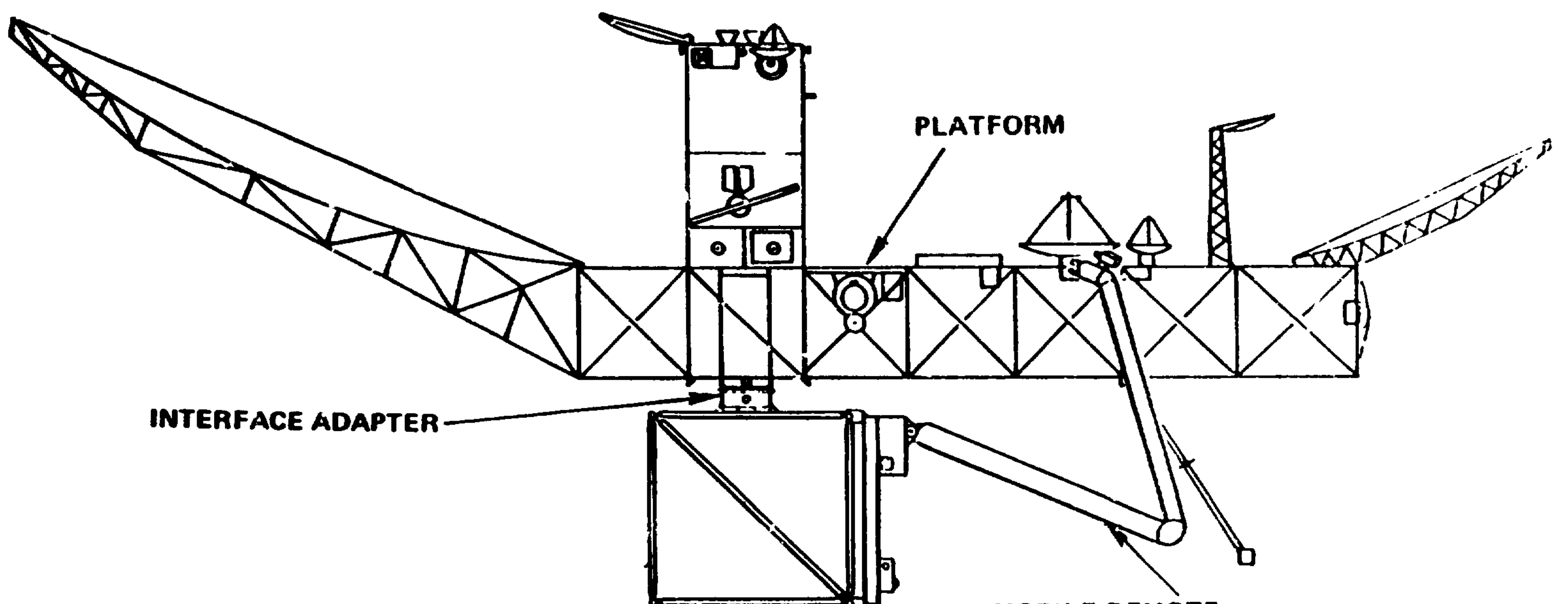
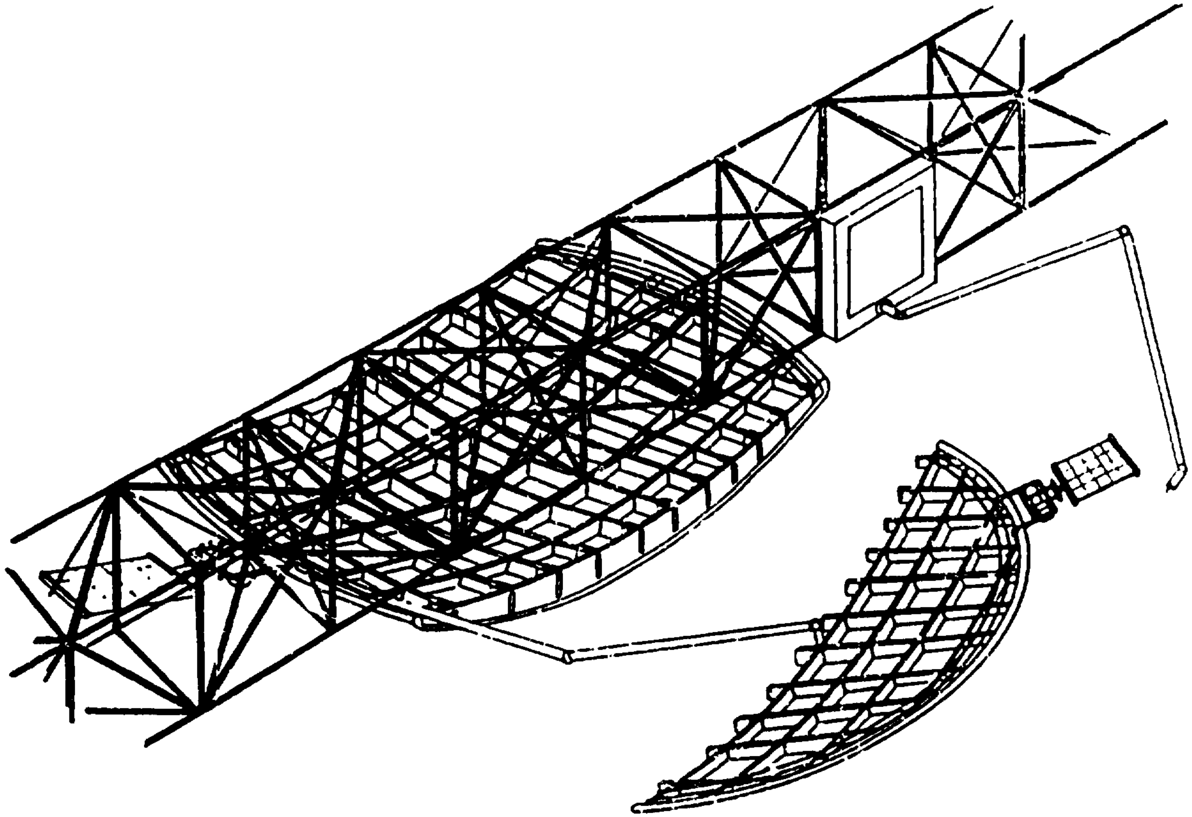


Interplanetary Vehicles (Pathfinder Program)

Looking into the future, interplanetary missions to explore the solar system will require very large spacecraft that must by assembled in space. NASA's Pathfinder Program is identifying and advancing the technologies and capabilities necessary to enable these missions. This figure shows a possible assembly method for a large aerobrake used on a spacecraft designed for a manned Mars exploration mission.

Interplanetary Vehicles (Pathfinder Program)



Mars Exploration Mission Configuration, Assembly of the Aerobrake Sections at Space Station

Construction Facility Requirements

Attachment location - Neither the facility or its construction projects should interfere with SSF systems. Obstruction of line-of-sight to SSF components should be minimized. Construction projects should be within sight of the habitable modules. For safety, all EVAs must be observable by an IVA crew member.

Project orientation - Both the facility and the construction projects should be oriented to minimize drag. The facility should provide required project orientation (e.g., sun avoidance)

Attachment method - The facility should allow flexibility in the method for project attachment. For example, an axisymmetric structure could be attached at a single point, while a long structure may require multiple attach points, and a large diameter wheel-like structure could be attached at its rim.

Positioning - Construction projects can be assembled by moving them past a fixed work station, or by using a portable work station to access all areas of the project.

Construction aids - Generic tools, fixtures and assembly aids should be provided by SSF while unique equipment must be provided by the project. Examples of SSF-provided aids are: lights; tools and tool containment devices; portable astronaut positioning systems, foot restraints, lifelines and tethers; adjustable structural supports, hold-downs, braces and attachment devices; video monitoring equipment and supports; portable measurement devices and instrumentation; and generic test and checkout equipment.

Equipment storage - A central enclosed storage location for the above equipment inventory should be provided. The storage area should also provide temporary storage for small components awaiting assembly, particularly those that need to be protected from the harsh space environment. A storage platform for temporary storage of larger components should also be provided at the construction facility.

Utilities - Electrical power and data lines are required by the construction facility and, in some cases, by the construction project. Some ssemblable satellites may also require thermal control until their on-board thermal control systems are activated.

Test and checkout equipment - Generic instruments and measurement devices for structural alignment and for thermal, electrical, and dynamic measurements should be provided by SSF.

Construction Facility Requirements

- Attachment location
  - Non-interference with SSF systems
  - Observation of EVA by IVA crew
- Project orientation
  - Minimize drag
  - Sun avoidance
- Attachment method
  - Single point
  - Multiple attachments
- Positioning
  - Translation or rotation
  - Fixed or portable work station
- Construction aids
  - Tools, fixtures, lights, assembly aids
- Equipment storage
  - Internal and external
- Utilities
  - Electrical power, data, thermal
- Test and checkout equipment
  - Alignment, temperature, electrical measurement, modal survey

Experiment/Construction Facility Concept

The proposed construction facility concept is shown in this figure. It consists of two 8-bay portions of the lower keel structure. These truss beams provide sufficient facilities for many construction projects currently envisioned and, at the same time, promotes SSF evolution. The facility includes several Structural Interface Adapters (SIAs), generic storage platforms, a storage module, a turntable, and, not shown in the figure, a surrogate payload bay and a portable work station. Utility trays are included to provide electrical power and data lines.

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Experiment/Construction Facility Concept

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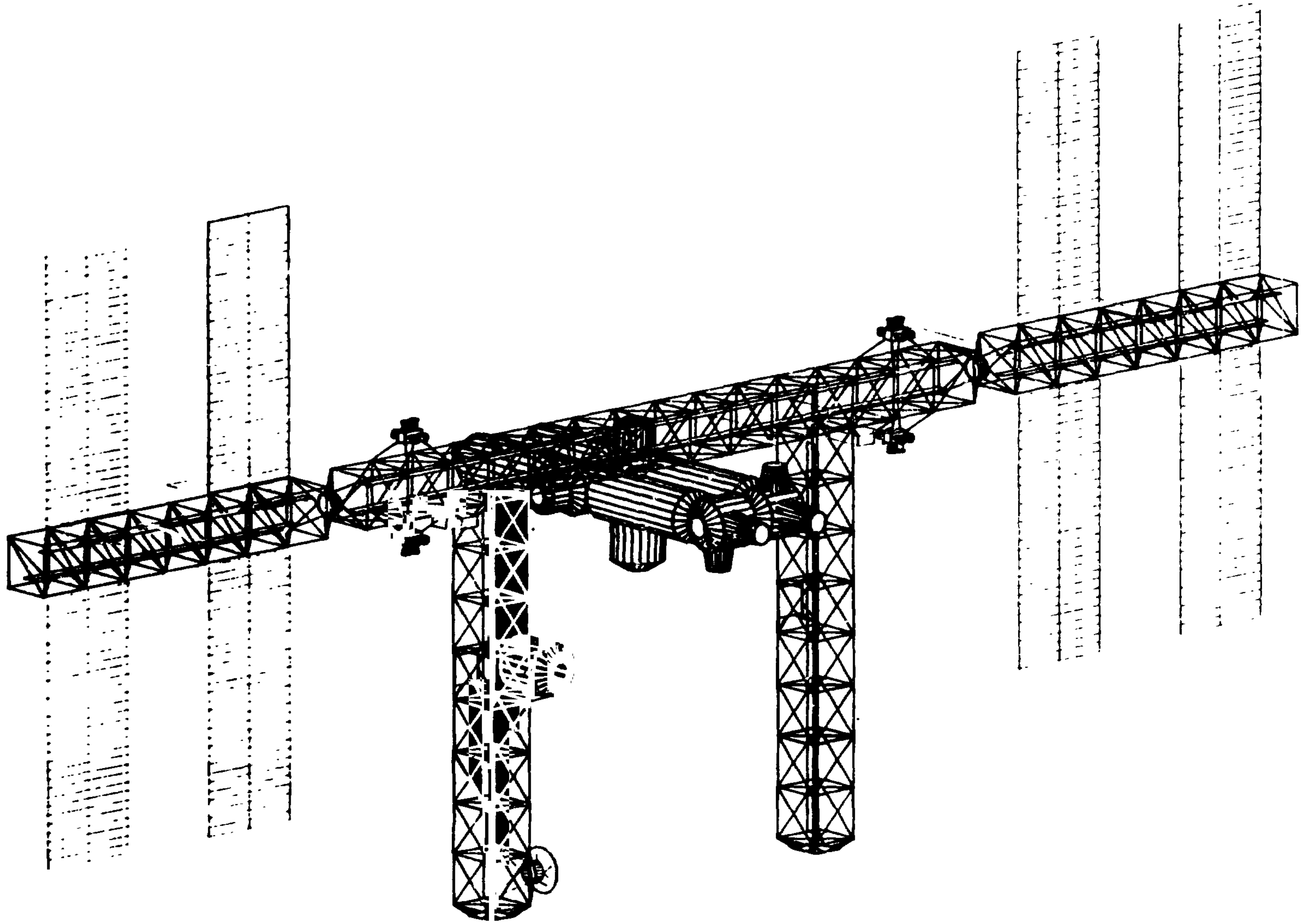
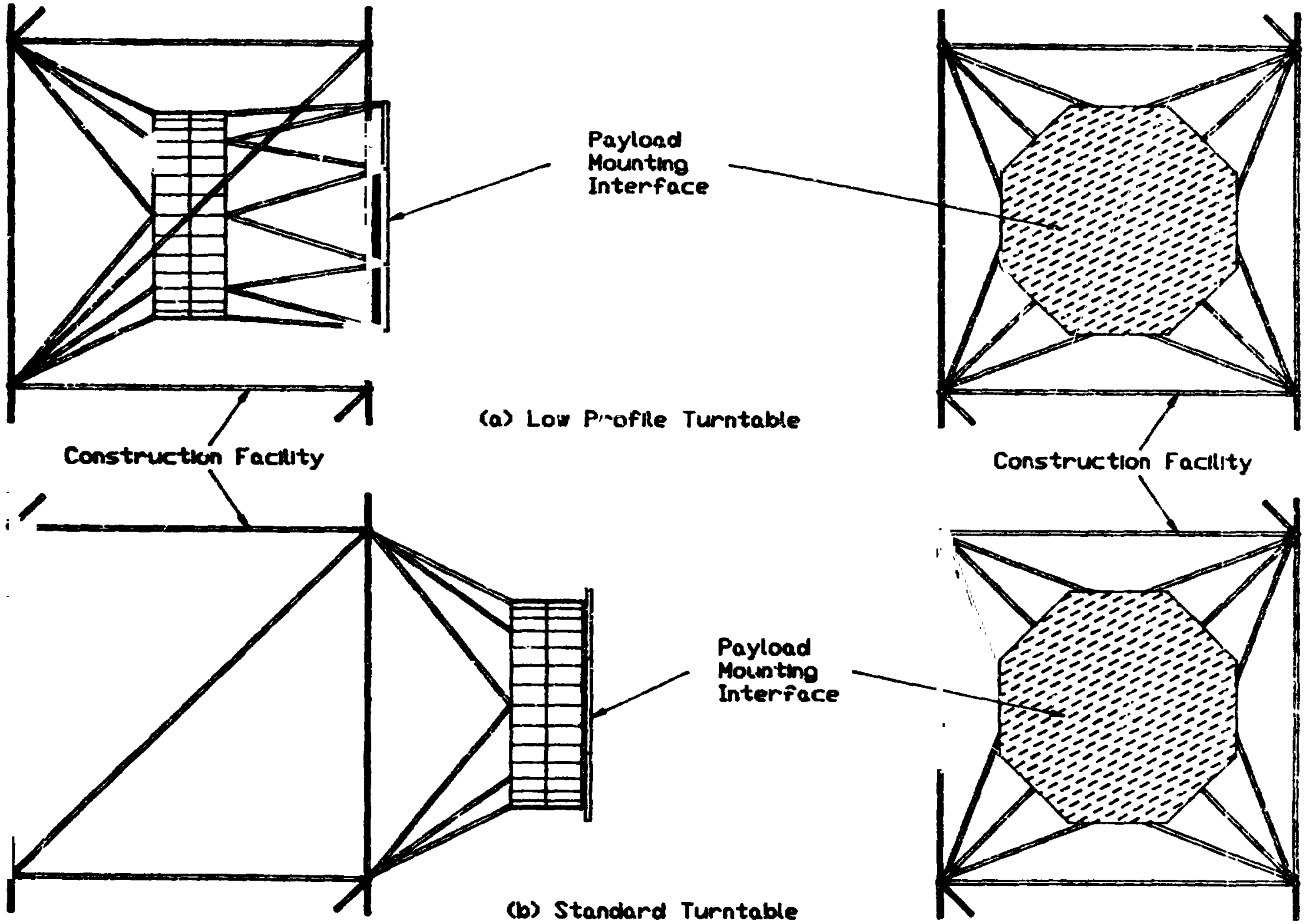


Turntable Concepts

A turntable allows attachment of a construction project or payload at a single location, and rotates to provide access to all sides.

The turntable concept shown is a modified alpha joint attached to the construction facility truss. The standard turntable is attached to the truss externally, in the same manner that the alpha joint is attached to the main power boom. If more volume is required for a large construction project, the turntable can be attached within the truss cube after removing a truss diagonal member and attaching an adapter truss. The use of the SSF alpha joint design supports commonality and provides the required electrical and data path across the interface. Its structural capability is also sufficient for large construction projects.

Turntable Concepts



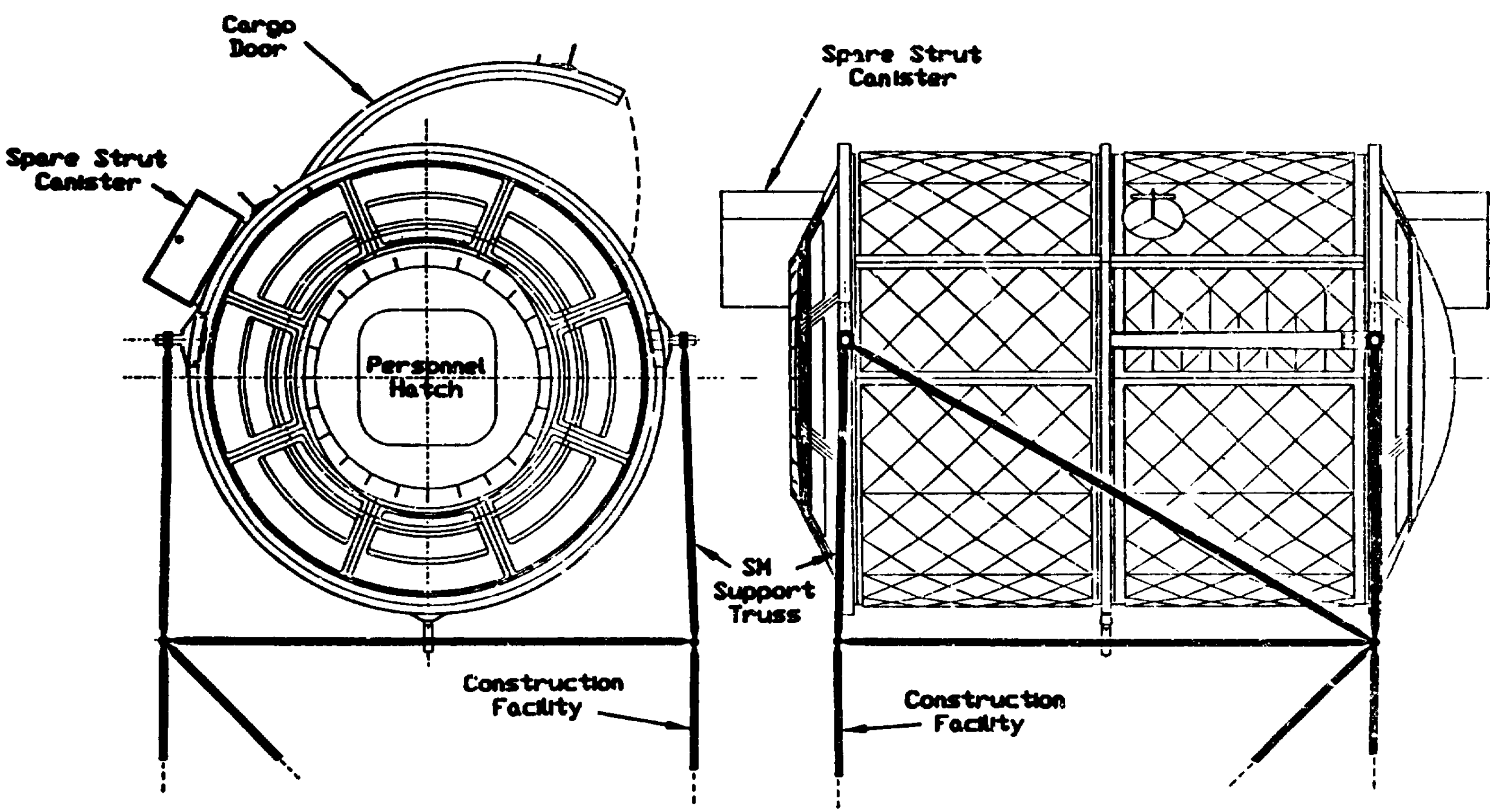
(a) Low Profile Turntable

(b) Standard Turntable

Storage Module (SM)

The proposed storage module design is a modified Logistics Module (LM). Its exterior shell structure is identical with the LM with two exceptions. First, an electrically operated cargo door is built into the side to allow large components to be stored and retrieved by the MSC. Since the storage module is not required to be pressurized, the cargo door does not need to be pressure tight. The second exception is the addition of attachment devices for a canister that contains spare SSF truss struts and nodes. The personnel hatch is retained to allow crew access without opening the large cargo door. The interior structure is modified to permit the storage of tools and other generic construction aids and instruments. It is attached to the construction facility using truss members that connect to its trunion and keel fitting pins.

Storage Module (SM)

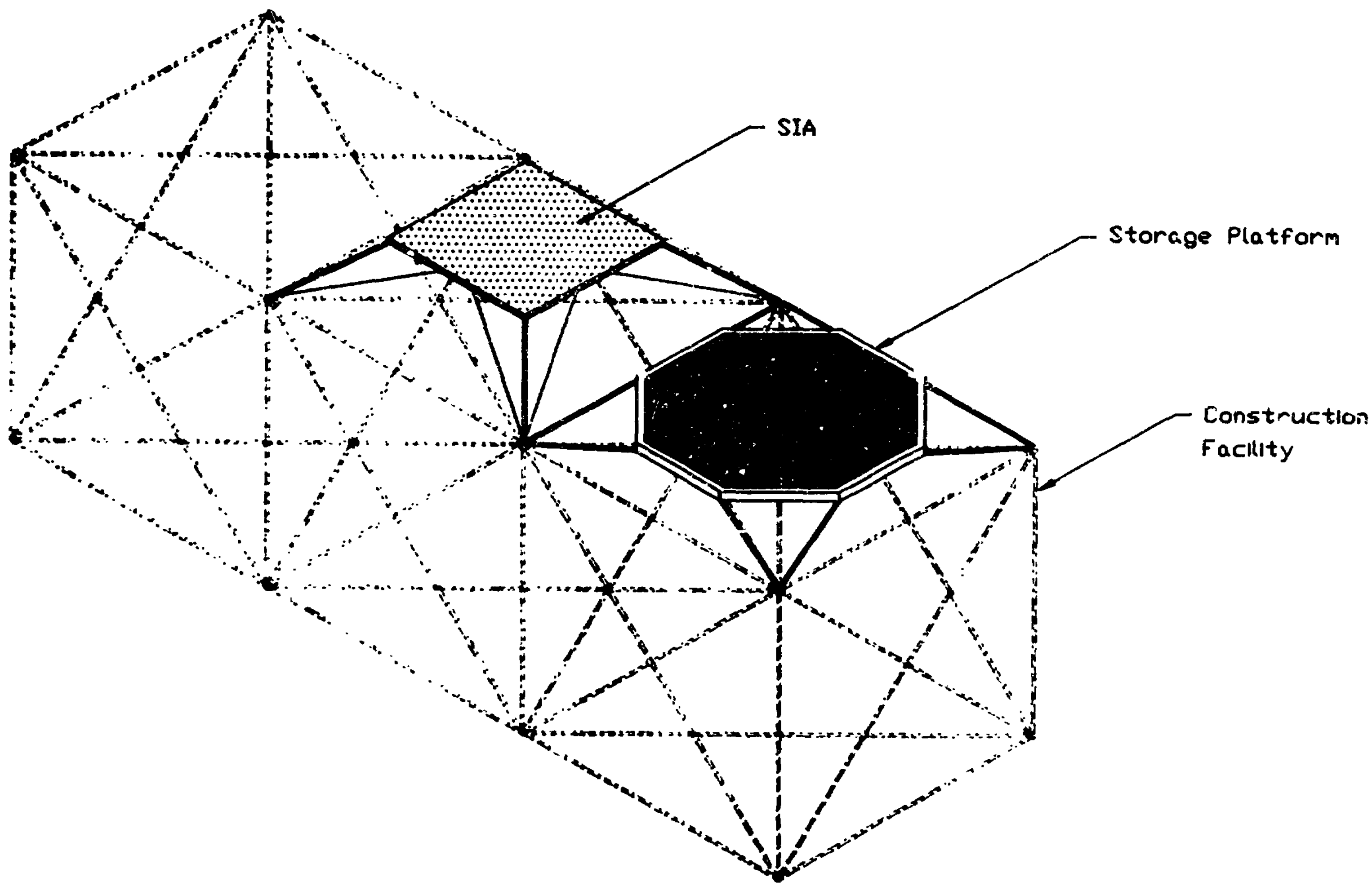


Generic Attachment Platforms

Attached Payload Attachment Equipment (APAE) that provide a generic attachment method for experiments will be provided by SSF. It consists of a structural interface adapter (SIA) that is attached to the SSF truss. A corresponding payload interface adapter (PIA) is attached to a payload. The APAE provides a physical, electrical and thermal interface with attached payloads. The construction facility will include several SIAs that can be used when needed.

A more generic storage platform is also proposed for the temporary storage of parts, equipment, containers and components awaiting assembly. It is an octagonal platform attached to the construction facility truss nodes that does not provide electrical or thermal interfaces. Its surface is a gridwork that will accommodate a generic tie-down mechanism that can easily be placed at any location on the grid. Containers or components can be restrained to these tie-down fixtures.

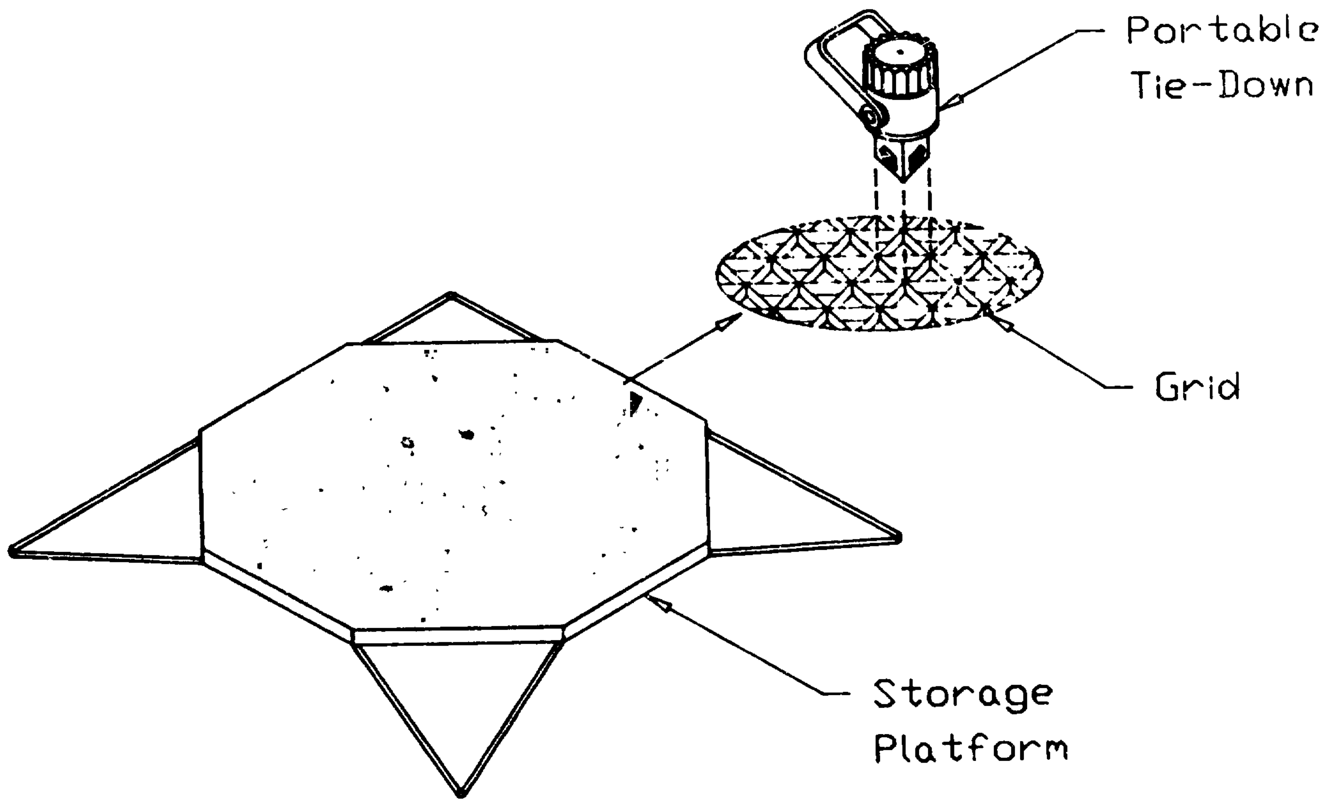
Generic Attachment Platforms



Storage Platform Concept

This figure shows more details of the platform, its gridwork surface and the protable tie-down mechanism. The grid can be either triangular, as shown, or square. The tie-down fixture has spring-loaded latches that firmly restrain the fixture when placed into one of the grid openings. The handle, attached to a rotating collar, can rotate about two axes, and is the attachment point for tie-down straps or other mechanisms. The fixture is easily released by an EVA crew member by turning the knob within the handle (after it is rotated out of the way). This releases the latches, and the fixture can be pulled out of the grid.

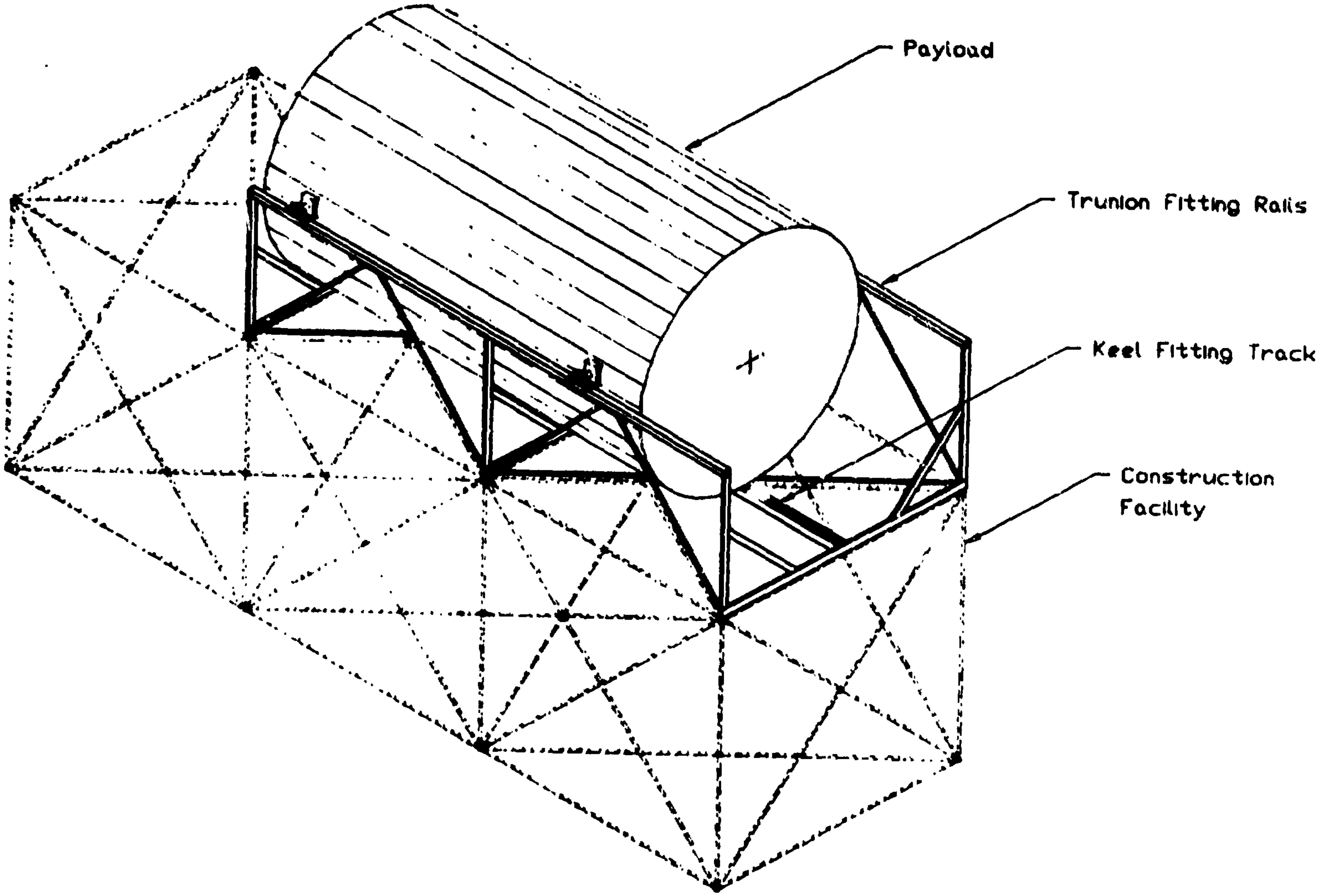
Storage Platform Concept



Surrogate Payload Bay

It may be necessary to accommodate large payloads and shipping containers that are tied directly to the Orbiter longerons via trunion and keel pins. The surrogate payload bay facility duplicates the geometry of the STS payload bay and includes adjustable longercn and keel trunion fittings. It can also supply the same utilities (electrical, thermal, etc.) that are supplied by the Orbiter, if required.

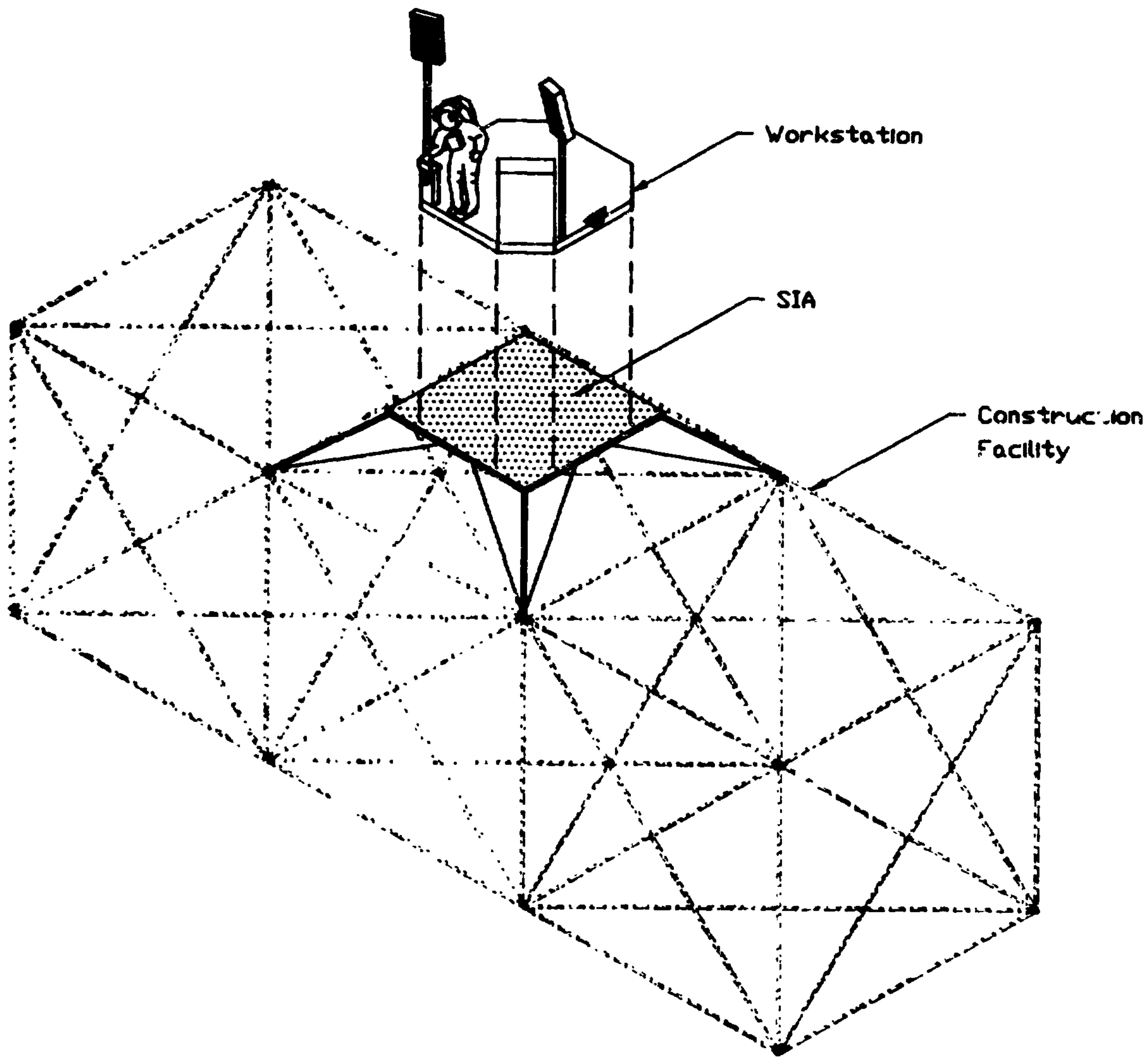
Surrogate Payload Bay



Work Station Concept

It has been demonstrated, both in neutral buoyancy simulations and in space, that EVA tasks can be performed more efficiently when the crew member works from foot restraints. In addition, construction times will be shortened if the parts and equipment needed for construction are close at hand. Therefore, a construction facility must provide a work station that will provide these and other accommodations. Shown in the figure is a concept for a dual purpose work station. While attached to a Structural Interface Adapter (SIA) it can be used as a fixed work station, and by using the Mobile Service Center (MSC), it becomes a portable work station. The SIA provides electrical power for lighting and other electrical needs when the platform is being used as a fixed work station, and for battery recharging when it is being stored. It becomes a portable work station by using the MSC to position it at a remote site. Several grapple fixtures are provided to allow a variety of MSC attachment locations. The work station is large enough to provide lighting, tools, and an area for attachment of containers of components needed for the construction project.

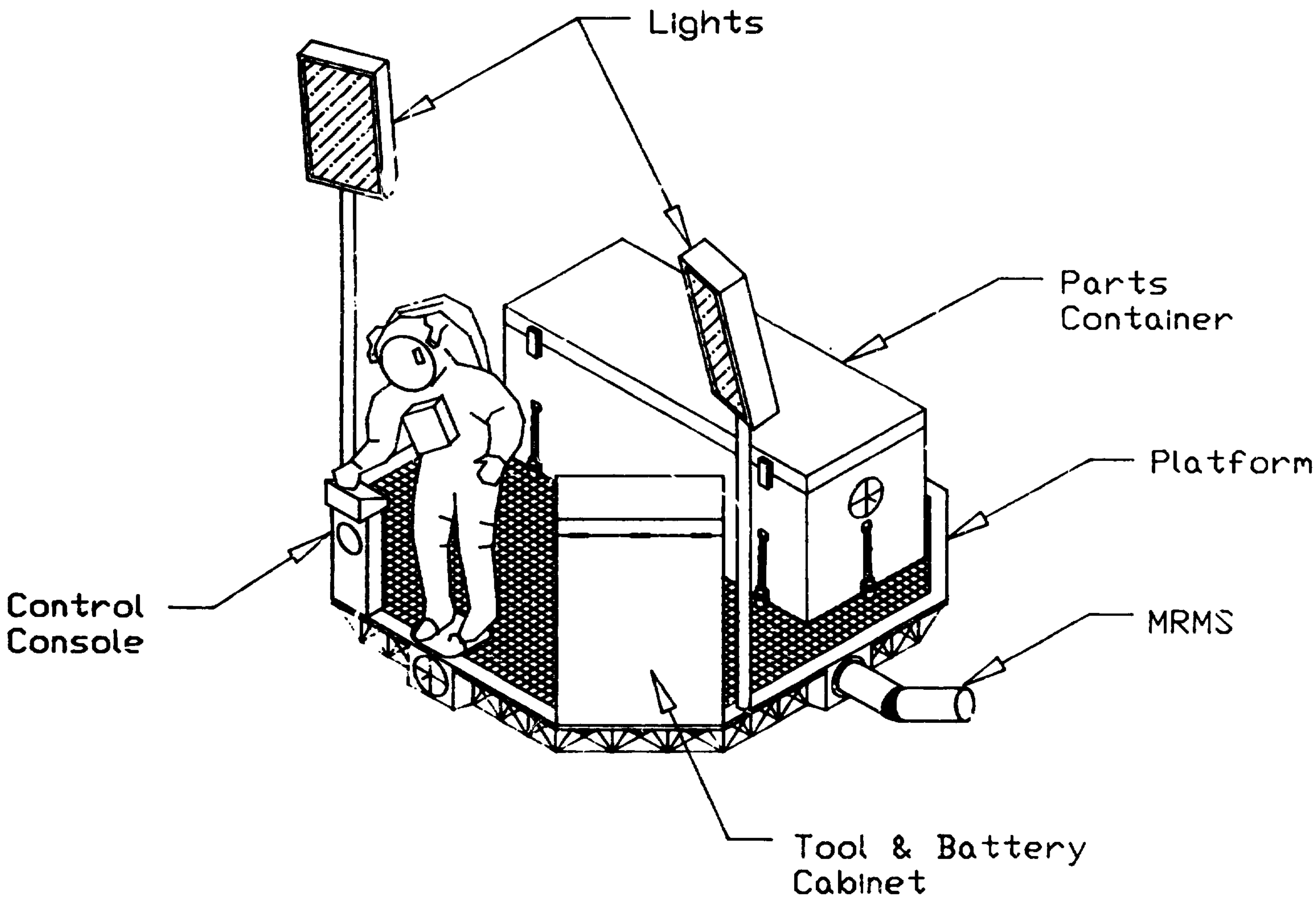
Portable Work Station Concept



Portable Work Station

Shown here in more detail, the work station is made up of a platform whose surface is a grid similar to the generic storage platform previously discussed. It is approximately 4 meters across (capable of being transported to the station within the STS cargo bay diameter) and accommodates a wide variety of attachment locations for foot restraints and tie-downs for equipment and components. Lighting for illumination during dark side passes and shadowed areas is provided by two arrays of lights positioned on either side of the primary foot restraint location. Video coverage is provided by portable video cameras attached to portable and adjustable stands Generic tools and other small equipment are stored in a cabinet within easy reach of the EVA crew. Also contained in that cabinet are rechargeable batteries used to provide electrical power when the work station is attached to the MSC. On the opposite side of the crew member, is a control console used to control such functions as lighting, communications, instrumentation, video coverage, heads-up visual displays, etc. It is also used to provide the crew member with control of the MSC position when used as a portable work station.

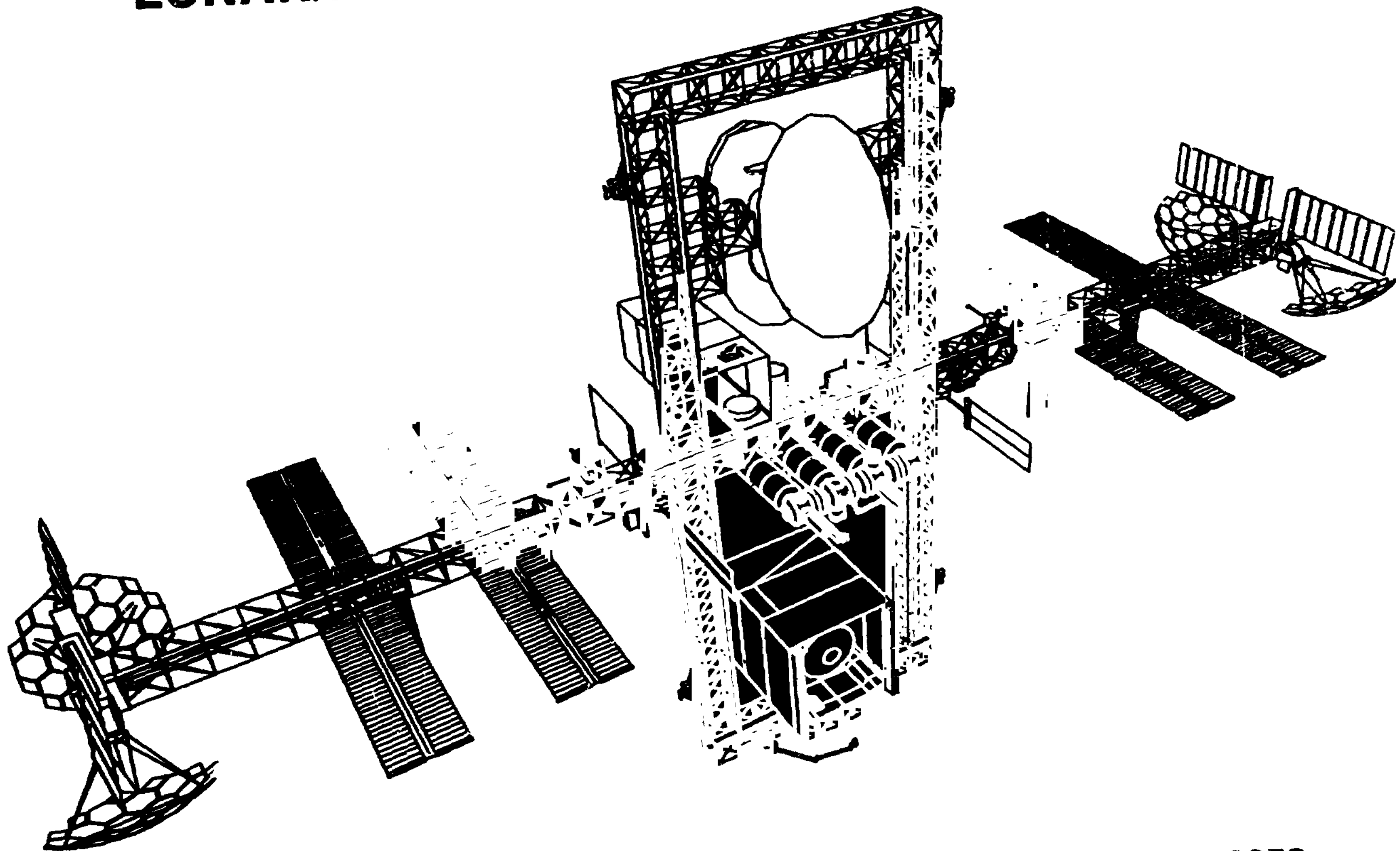
Portable Work Station



Lunar/Mars Transportation Node

Following several stages of evolution, Space Station Freedom is envisioned to become a transportation node supporting lunar and Mars exploration. This drawing shows the facilities to accomplish these missions as well as satellite and OTV servicing. The construction facility described in this paper is the initial evolutionary step in achieving this goal.

LUNAR/MARS TRANSPORTATION NODE



LaRC SSFO

Summary

In summary, a construction facility is needed for technology development demonstrations in support of NASA's Pathfinder Program, for near term construction projects such as Geo Platforms and LDR, and for scientific experiments. The facility proposed here is a cost effective solution because it is a modest size facility that makes use of components that are common to Space Station Freedom. It provides benefits to SSF by providing a portable EVA work station needed for SSF external maintenance and repair. The concept includes both internal and external storage locations for spare parts, components, tools and other assembly aids. It also enhances the location of the microgravity envelope within the modules by lowering the station's center of mass. And, finally, it is the next step in the evolution of Space Station Freedom toward becoming the space transportation node of the future.

Summary

- A construction facility is needed
  - Technology development demonstrations
  - Near term construction projects
  - Science experiments

- The proposed facility is a cost effective solution
  - Modest size
  - Commonality

- Benefits to Space Station Freedom
  - Portable work station
  - Internal and external storage locations
  - Microgravity enhancement
  - Supports Space Station Freedom evolution