SPACE STATION ATTACHED PAYLOADS

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Before considering Space Station Freedom and its planned provisions for accommodating attached payloads, a brief discussion of the evolution of the space station is warranted.

The concept of the space station goes back at least to 1869 when Edward Everett Hale mentioned the "Brick Moon" in the Atlantic Monthly. As illustrated in Figure 1, Hale proposed a spherical space station made of bricks, 60 meters in diameter, that would have a crew of 37, and be located in a 6000-km orbit. The station was envisioned to serve as a navigation aid for ships: communications were to have been by Morse code, with signals created by the station's occupants jumping up and down on the station's exterior surface.

Although there were many other early concepts, serious thinking about actually building a space station began in the late 1940's and into the 1950's with many groups focusing on the practical uses of such a facility. With the 1960's devoted to the Apollo/Saturn program and the 1970's to developing a reusable space transportation system, the space station activity was relegated to the back burner.

When the first space shuttle flew in April 1981, once again the space station was considered the next logical step in manned space flight, and in 1984 the Reagan Administration committed the nation to the goal of developing a permanently manned space station. President Reagan also invited U.S. friends and allies to help with building the space station, thereby creating an international program involving the U.S. and some 15 other countries.

The space station configuration has evolved considering the various requirements of nearly 300 proposed payloads. Figure 2 illustrates the "ideal space station" with some of these user requirements superimposed on a space station configuration. Two things are evident from this figure, first some user requirements conflict with others, and secondly users generally want more than could be afforded. NASA has, however, used these user requirements to shape the space station into the current configuration which also reflects the impact of the Challenger accident as well as budget considerations.

The current space station configuration, shown in figure 3, represents the so-called revised baseline configuration. Eventually this configuration is supposed to grow into an enhanced version which is shown in figure 4. The evolution of the space station configuration will, however, greatly depend on the ultimate use envisioned for the station in the future.

The detailed design is under way with the U.S. and its international partners each working on their parts of the programs. Figure 5 shows the division of responsibilities between the various program participants. The U.S. part of the program has been divided into four work packages as follows:

WORK PACKAGE 1

The Marshall Space Flight Center (MSFC) and its contractor, Boeing Aerospace, will design and manufacture: the astronaut's living quarters - the Habitation Module; the U.S. Laboratory Module; the logistics elements; the resource node structures connecting the modules; the Environmental Control and Life Support System; and the Thermal Control and audio-video systems located within the pressurized modules. It also is responsible for the technical direction of the Work Package 2 contractor for the design and development of the engine elements of the propulsion system. In addition, MSFC is responsible for operations capability development associated with Freedom Station payload operations and planning.

WORK PACKAGE 2

The Johnson Space Center (JSC) and its prime contractor, McDonnell Douglas Astronautics Company, will manufacture: the integrated truss assembly; the propulsion assembly; the mobile transporter system; the outfitting of the resource node structures provided by Work Package 1; the Extravehicular Activity (EVA) system; the external Thermal Control system; the attachment systems for the Space Shuttle and experiments packages; the Guidance, Navigation and Control System; the Communications and Tracking System; the Data Management System; and the airlocks. It is also responsible for the technical direction of the Work Package 1 contractor for the design and development of all man systems. In addition, JSC is responsible for flight crews, crew training and crew emergency return definition, and for operation capability development associated with operations planning.

WORK PACKAGE 3

The Goddard Space Flight Center and its prime contractor, the Astro-Space Division of General Electric Company, will manufacture: the servicing facility, the flight telerobotic servicer, the accommodations for attached payloads, and the U.S. unmanned free-flyer platforms.

WORK PACKAGE 4

The Lewis Research Center and its prime contractor, the Rocketdyne Division of Rockwell International, will manufacture the electrical power systems.

The other countries involved in the space station program include Canada, Japan, and the 13 member countries of the European Space Agency. Canada plans to provide the Mobile Servicing Center which together with a U.S.-provided, rail-mounted, mobile transporter will play the main role in Space Station Freedom's assembly and maintenance, moving equipment and supplies around the station, releasing and capturing satellites, supporting EVA activities and servicing instruments and other payloads attached to the station. Japan plans to provide a multipurpose laboratory which consists of a pressurized module, an exposed facility for attached payloads, and an experiment logistics module. The European Space Agency plans to provide attached and free flying laboratories and an unmanned polar platform.

The program organization is shown in figure 6 and includes level I in NASA Headquarters being responsible for policy and overall program direction; level II, the Space Station Program Office in Reston, Virginia being responsible for program management and technical content; and level III, the various centers involved with the work packages. Included in level III is the Kennedy Space Center with responsibility for launch operations and the Langley Research Center with responsibility for the evolutionary definition of the space station.

The assembly sequence for the station is shown in figures 7 and 8. The assembly begins in 1995 and proceeds from manned-tended capability, to assembly complete capability in some 20 Space Transportation System (STS) flights over a 4-year period. This assembly sequence is continuously being revised as the configuration becomes more defined. There are 13 flights associated with the manned base, 2 outfitting flights, and 4 logistics flights. Congress has also included an extended duration orbiter flight to involve some early activity with attached payloads.

The station will provide a research laboratory in space with the ability to support all types of experiments as indicated in figure 9. The combination of pressurized laboratories, a structure for attached payloads, and unmanned platforms, together with the permanent presence of an interactive crew, will enhance a number of research disciplines. Each research discipline has unique requirements that are satisfied by the station. Life sciences, for example, involves activity inside the pressurized laboratories with continuous crew interaction. Materials processing also requires use of the pressurized laboratories together with high power and low gravity. Earth sciences research is more focused toward the attached payload activity with minimum contamination to instrument visibility. Potential Earth sciences research on the space station is summarized in figure 10 and includes research on geodynamics, land processes, oceanography, and atmospheric dynamics and radiation.

Potential attached payload locations on the space station structure are shown in figure 11 where the Earth-viewing direction is towards the bottom of the figure. There are a number of locations for attached payloads and depending on the class of payload, different payload accommodation requirements which must be provided by the station as shown in figure 12. Major attached payloads, for example, may require active thermal cooling and provisions for pointing by means of a station-provided payload pointing system. Attached payloads could even be as small as distributed sensors in non-standard locations with modest needs for power and data management.

For accommodating attached payloads the space station has attached payload accommodations equipment as shown in figures 13 and 14. This equipment is designed to support payloads that weigh up to 25,000 lbs and provides for power, data management, and active cooling. The multiple payload/deck carrier is designed to accommodate multiple payloads, major payloads, and payloads which require pointing capability. The payload pointing system planned for the station is shown in figure 15 and is designed for 3 axes pointing with provisions for power, active cooling, data management, and payload sensor input for pointing.

To completely cover the station's attached payload capability, additional reference should be made to the Japanese Experiment Module pictured in figure 16. This module has an exposed facility for accommodation of attached payloads. Some of the activity planned on the exposed facility, such as exchange of experimental equipment and construction of large structures in space will require frequent crew access. However, by using a local manipulator and an experiment airlock, both operated within the pressurized module, this access can partially be accomplished while minimizing extravehicular activity.

The station will also be designed to accommodate so-called small and rapid response payloads as indicated in figures 17 and 18. Small and rapid response payloads include trunnion/keel small payloads, genic small payloads and small payloads proposed to be located on the Japanese exposed facility. These types of attached payloads do not require the previously mentioned attached Payload Accommodations Equipment, but include provisions for power, thermal control, and data management.

An important concern for attached payloads is payload visibility. With large panels associated with the station's photovoltic power system and with radiators for heat rejection, etc., the visibility of attached payloads varies greatly depending on payload location. Figure 19 shows some of the viewing restrictions for both space-viewing and Earth-viewing payloads. For Earth-viewing payloads on the lower surface of the station structure the field-of-view varies from 55 to 75 degrees depending on payload location outboard or inboard of the radiator panels.

In summary, the Space Station Freedom is being designed and developed with user requirements being used to shape the configuration. Plans include accommodation provisions for a wide variety of attached payloads including the Earth sciences research activities which are the focus of this conference. The station program is even beginning some preliminary payload manifesting which involves planning for accommodation of payload during the station's assembly flights. Potential payload organizations should be aware of the station's plans for payload accommodations so as to guide their own payload activities for future space station use.

Figure 1: Space Station Concept From 1869 Atlantic Monthly

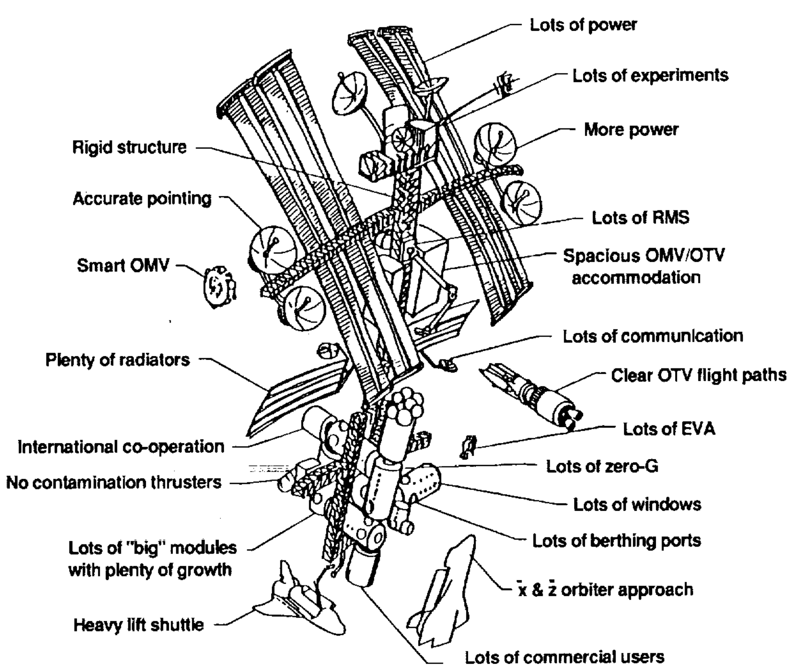


Figure 2: The Ideal Space Station

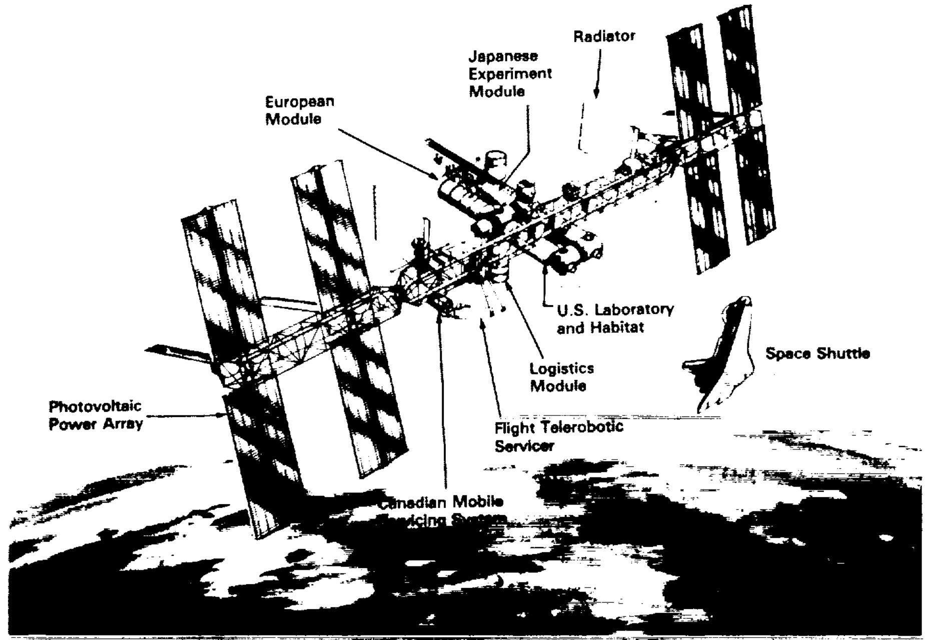


Figure 3: Revised Baseline Configuration

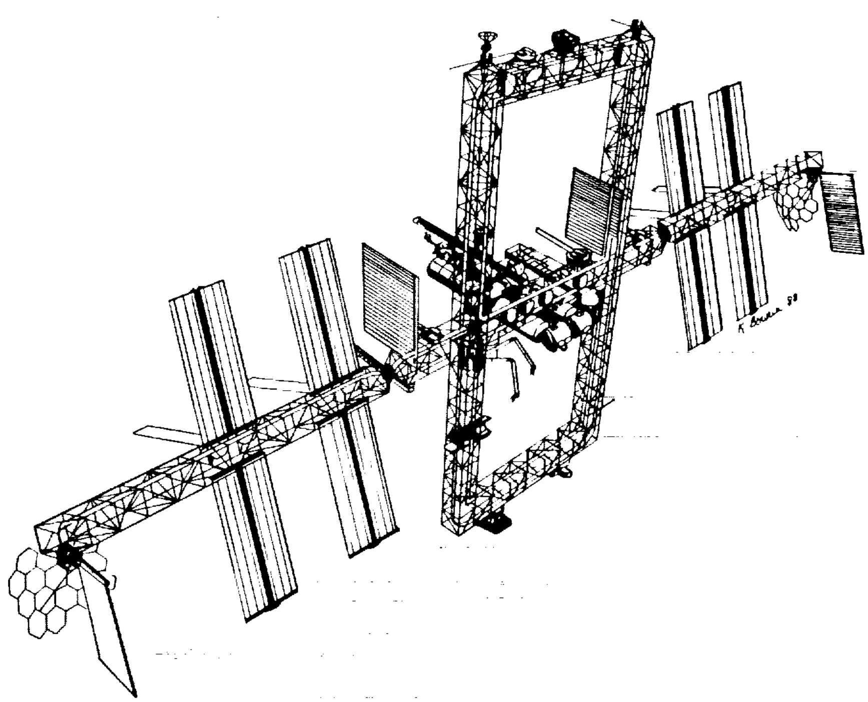


Figure 4: Evolutionary Growth Option

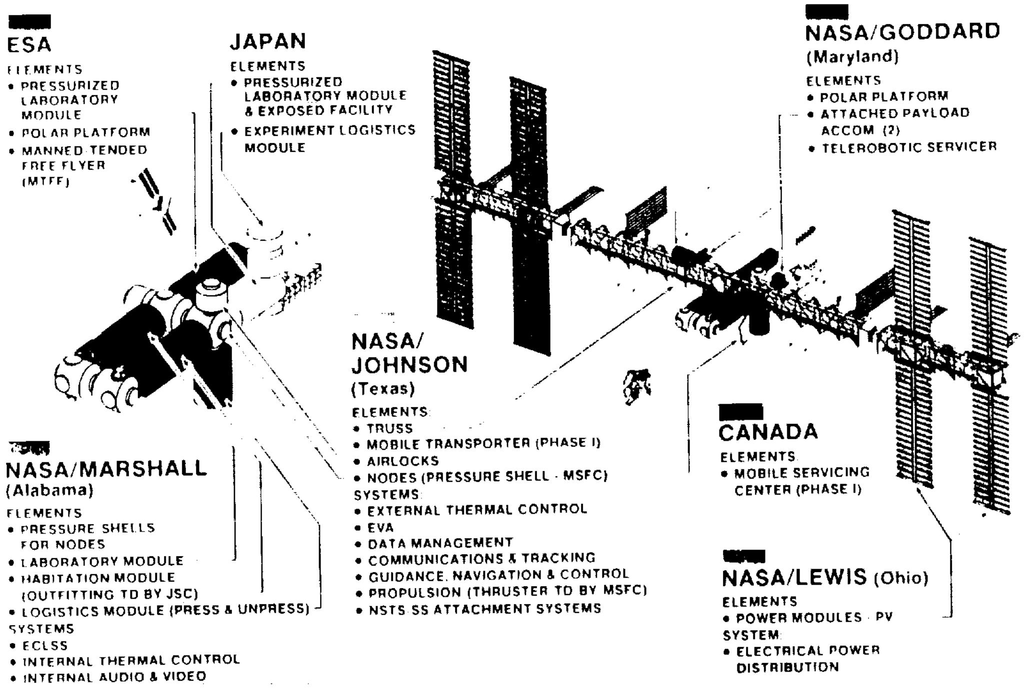


Figure 5: Space Station Freedom Elements and Responsibilities

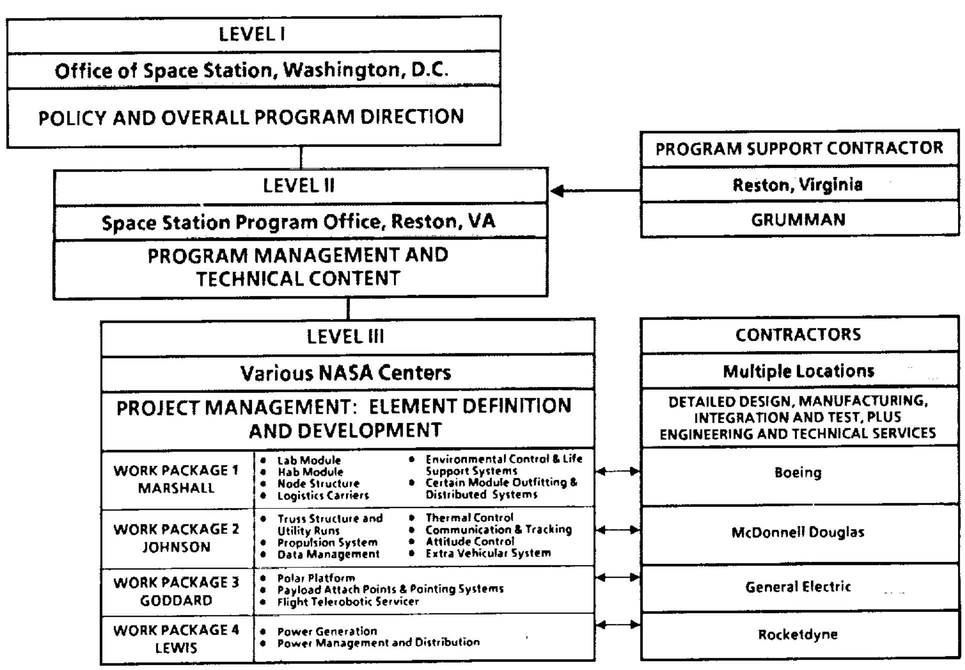
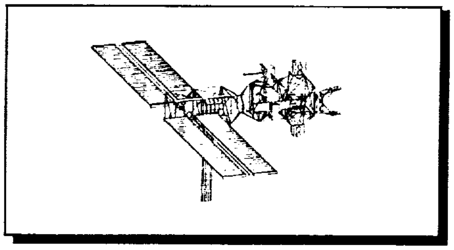
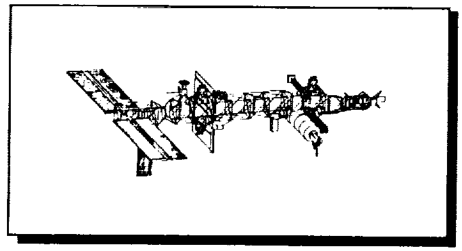


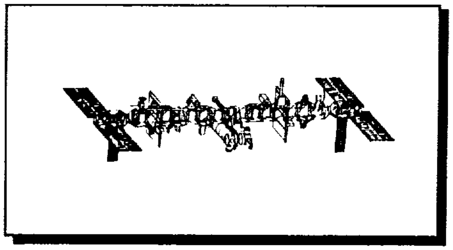
Figure 6: NASA Space Station Freedom Program Organization



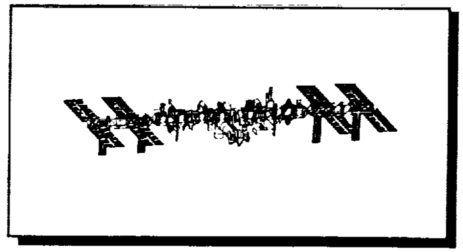
First Element Launch



Man-Tended Capability



Permanently Manned Capability



Assembly Complete

Figure 7: Assembly Sequence Capability Build-Up

	FLIGHT #			
1995	1	MB-1	18.75 PV MODULE, STBD TRUSS, ALPHA JOINT ERECTOR SET, AVIONICS, TANK FARM, WATER ELECTROLYSIS, RCS MODULES (2), UNPRESS. DOCK. ADAPTER, S-BAND ANTENNA	
	2	MB-2	AFT STBD NODE, STBD TCS W/9 RAD. PANELS, FTS AND SHELTER, STINGER/RESISTOJET, TDRSS ANTENNA, TANK FARM, PRESS. DOCKING ADAPTER, CMG'S (6)	
	3	MB-3	AFT PORT NODE, MSC PHASE 1, TANK FARM, STBD RADIATOR PANELS, PRESS. DOCKING ADAPTER, FMAD, STANDARD AIRLOCK	
	4	MB-4	U.S. LAB MODULE	← MAN-TENDED
		P-1	U.S. POLAR PLATFORM	
1996	5	MB-5	PORT INBD PV MODULE, ALPHA JOINT, PORT TRUSS, RCS MODULES (2), PORT RADIATOR, STBD RADIATOR PANELS, TANK FARM, SSEMU VERIFICATION UNIT	
	6	OF-1	PRESS. LOG MOD, MODULE OUTFITTING	
	7	UOF-1	ATTACHED PAYLOADS, MICROGRAVITY LAB OUTFITTING, MAN-TENDED EXPERIMENT OPERATIONS* (UTILIZING EXTENDED DURATION ORBITER)	
	8	MB-6	SSRMS-2, HB AIRLOCK, ATTACH P/L AND EQUIPMENT	
	9	MB-7	U.S. HAB MODULE	
	10	MB-8	FORWARD NODES, CUPOLAS (2)	
	11	MB-9	CREW (4), LOGISTICS MODULES, SSEMU'S (4)	← PERMANENTLY MANNED
1997	12	MB-10	STBD, PORT OUTBOARD PV MODULES	
	13	L-1	LOGISTICS MODULES, SPDM	
		ARIANE	ESA POLAR PLATFORM	
	14	MB-11	JEM MODULE, JEM EXPOSED FACILITY #1, CREW (8)	
	15	L-2	LOGISTICS MODULES, ATTACH P/L AND EQUIPMENT	
	16	MB-12	ESA MODULE	
	17	L-3	LOGISTICS MODULES, MMD PHASE 1	
	18	MB-13	JEM EXPOSED FACILITY #2, JEM ELM, JEM LOGISTICS AND PAYLOADS	
	19	L-4	LOGISTICS MODULES	
1998	20	OF-2	PRESS. LOG MOD, MODULE OUTFITTING	← ASSEMBLY COMPLETE
		ARIANE	ESA MTFF	

* IN THE EVENT FULL MISSION OBJECTIVES CAN NOT BE ACHIEVED ON UOF-1, A SECOND EXTENDED DURATION ORBITER FLIGHT WILL BE ADDED.

Figure 8: Assembly Sequence Flights

STATION ELEMENTS	STATION ATTRIBUTES	DISCIPLINES ENHANCED
• Pressurized laboratories	• Permanent presence	• Life sciences
• Structures for attached payloads	• Interactive crew	• Materials processing
• Unmanned platforms	• Repetitive access	• Astrophysics
	• High level of power	• Earth sciences
	• Gravity force nearly zero	• Technology

Figure 9: Space Station Capability as a Research Laboratory

GOAL: To investigate the Earth as a system, from its interior through the inner magnetospheric boundary.

- **GEODYNAMICS**
  - — Crustal Dynamics
  - — Gravitational and Magnetic Fields
- **LAND PROCESSES**
  - — Terrestrial Ecosystems
  - — Hydrology
  - — Geology
  - — Remote Sensing
- **OCEANOGRAPHY**
  - — Ocean Topography
  - — Ice Formations
- **ATMOSPHERIC DYNAMICS AND RADIATION**
  - — Global Climate Studies
  - — Meteorology
  - — Aerology

Figure 10: Earth Sciences Research on Space Station

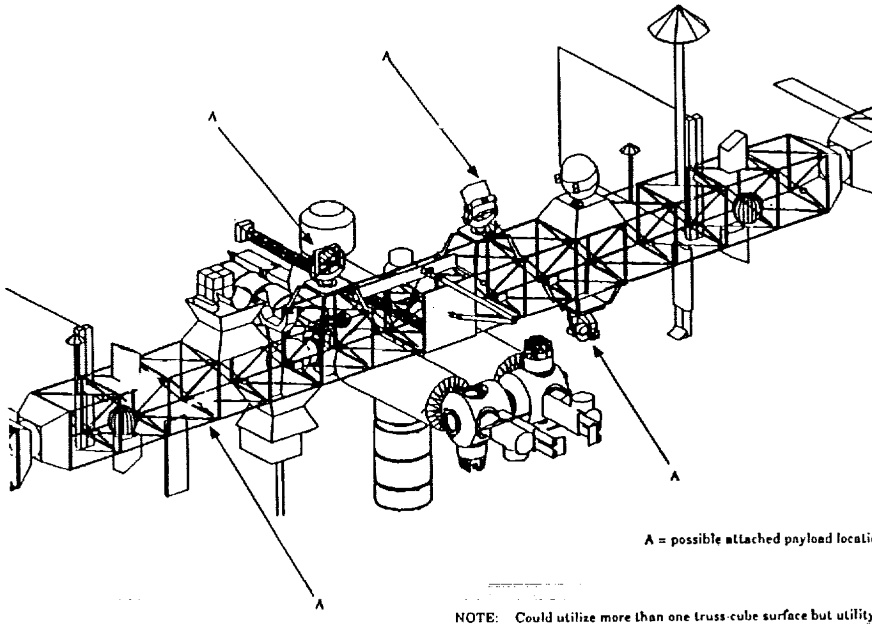


Figure 11: Potential Attached Payload Locations

PAYLOAD CLASSIFICATION

CLASS	PAYLOAD FEATURES
MAJOR	• LARGE • REQUIRES MAJOR APAE RESOURCES • ACTIVE THERMAL COOLING • SOME NEED PPS FOR POINTING • LONG STAY
SMALL AND/OR RAPID RESPONSE	• SMALL • NO ACTIVE THERMAL COOLING • MODEST POWER/DATA RESOURCES • VARIETY OF FIELDS OF VIEW • SET ASIDE RESOURCES
DISTRIBUTED SENSOR	• CAN BE VERY SMALL IN SIZE (LIKE ACCELEROMETER) • NON-STANDARD LOCATIONS • MODEST POWER/DATA RESOURCES • CAN BE ANALYTICALLY INTENSIVE • CAN HAVE UNIQUE PACKAGING

Figure 12: Manned Base Attached Payload Accommodations

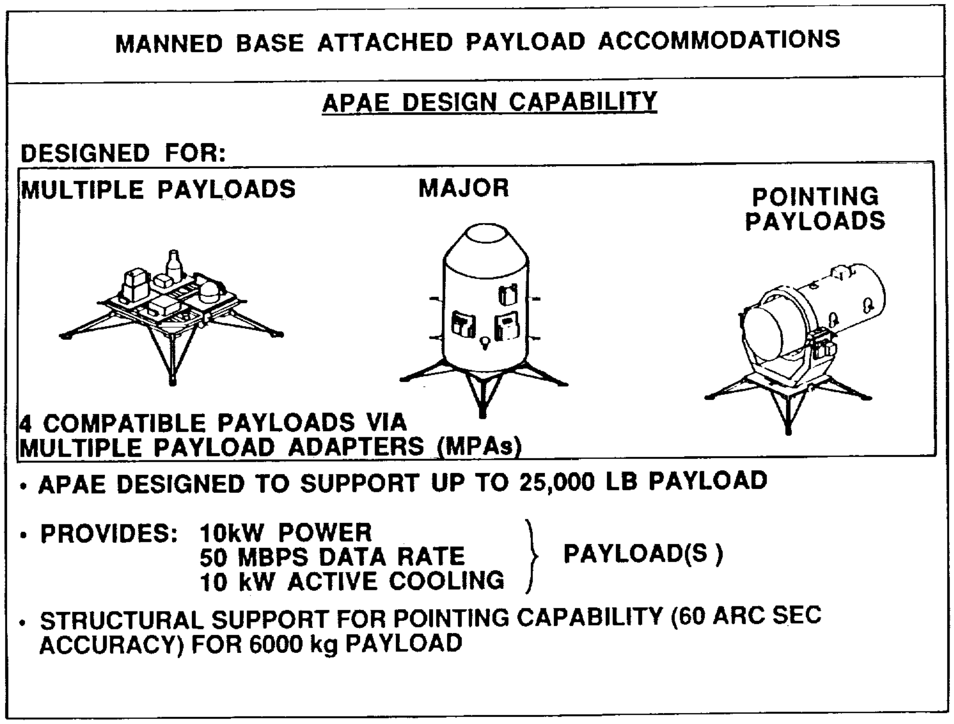


Figure 13: Attached Payload Accommodation Equipment (APAE) Design Capability

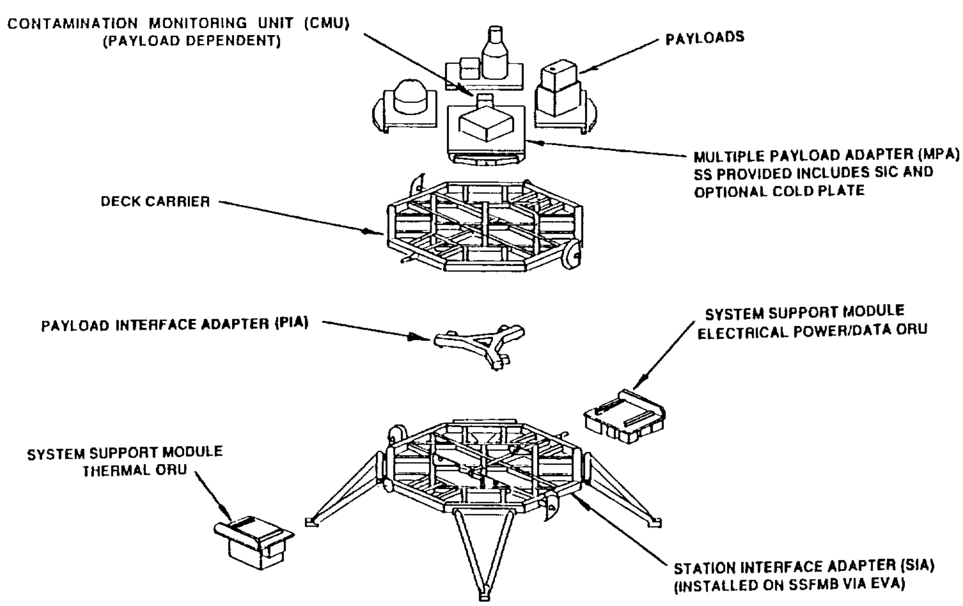


Figure 14: Multiple Payload/Deck Carrier Configuration

- 1 ARC MINUTE POINTING ACCURACY
- 30 ARC SECOND POINTING STABILITY (OVER 1800 SECS)
- 15 ARC SECOND/SECOND JITTER
- 3 AXES
- 5 kW OF POWER/ACTIVE COOLING
- 50 MEGABITS HIGH RATE DATA/IMAGERY
- 6000 kG PAYLOAD - 3 METERS WIDE, C.G. TO BASE 2.5 METERS
- ACCEPTS PAYLOAD SENSOR INPUT FOR POINTING

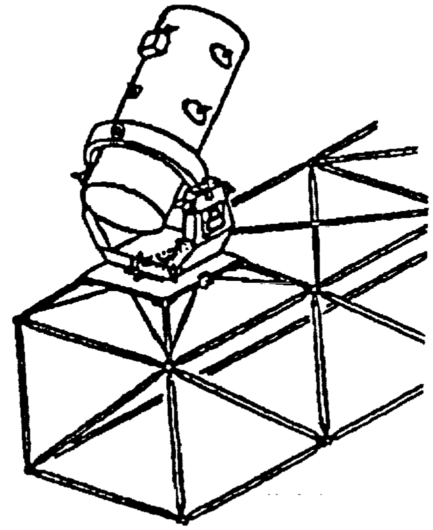


Figure 15: Payload Pointing System (PPS)

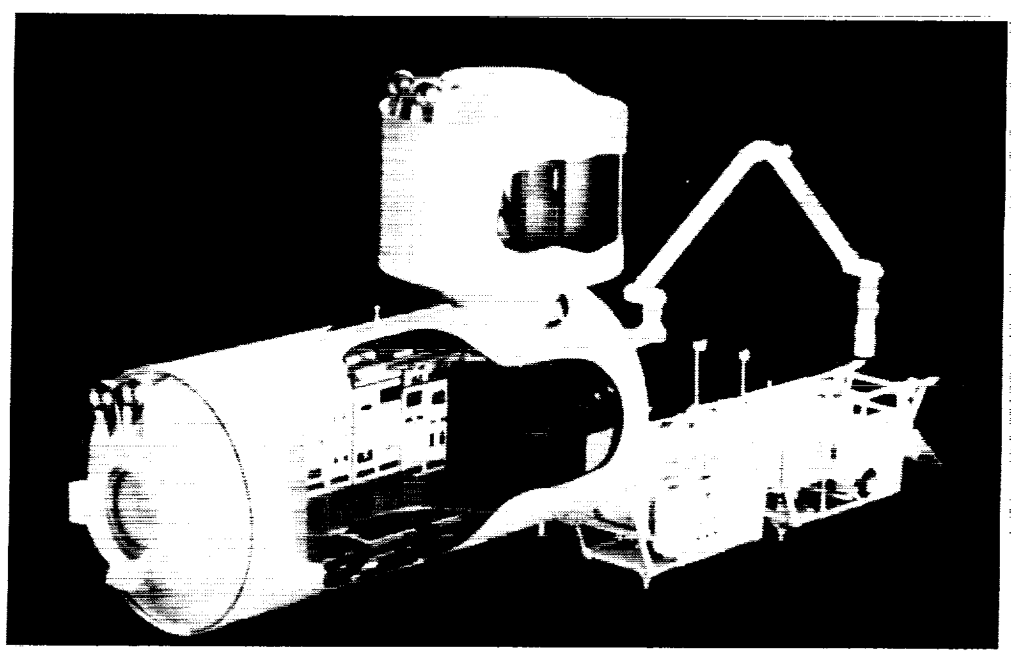


Figure 16: Japanese Experiment Module

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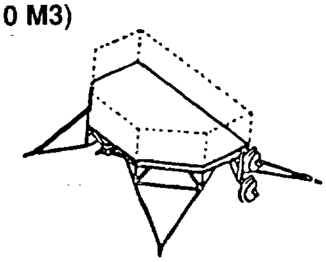
EXTERNAL SARR PAYLOAD ENVELOPE & PROPOSED CONSTRAINTS

TRUNNION/KEEL (T/K) SARR PAYLOAD:

FIT INTO 4M X 1.25M X 2M ENVELOPE (MAX VOL < 10 M3)

- ≤ 900 kG
- ≤ 900 WATTS
- ≤ 0.3 MBPS UPLINK/2.0 MBPS DOWNLINK
- ≤ 100 MB DATA STORAGE/ORBIT

CAN ACCOMMODATE MORE THAN ONE PAYLOAD
RMS GRAPPLE FIXTURE (ON T/K CARRIER)



GENERIC (GEN) SARR PAYLOAD:

FIT INTO 1.25 M X 1.25 M X 1.25 M ENVELOPE (MAX VOL ≤ 2 M3)

- ≤ 300 kG
- ≤ 300 WATTS
- ≤ 0.3 MBPS UPLINK/2.0 MBPS DOWNLINK
- ≤ 100 MB DATA STORAGE/ORBIT

ORU COMPATIBLE I/F (ORU TOOL)

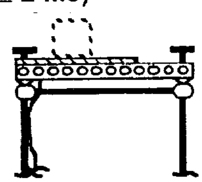


Figure 17: Small and Rapid Response Payloads

INTERFACE COMPARISON CHART FOR RELATIVELY SMALL ATTACHED PAYLOADS* ON TRUSS AND JEM EF (PROPOSED)

Interface or Physical Constraint	PAYLOAD		
	SARR Trunnion Keel	SARR Generic	JEM Exposed Facility
Weight	≤ 1980 lbs ≤ 900 kg	≤ 660 lbs ≤ 300 kg	typically 1100 lbs or 500 kG
Volume Limitations Physical Dimensions	~ 10m3 1.25m x 2.0m x 4.0m	~ 2m3 1.25m x 1.25m x 1.25m	~ 2m3 0.8m x 1.0m x 1.85m (0.8m x 1.0m footprint)
Thermal Cooling	only passive	only passive	≤ 6kW active cooling
Power Constraint	≤1.5kW	≤0.3kW	≤6.0kW
Data Rates Downlink Uplink	 2.0 Mbps 0.3 Mbps	 1.4 Mbps 0.3 Mbps	 4 Mbps 4 Mbps
Access to Pressurized Module	None	None	Possible thru JEM Airlock
Pointing Capability Provided	None	None	None

* These do not require an APAE

Figure 18: Small and Rapid Response Payloads Interface Comparison

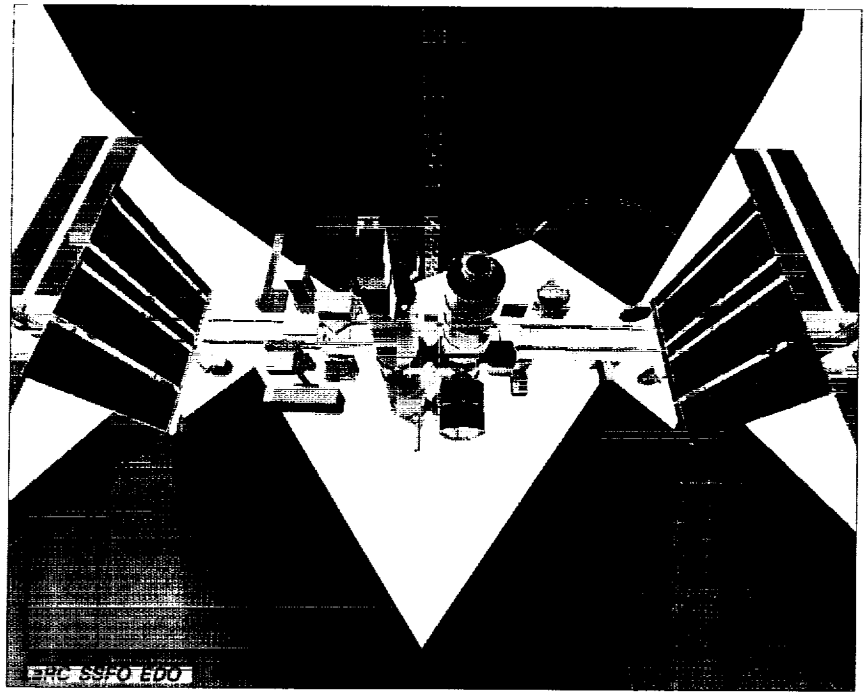


Figure 19: Maximum Unobstructed Symmetric Fields of View