MSD

GRAPHICAL ANALYSIS

OF

MARS VEHICLE ASSEMBLY

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The task assigned to the Mission Planning and Analysis Division for FY89 was to produce a video tape depicting the assembly of a Mars Piloted Vehicle at a man tended vehicle assembly platform, co-orbiting with Space Station Freedom. This request was made by the Transportation Node Integration Agent of the Lunar/Mars Exploration Office. Along with the request, a data package was provided which contained the latest technical briefings by the Transportation Node and Space Transportation Integration Agents. This information was used as the basis of a conceptual study performed using kinematic manipulator simulations.

MARS VEHICLE ASSEMBLY ANALYSIS

CONCEPTUAL STUDY OF THE ASSEMBLY OF A MARS VEHICLE AT A CO-ORBITING, MAN-TENDED TRANSPORTATION NODE PERFORMED IN SUPPORT OF THE TRANSPORTATION NODE INTEGRATION AGENT OF THE LUNAR/MARS EXPLORATION OFFICE

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BASELINE ASSUMPTIONS:

- MARS VEHICLE ASSEMBLY FIXTURE BASED ON LOCKHEED "SKYHOOK"
- FLIGHT MANIFESTS BASED ON WORK BY EAGLE ENGINEERING
- ERECTABLE AEROBRAKE DESIGN (HUB AND PETAL)
- ETO LAUNCH VEHICLE: SHUTTLE "Z" (124.4 MT TO LEO)
- MANIPULATOR OPERATIONS PERFORMED USING CURRENT (PRE-SCRUB) DESIGN OF SPACE STATION FREEDOM (SSF) MOBILE SERVICING CENTER (MSC)

RESULTS OF ANALYSIS:

- COMPUTER GRAPHICS VIDEO TAPE OF ASSEMBLY OPERATIONS

Due to time constraints, it was decided to use the Space Station Freedom Mobile Servicing Center (MSC) as the manipulator for this study, since this system was already modeled in the simulation. The provided design of the Mars Vehicle Assembly Fixture, dubbed the Skyhook by its developers at Lockheed, was incompatible with MSC in terms of manipulator reach capability and mobile base positioning requirements. In addition, the Skyhook provided inadequate storage facilities for the Trans-Mars Injection Stages, which were also used to store the propellant required for the interplanetary mission. For these reasons, the Skyhook was modified.

The flight manifests developed by Eagle Engineering dealt only with the lift capability of the Shuttle "Z" launch vehicle and made no mention of the arrangement of the elements in the cargo bay. Since this analysis was conceptual in nature, it was decided to worry only about volume constraints when depicting the individual flight manifests involved in the vehicle assembly process. These volume constraints also drove the design of the aerobrake. The data package provided hub-and-petal designs which involved either eight or ten petals. Sizing of the aerobrake and attempting to fit it in the Shuttle "Z" cargo bay forced the development of a twelve petal model.

Deployment of the completed Mars vehicle is a major operational concern. A mechanism will probably be required to provide adequate clearance between the vehicle and the assembly fixture before any separation reaction control system firings are allowed. In addition, the size and mass of the Trans-Mars Injection Stages would seem to make the standard MSC design unsuitable for their transportation to and from the storage area. In response to these problems the concept of a "High Mass Mobile Transporter" was devised. This mechanism, which is modeled as the transportation mechanism of the MSC fitted with fifteen meter slide mechanism for the purpose of payload handling, was used in this study for both of the aforementioned tasks.

MARS VEHICLE ASSEMBLY ANALYSIS

MARS VEHICLE ASSEMBLY FIXTURE (SKYHOOK) MODIFIED TO ACCOMMODATE:

- MSC CAPABILITIES
  - REACH AND CLEARANCE
  - MOBILE TRANSPORTER DESIGN
- TRANS-MARS INJECTION STAGE (TMIS) STORAGE REQUIREMENTS

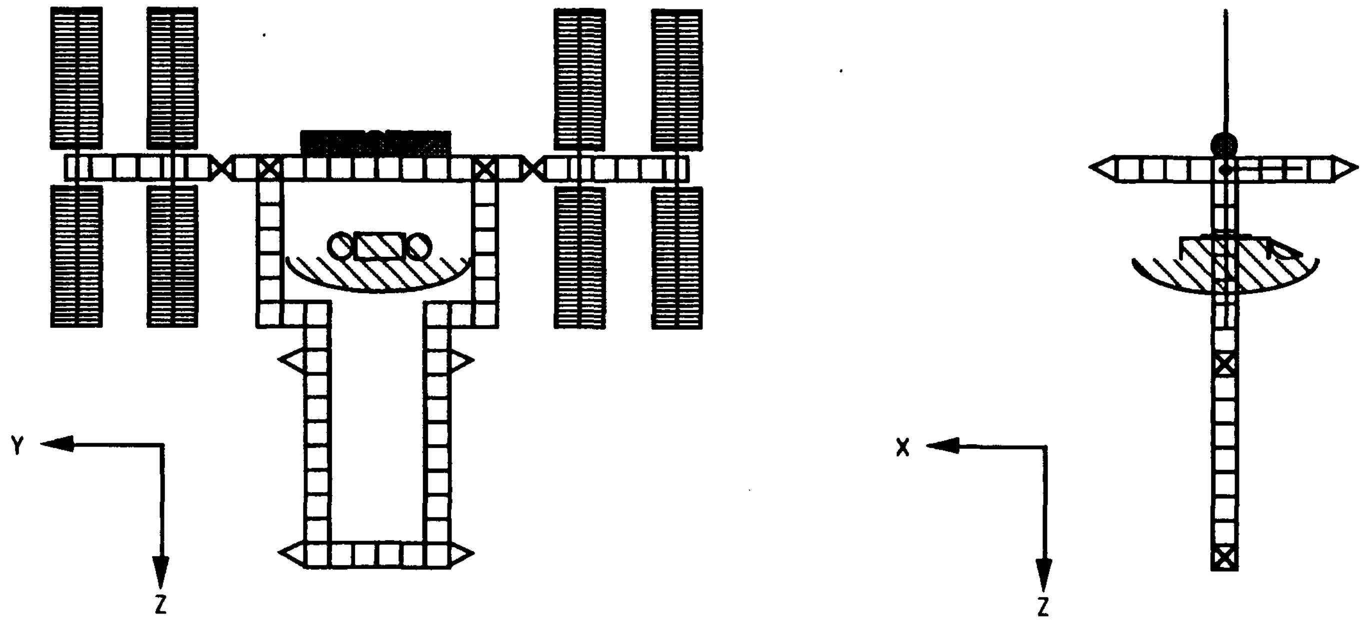
INDIVIDUAL FLIGHT MANIFESTING BASED SOLELY ON VOLUME CONSTRAINTS

DEVELOPED TWELVE PETAL AEROBRAKE DESIGN TO ACCOMMODATE SHUTTLE "Z" VOLUME CONSTRAINTS

INTRODUCED "HIGH MASS MOBILE TRANSPORTER" (HMMT) TO ACCOMMODATE:

- DEPLOYMENT OF COMPLETED MARS VEHICLE
- TRANSPORTATION OF FULLY FUELED TMIS

MARS VEHICLE ASSEMBLY ANALYSIS

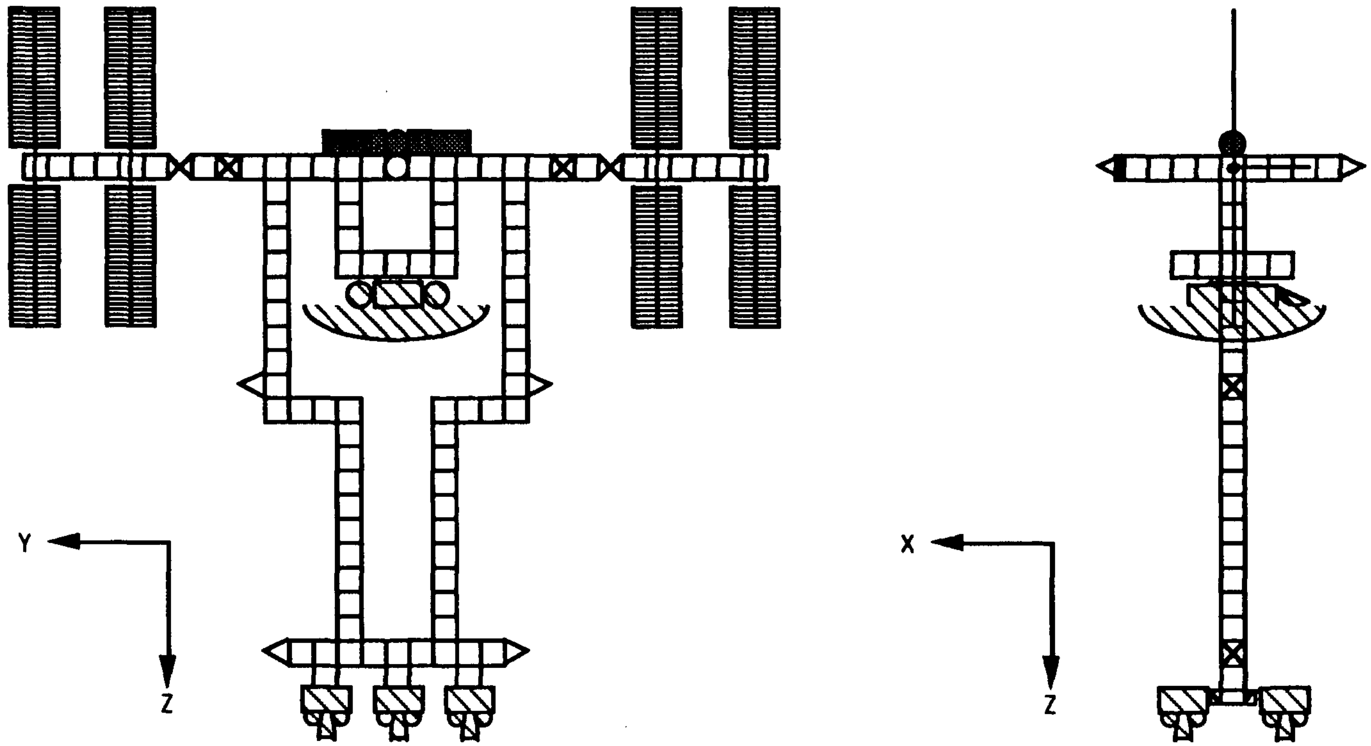


LOCKHEED SKYHOOK

The original design of the Lockheed Skyhook consists of a transverse boom, front and back "porches", and two descending keels, which extend to a short lower boom. Unfortunately, with this design, the MSC does not have anyplace to stand which allows adequate proximity to the primary work areas inside the hollow of the aerobrake. The aerobrake must be positioned as shown in the figure to allow for the installation of the excursion vehicle later in the assembly sequence. Another important drawback in this design involves the intersection of the keels and porches with the transverse boom. The manner in which the MSC attaches to the truss structure precludes the mechanism form standing on a trussbay face which makes an inside corner with another trussbay face. It is therefore impossible for a MSC which is operating on either the transverse boom or on one of the porches to maneuver itself onto one of the keels. This constraint also exists for the High Mass Mobile Transporter.

While the basic design for the modified Skyhook is unchanged, the transverse boom has been extended to allow an appropriate offset between the porches and the keels. Additional truss structure has been added to allow the MSC access to the primary working area during assembly. The size of this new structure is driven by the necessity of the MSC to be able to acquire access to the structure and maneuver freely on it. The excursion vehicle fits through the opening in the structure to its attach point on the central hub of the vehicle. Comparison of the lower keel on this modified vehicle assembly fixture with its counterpart on the original Skyhook will illustrate the lack of adequate storage space on the original design.

MARS VEHICLE ASSEMBLY ANALYSIS



MODIFIED SKYHOOK

The modification of the Skyhook resulted in a significant increase in size, which is illustrated in this table. Since the major difference is in the number of trussbays, the change in mass is relatively minor.

MARS VEHICLE ASSEMBLY ANALYSIS

RESULTS OF SKYHOOK MODIFICATION

	BEFORE	AFTER
MASS (MT)	89	94
TRUSS BAYS	96	154
HEIGHT(M)	120	150
WIDTH(M)	135	160
DEPTH(M)	50	50

The next two charts show the flight manifests depicted in the assembly video.

MARS VEHICLE ASSEMBLY ANALYSIS

FLIGHT MANIFESTS

- FLIGHT ONE
  - MARS PILOTED VEHICLE (MPV) CORE (INCLUDES AEROBRAKE HUB)
  - TRANS-EARTH INJECTION STAGE (TEIS) TANKS
  - AEROBRAKE PETALS
  - TMIS
- FLIGHT TWO
  - TEIS ENGINES
  - SOLAR ARRAYS (2)
  - HABITATION MODULE SUPPORT TUBES (2)
  - COMMUNICATIONS ANTENNA FARM
  - TMIS
- FLIGHT THREE
  - HABITATION MODULE ASSEMBLIES (2)
  - TMIS

Integration of the design of the transportation node with the design and operational requirements of the supporting manipulator system is mandatory in order to optimize the size and cost of both systems. The fact that the assembly fixture used in this study is an order of magnitude larger than Space Station Freedom reflects this fact. While this study shows that the current design of the MSC provides adequate reach to support the assembly of large interplanetary vehicles, it is also clear that the mass handling capability of the current MSC design is insufficient for this task. Deployment of the completed vehicle will also be a major driver in vehicle, assembly fixture, and mechanism design.

MARS VEHICLE ASSEMBLY ANALYSIS

FLIGHT MANIFESTS (CONTINUED)

- FLIGHT FOUR
  - PHOBOS/DEIMOS EXCURSION VEHICLE
  - TMIS
- REMAINING FLIGHTS DELIVER TMISs AND FUEL

The following pages contain figures which were produced using the same database and software package which was used to produce the video which documents this study. The credits which apply to this video are as follows:

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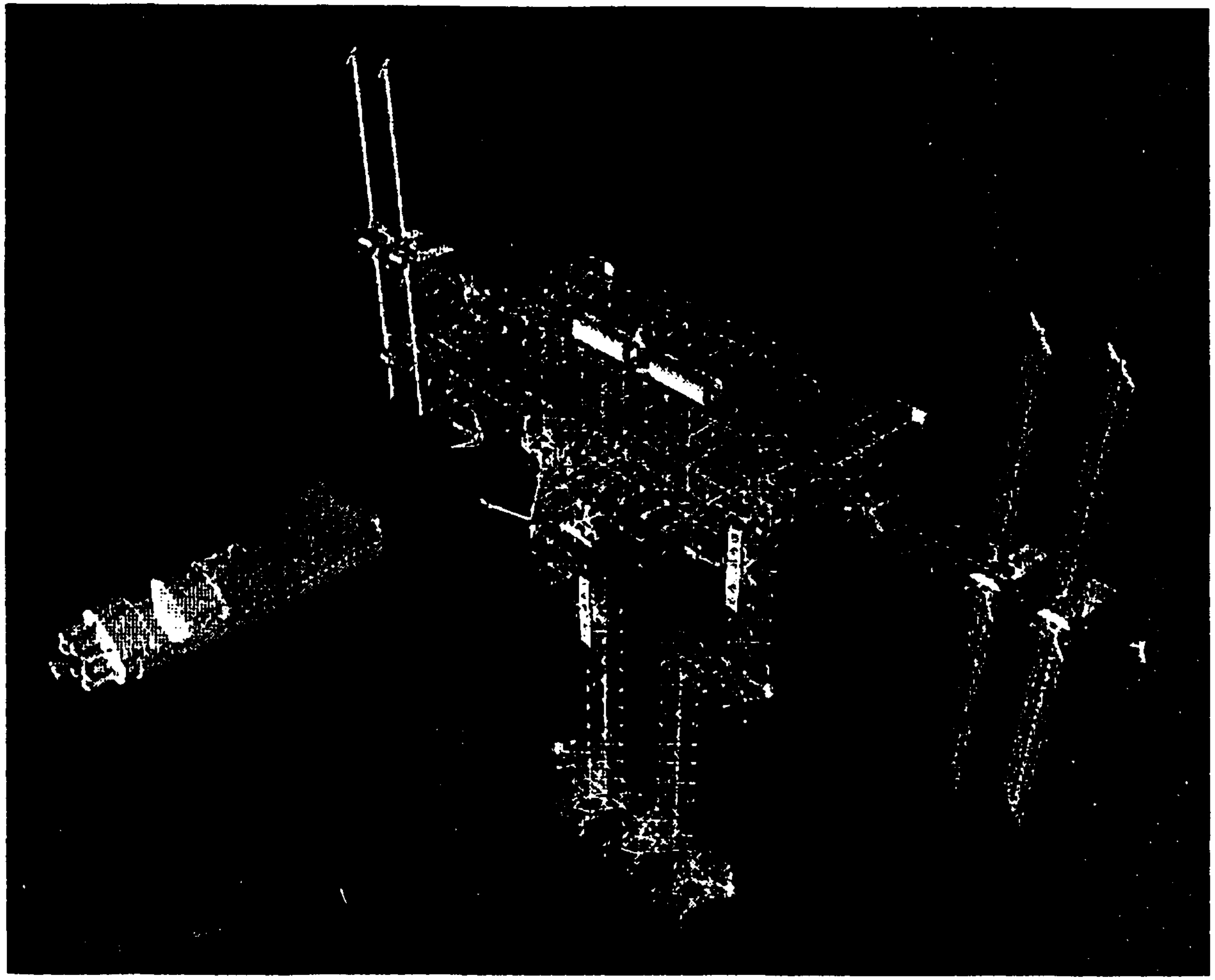
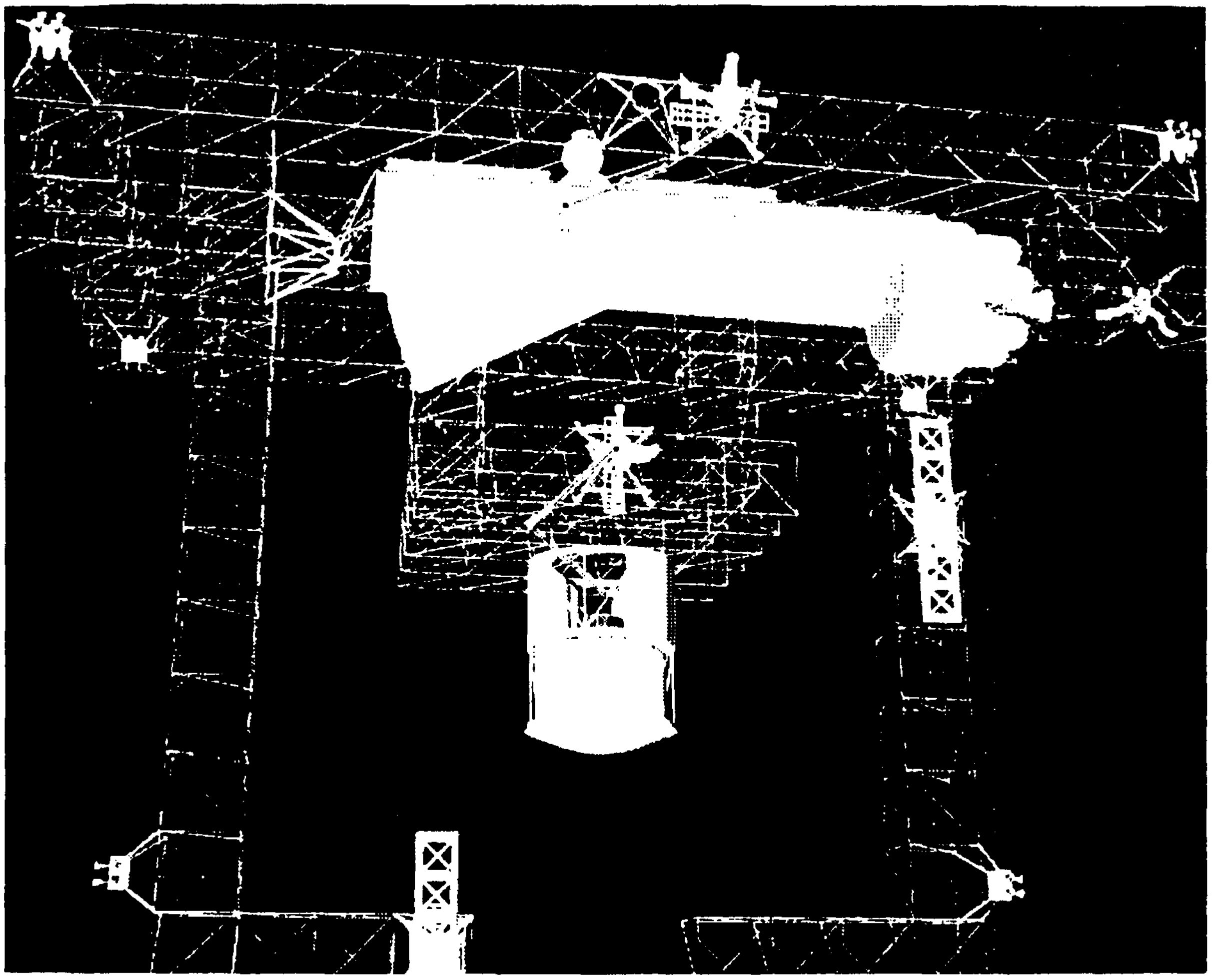
MARS VEHICLE ASSEMBLY ANALYSIS

CONCLUSIONS/KEY ISSUES

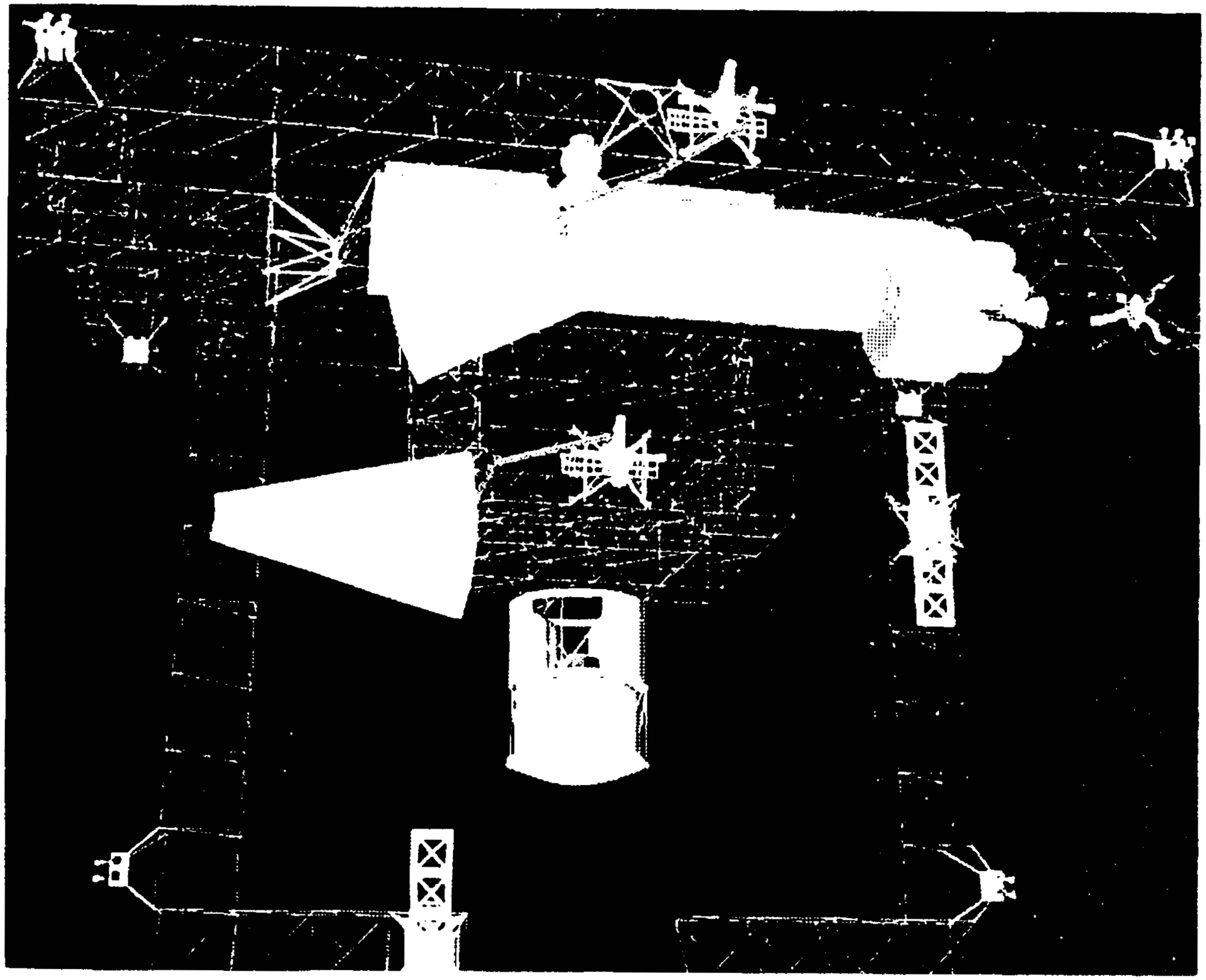
- TRANSPORTATION NODE MUST BE DESIGNED TO ACCOMMODATE MANIPULATOR OPERATIONS
- TRANSPORTATION NODE ORDER OF MAGNITUDE LARGER THAN SSF
  - 154 BAYS OF TRUSS VS. 21
  - 17 BAYS BETWEEN ALPHA JOINTS VS. 15
- REACH CAPABILITY OF CURRENT SSF MSC ADEQUATE TO PERFORM ALL ASSEMBLY TASKS ANALYZED
- MASS HANDLING CAPABILITY OF CURRENT SSF MSC INADEQUATE TO PERFORM ALL ASSEMBLY TASKS ANALYZED.
  - MSC MUST MANEUVER FULLY LOADED SHUTTLE "Z" (137.4 MT)
- MOBILE TRANSPORTERS MUST HAVE FULL PLANE CHANGE AND CORNER TURNING CAPABILITY
- DEPLOYMENT DEVICE (HMMT) MUST BE CAPABLE OF HANDLING FULL-UP MARS VEHICLE (MPV + 6 TMIS: 1050 MT)



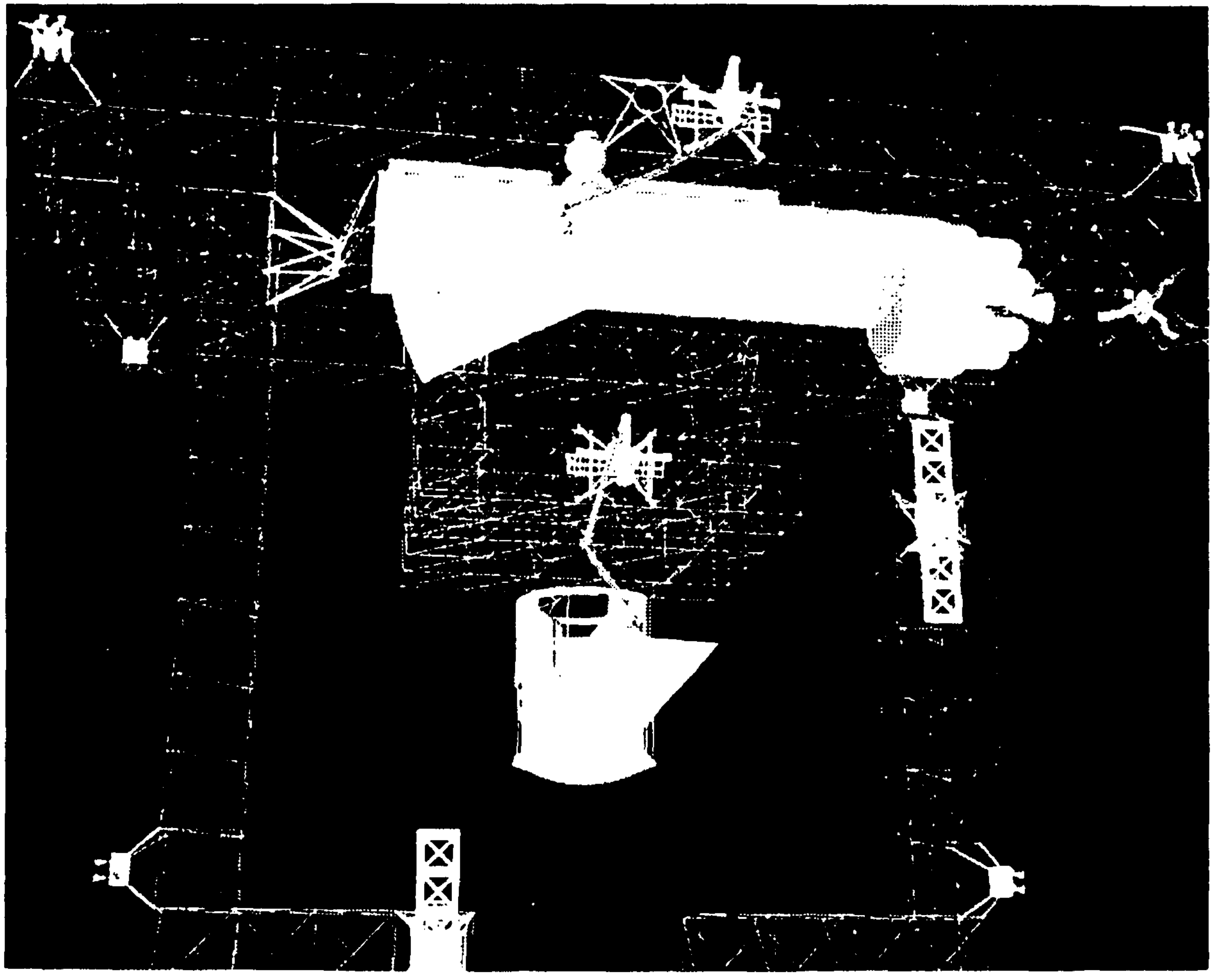
Shuttle 2 Approaching Skyhook



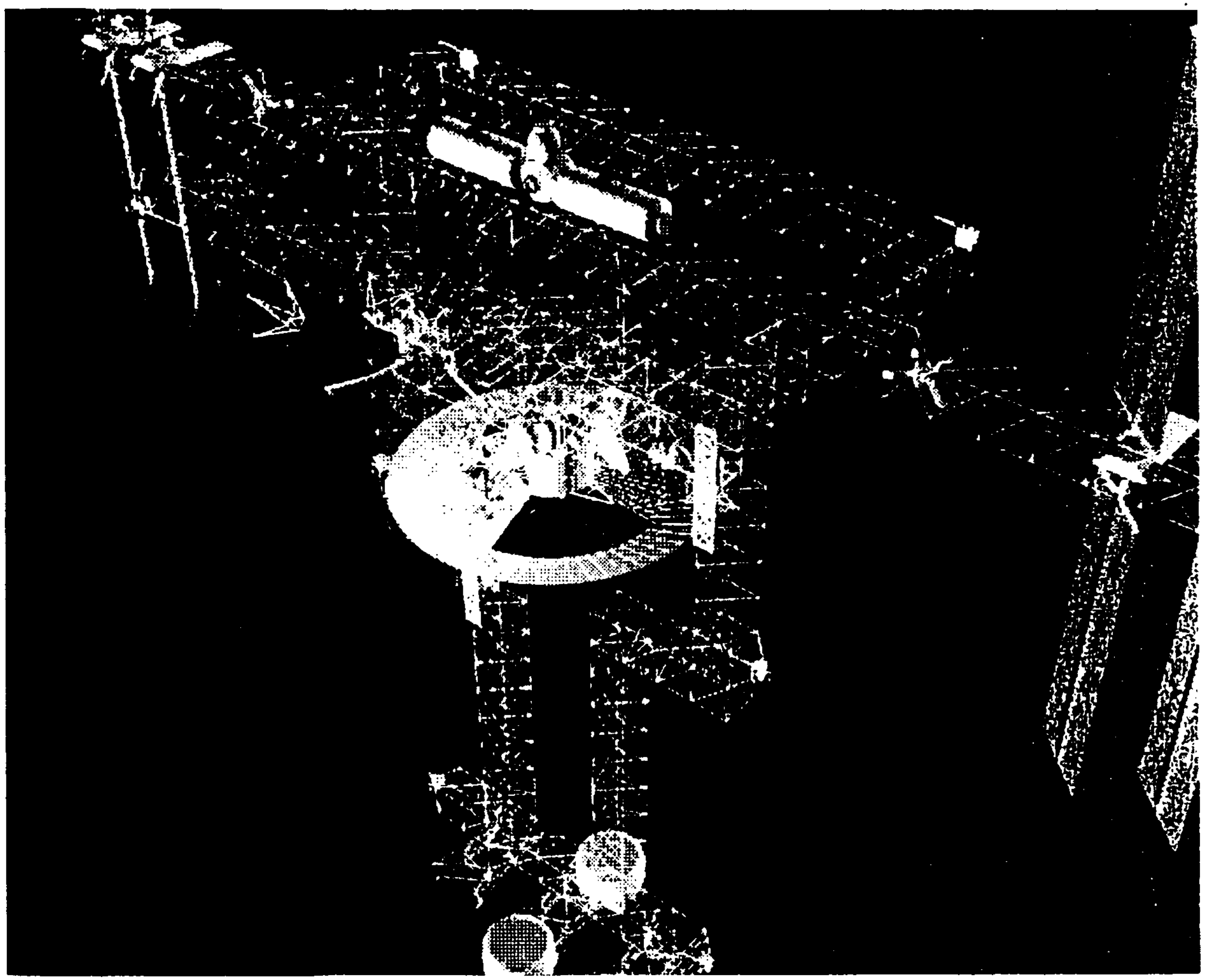
MSC placing core in construction position



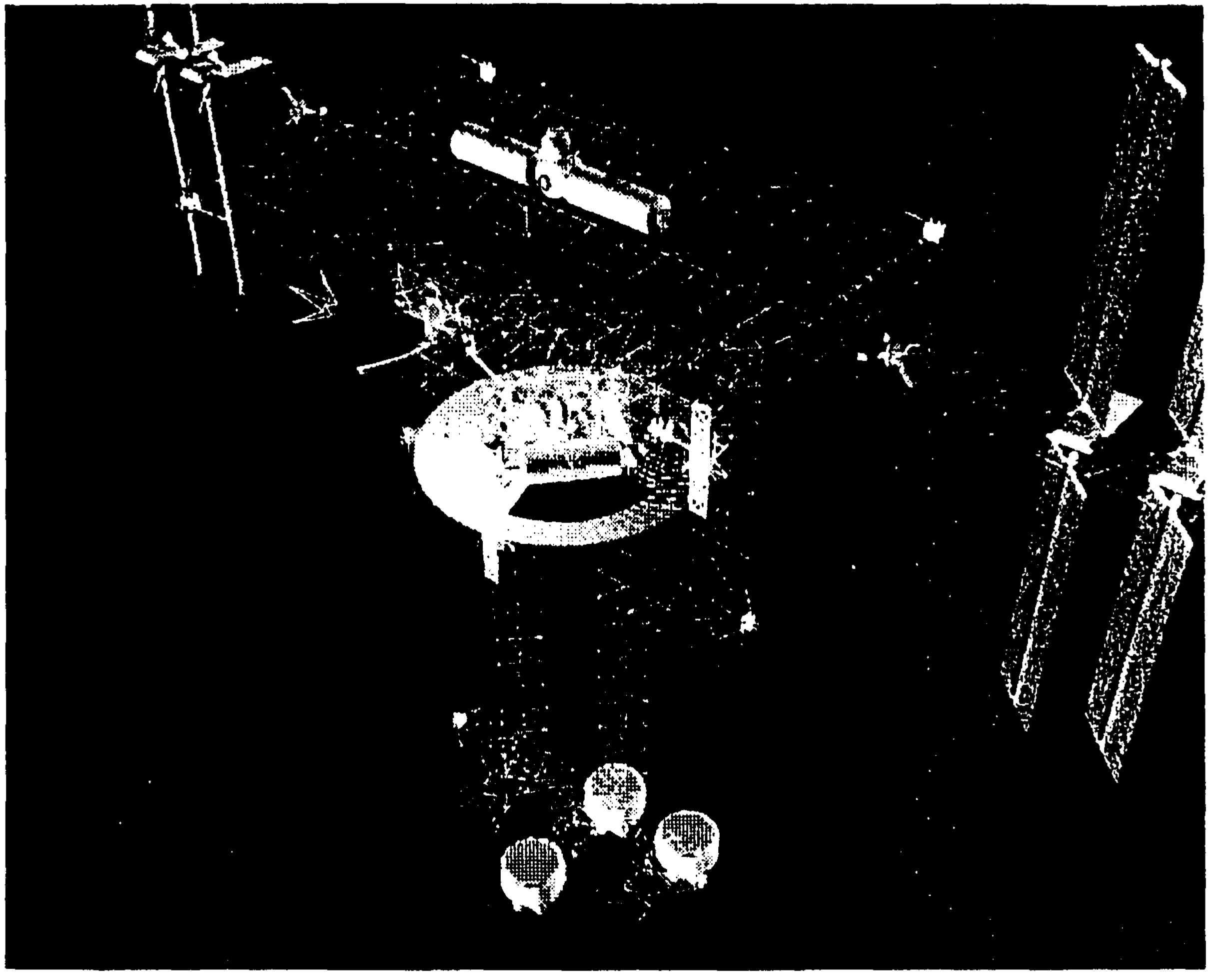
MSC retrieves 1st aero shell piece



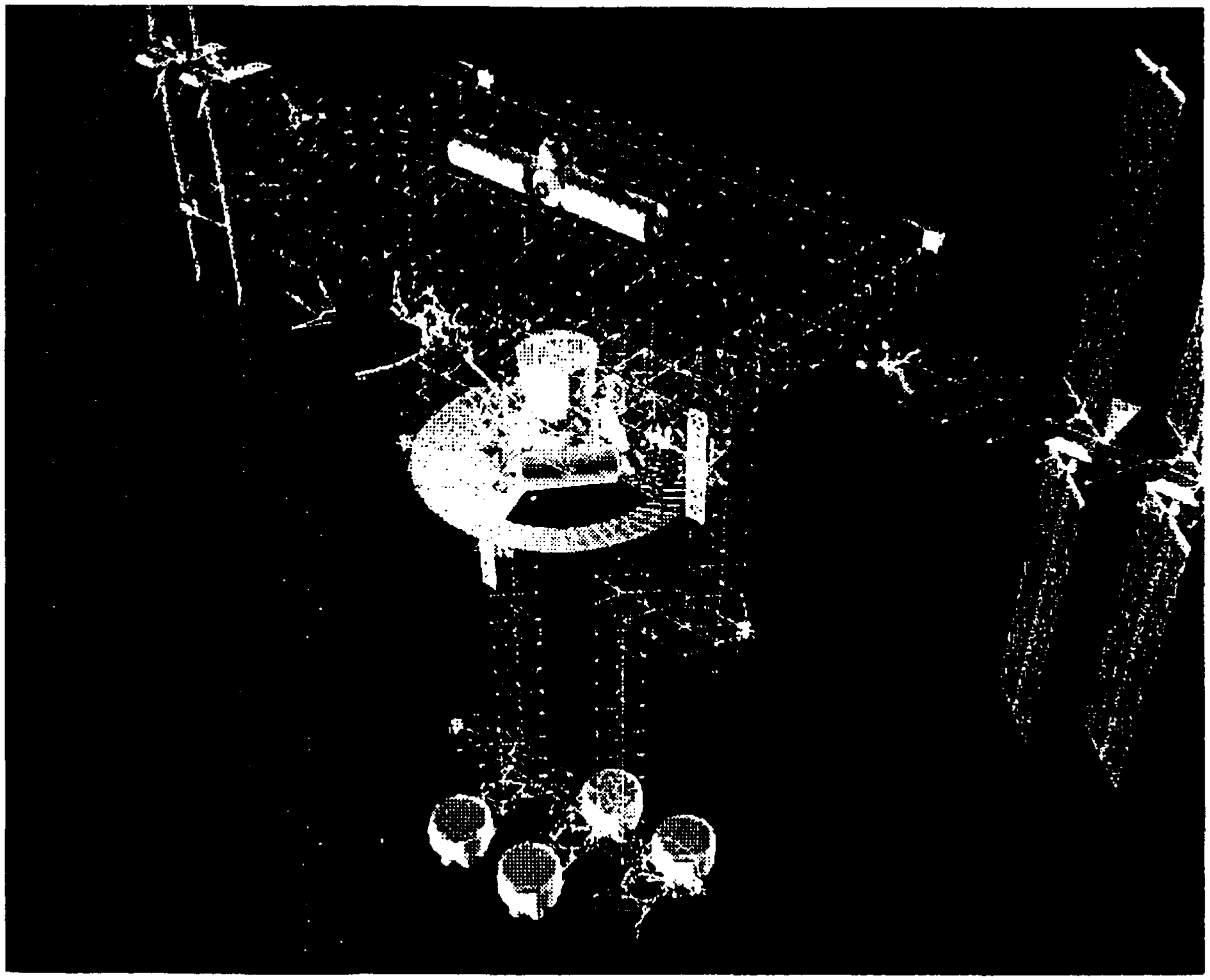
MSC places 1st clamshell piece



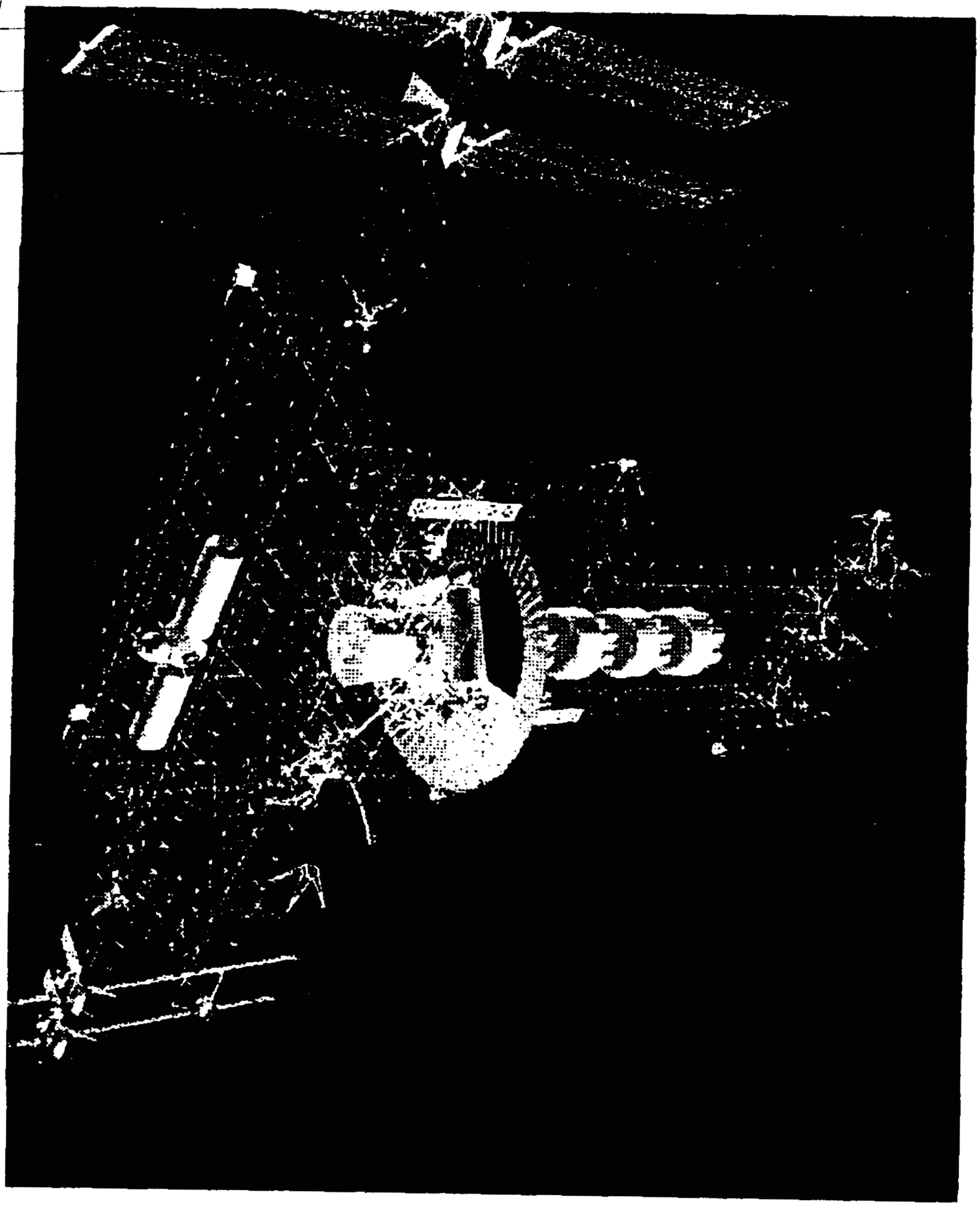
Finish of flight 2



finish of flight 3



Finish of Flight 4



finish of construction