ERECTABLE/DEPLOYABLE CONCEPTS FOR LARGE SPACE SYSTEM TECHNOLOGY

W. E. AGAN
VOUGHT CORPORATION

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OUTLINE

This presentation reports the progress and status that the Vought Corporation has made on the Erectable/Deployable Concepts Contract for the Marshall Space Flight Center. Mr. Erich Engler is the Contract Monitor. The order of presentation starts with a statement of the objective and scope which sets the stage for the work that has been completed. A brief schedule and the six individual tasks are identified along with what has been accomplished in each of those areas. A short, 16 mm, film of the deployment of a structural module demonstrates the applicability of this effort toward near term missions.

Outline

- Objective and scope
- Schedule
- Development of new erectable space structure concepts
- Preliminary design of selected systems
- Preliminary development of assembly techniques and aids
- Component fabrication and test
- Tolerance and utility analysis
- Payload/experiment carrier design study
- Module deployment film
- Summary

OBJECTIVE

The objective of this program is to develop new joints and/or elements to build a technical data base for near term space platform missions. This objective is fulfilled by identifying new structural members and attachments.

Objective

Contribute to the overall data base for various proposed missions/projects using erectable/deployable structures through the identification and analysis of new structural elements approaches and end attachments.

SCOPE

The contract is basically comprised of six tasks. The first task is a review of what work had been done in the past. From that data base, new designs are developed and compared to each other and existing designs. The most promising concepts are selected for preliminary design. Next is the development of preliminary assembly techniques and aids followed by a component fabrication and proof of concept test. Two additional tasks were added to the contract to emphasize utility incorporation and tolerance analyses into the overall design of the joints and members. The sixth task was a payload experiment design study.

Scope

Task 1: Development of new erectable space structure concepts

- Review all LSS missions to date
- Review all LSS structural concepts proposed to date
- Generate new concepts

Task 2: Preliminary design of selected systems

- Evaluation and selection criteria
- Investigate existing concepts
- Establish new concepts
- Evaluate all concepts
- Preliminary design

Task 3: Preliminary development of assembly techniques and aids

- Requirements
- Definition and evaluation
- EVA/manned assembly demonstration and simulation program

Task 4: Component fabrication and test

Task 5: Tolerance and utility analysis

- Tolerance study
- Incorporation of utility provisions

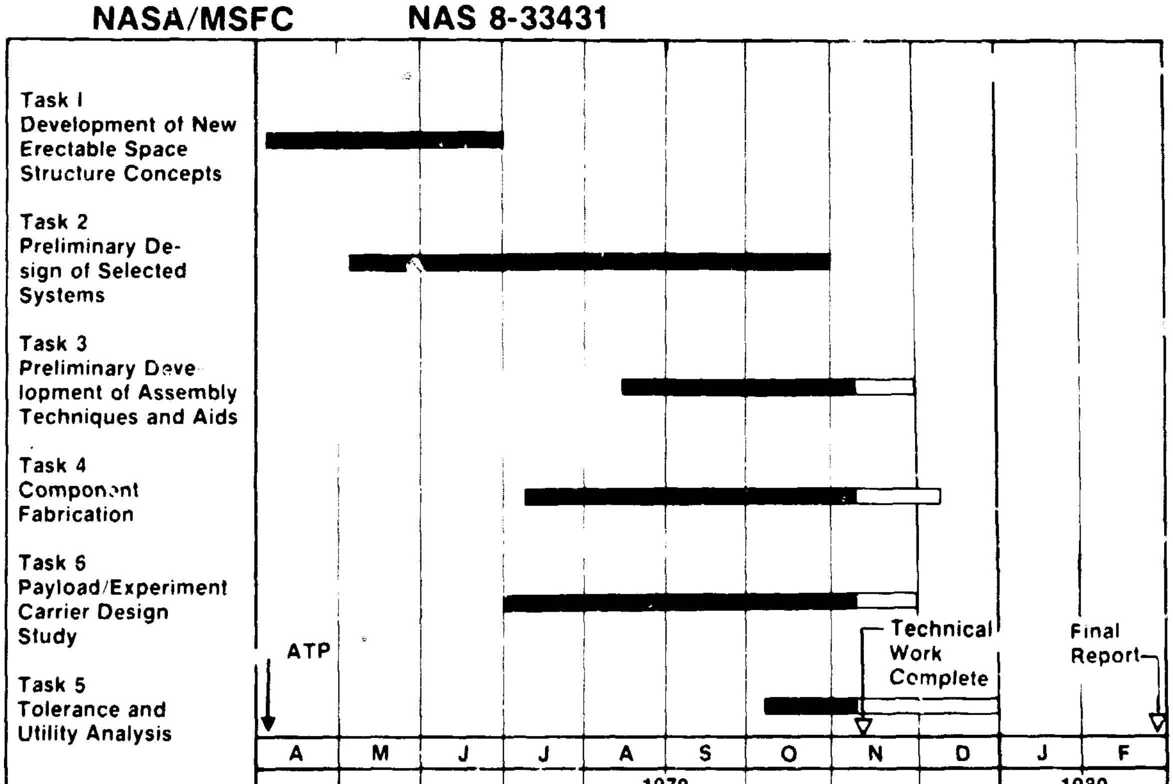
Task 6: Payload/experiment carrier design study

ERECTABLE CONCEPTS FOR LARGE SPACE SYSTEM TECH

The contract go ahead was in April and completion will be in December. There are three tasks yet to complete: Task 4, the component fab and test which is now underway; the utility and tolerance analysis; and payload experiment carrier study, which will also be concluded in December. The final report will be issued in February.

Erectable Concepts for Large Space System Tech

NASA/MSFC NAS 8-33431



DEVELOPMENT OF NEW ERECTABLE SPACE STRUCTURE CONCEPTS

The first task was to review the missions expected in the next five to fifteen years. As previously stated, the objective of the contract was to make our work applicable to the near term missions. Guidelines for the study included a 1985 to 1990 low earth orbit platform as a primary consideration, and geostationary structure as a secondary consideration. The resulting structure would have to function with or without Spacelab pallets and it would be assembled by man with machine assistance. That particular philosophy may be changing in the future for man to be an observer only. At least two RMS's would be available for deployment and assembly. The task was to develop either members or modules such that platforms or other applications could be built in a building block fashion. In this way the sequential assembly of the modules will permit constructing a variety of platform configurations. Attention was also to be given how to incorporate utilities, either electrical or fluid, into the members or into the joints or across the joints. Utilities provisions may very well influence the configuration or assembly procedure/equipment and must be considered upfront. Eleven (11) missions were considered applicable. Some examples reviewed are, Electronic Mail, Pin hole Satellite, deployable antennas and Science and Applications Space Platform that was studied toward the end of 1978. The Science and Applications Space Platform was believed the most applicable; therefore, our work has been directed at joints and/or members that would be useful in that endeavor.

Development of New Erectable Space Structure Concepts

Review of LSS Missions to Date

Objective: Identify near-term missions that would use erectable/deployable structures to provide applicability to concept evaluation and selection

Guidelines:

- 1985-1990 LEO platform
- GEO requirements on secondary basis
- Function with or without spacelab pallets
- Assemble by man with machine assistance
- Two RMSs available for deployment and assembly
- Utility provisions

Results: Eleven (11) LSS missions are applicable
Science and application space platform most applicable

DEVELOPMENT OF NEW ERECTABLE

SPACE STRUCTURE CONCEPTS

Out next task was to look at what industry had done in the past. The reasons for that approach were to establish a point of departure, to avoid duplication and also to stimulate thought process for generating new ideas. At a minimum, 43 existing joint ideas that had a practical merit were identified. A patent search, going back to the 1890's, revealed 73 different insertion type joints that could possibly work. Approximately 45 structural elements were identified.

Development of New Erectable Space Structure Concepts

Review of LSS Structural Concepts Proposed to Date

Objective: To collect previously proposed structural joints and elements to

- Establish point of departure for new ideas
- Avoid duplication
- Stimulate idea spinoff

Results:

— Forty-three (43) joining methods were identified

— Seventy-three (73) patented joining methods were reviewed

— Forty-five (45) structural elements or methods were identified

DEVELOPMENT OF NEW ERECTABLE SPACE STRUCTURE CONCEPTS

Prior to the generation of new ideas through brainstorming, the types of joints that would actually be required were identified. Single member strut or unions basically require either a side latching type of joint or insertion type of joint, or possibly a hybrid of the two. Deployable modules, which are comprised of several members and go through kinematic motion to a final configuration, require approximately nine (9) different types of joints or nodes. Examples are single pivot or double pivot, telescoping members, etc. From the background of previous ideas and the above requirements 72 different types of joints were generated. Very simple to very complex ideas were considered. The 72 ideas did not necessarily have practicality; they were just ideas. Similarly, 38 different structural members were generated. Again, they ranged all the way from the very simple linear members to a multi-member deployable module. This wide range of concepts was considered to be a structural member.

Development of New Erectable Space Structure Concepts

Generate New Concepts

Objective: Develop new structural joints and elements

Required joint types:

Deployable Modules:	Strut/union erectables:
1. Single pivot node	1. Side latching joints
2. Double pivot node	2. Insert joint
3. Rotating intermediate pivot fitting	3. Hybrids
4. Stretch members (telescope)	
5. Shrink members (telescope or knee joint)	
6. Removable members	
7. Module-to-module attachment	
8. Nodal knee joint	
9. Mission equipment attach	

Results:

— Seventy-two (72) new joining ideas were generated

— Thirty-eight (38) new structural member ideas were conceivec

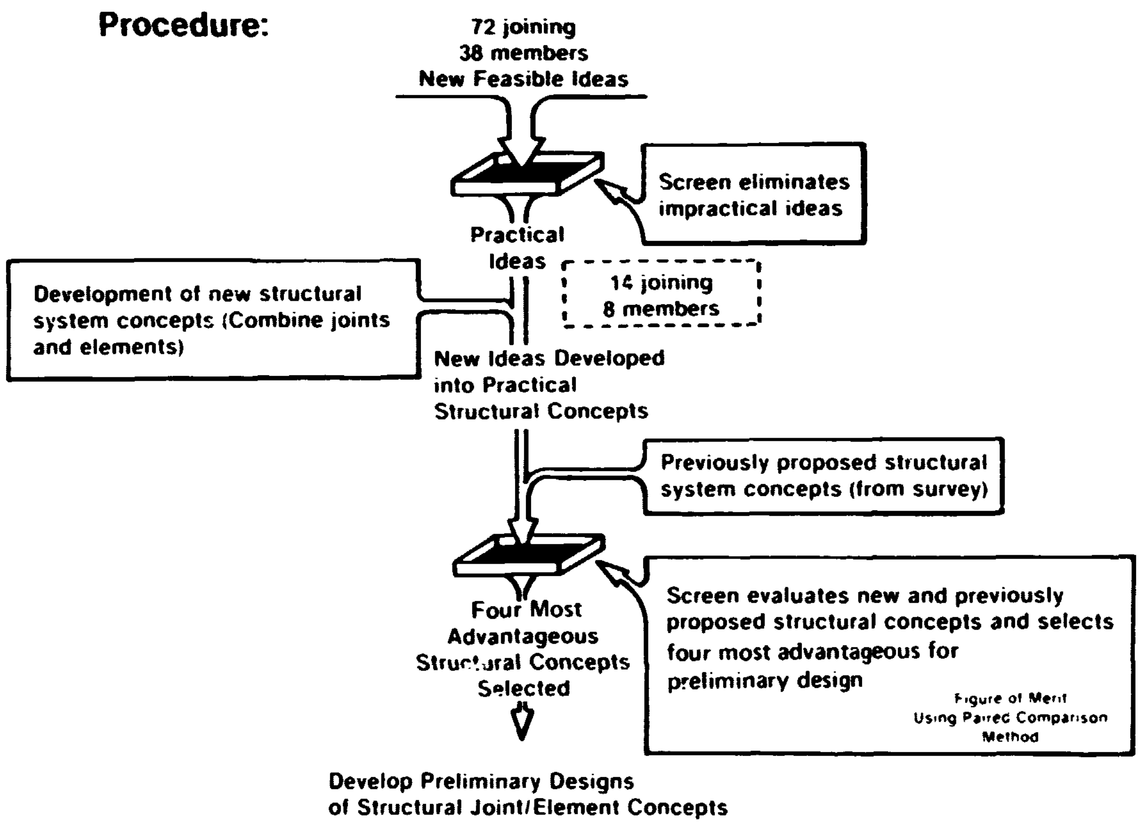
PRELIMINARY DESIGN OF SELECTED SYSTEMS

Having the multitude of ideas, a screening process was used to eliminate the impractical ones. This was done on an engineering qualitative basis. The 72 joints and 38 members were screened to 14 joining devices and 8 members, including the joints and members that had been previously proposed. Those results were then subjected to a more detailed figure of merit type of evaluation. Examples of evaluation parameters are ease of capture, ease of locking, alignment, adjustment, durability, thermal distortion, etc. From that paired comparison evaluation, 7 joints and members were selected for further development in preliminary design. Those seven (7) concepts will be discussed.

Preliminary Design of Selected Systems

Objective: Evaluate and select most promising structural concepts and develop through preliminary design

Procedure:

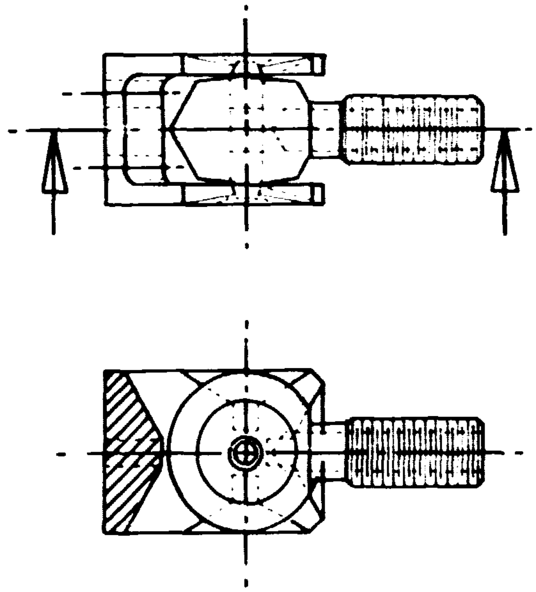


The first joint is an automatic coupler. Its characteristics are that it can be inserted either in the axial direction or from the side. It is a hybrid; it can be inserted in either direction. It has ± 12.5 mm gathering range and a soft capture misalignment of ± 5°. Another feature of this particular joint is that the release mechanism, although not finely perfected here, is on the member end as opposed to the union end. In this case the release mechanism can be operated by a person using one arm or one RMS such that removal after release can be in one motion. This is as opposed to releasing from the union end and pulling the member away, which would require two (2) appendages.

Preliminary Design of Selected Systems

Automatic Coupler Clevis Joint

Design 36



Characteristics:

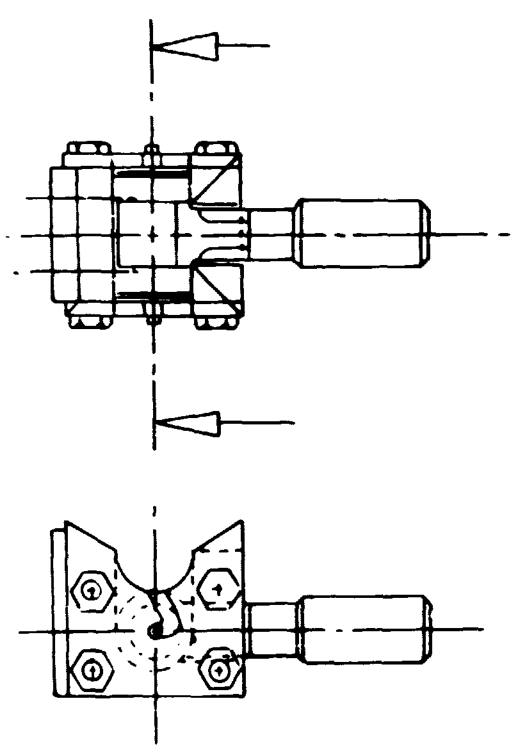
1. Insert either side or end
2. ± 12.5 mm gathering range
3. Soft capture misalignment:
   ± 5° out of plane or ± 1 mm axial
4. Hard locks automatically as misalignment is removed
5. ± 90° pivot as a clevis
6. Can be released

PRELIMINARY DESIGN OF SELECTED SYSTEMS

The second concept is a side latching detent joint. It has the same characteristics as the automatic coupler in that it has a wide angle of insertion. It can be inserted in the 0° or 90° direction. Both of these parts have been fabricated and have gone through proof of concept testing.

Preliminary Design of Selected Systems

Side Latching Detent Joint



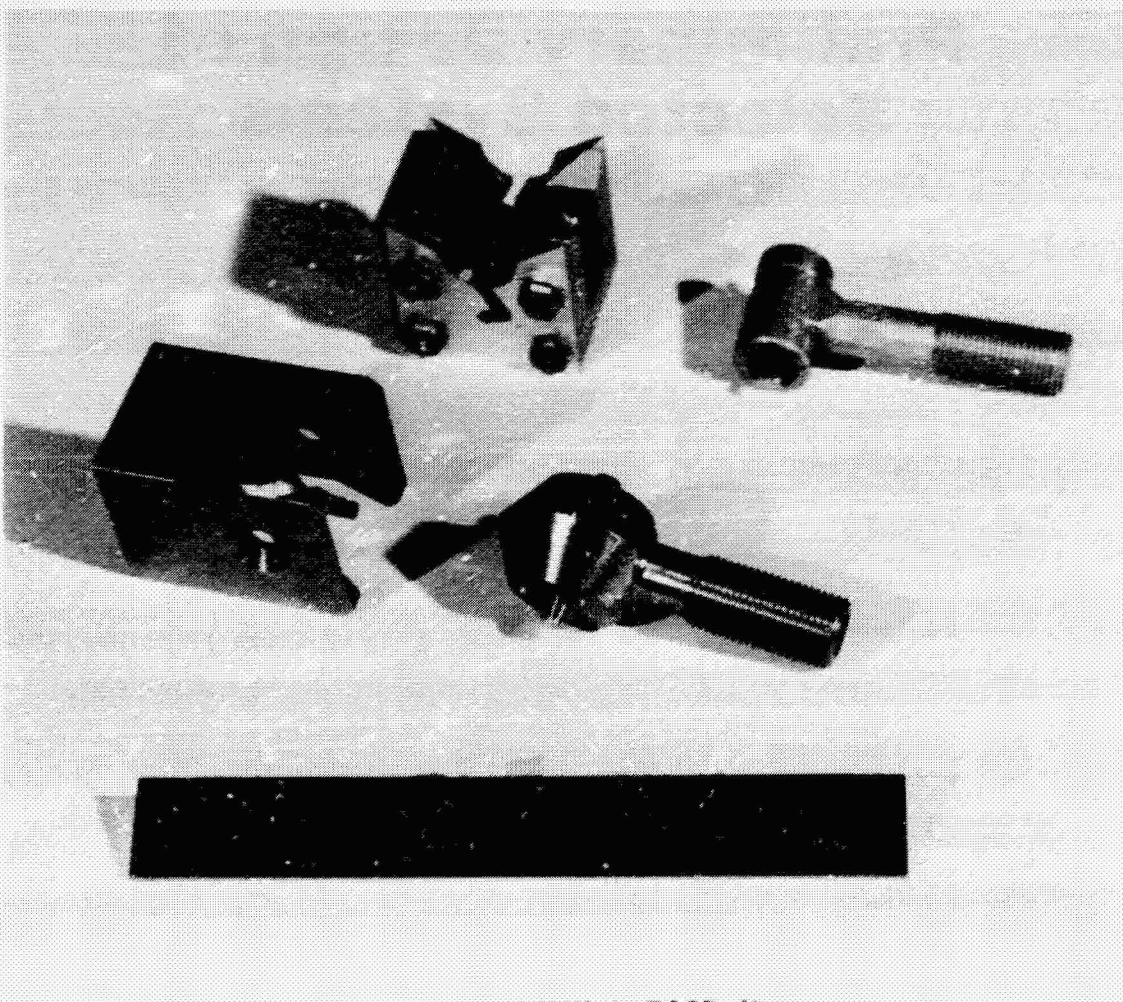
Design 27

Characteristics:

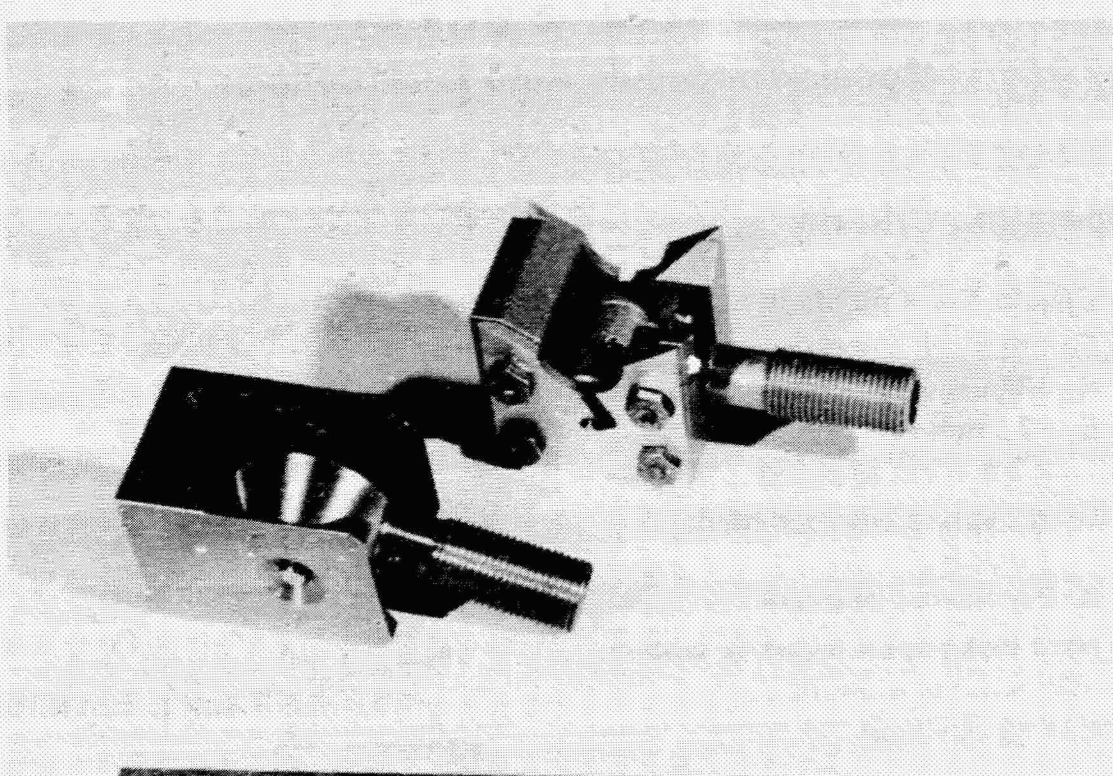
1. Insert one side
2. ±12.5 mm gathering range
3. Hard locks when fully inserted as misalignment is removed
4. +90° pivot as a clevis

Photograph of the automatic coupler and side latching detent joints disassembled.

The black scale is 15 cm long.



This is a photograph of the automatic coupler and side latching detent joints assembled. The black scale is 15 cm long.



The third joint concept is called a module-to-module coupler. Because the other four selected elements were modules, a method of connecting two modules together was required. Most likely the two modules will never be perfectly aligned. Therefore criteria were established so that one of the four joints would connect or soft capture when there is a 10° misalignment between modules. Once the modules are aligned, possible joint mismatch due to tolerances may exist in the mating plane (radial) and perpendicular to the mating plane. Soft capture in the plane is $\pm$ 12.5 mm radial and 1 mm radial for hard capture. Capture perpendicular to the mating plane will occur if all four joints are within 2.5 mm.

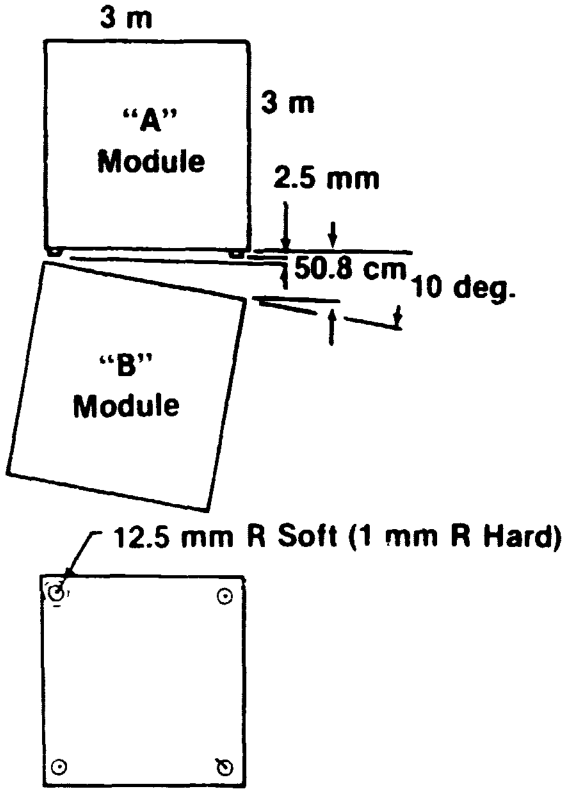
Preliminary Design of Selected Systems

Module-To-Module Auto Lock Coupler

Concept 22A and 22B

Operating Criteria:

1. Couple 3 or 4 points in a plane
2. Soft capture misalignment:
   A. 10° angular
   B. 12.5 mm R
      2.5 mm out of plane
3. Hard capture misalignment:
   A. 1 mm R
   B. 2.5 mm out of plane
4. Hard locks upon insertion with no additional operations
5. Can be released

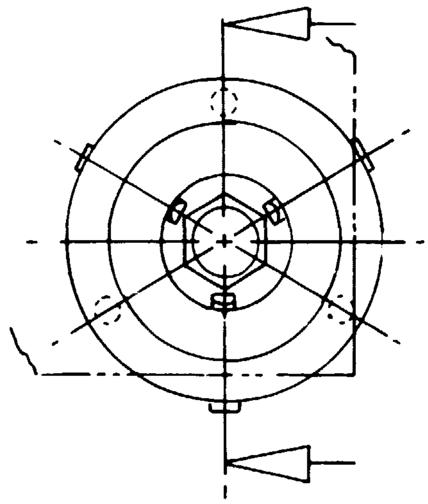


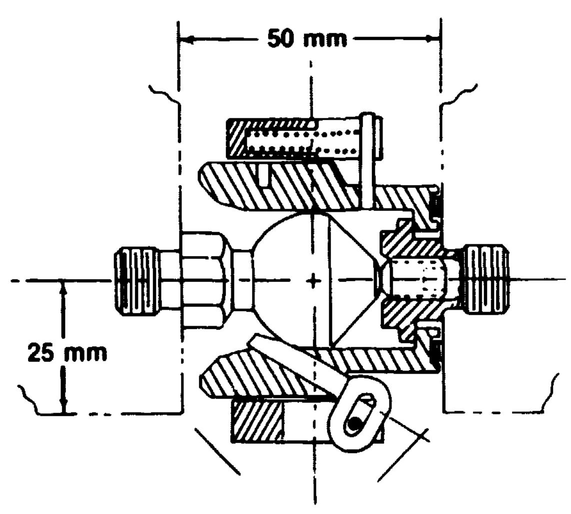
The module-to-module concept is a typical probe drogue type of joint, a conical surface on the front and spherical surface on the back. The probe part is the less expensive; it is mounted to the corner of the modules. There are three fingers around the circumference of the drogue part. As the probe enters the drogue, the fingers are pushed back out of the way and after passing over center, the fingers - which are spring loaded - return to capture the probe. There is 2.5 mm of forward motion permissible at that position. This allows the four joints to be engaged and locked and able to carry loads while mis-aligned by 2.5 mm perpendicular to the mating plane. As the probe proceeds into the drogue the fingers continue to capture the element thus preventing reverse motion.

Preliminary Design of Selected Systems

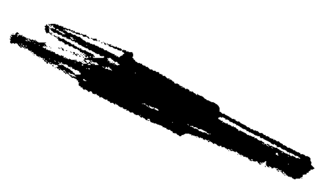
Module-To-Module Auto Lock Coupler

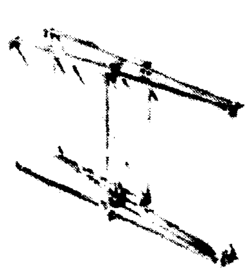
Design 22B

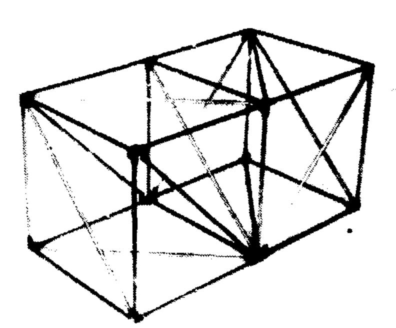




The fourth element is a deployable module. The 1/10 scale model shown below is a double cell double fold configuration. Each cell is a 3 m cube. A variety of joints and members exist in this structure. There are telescoping diagonals, single clevis joints, and double swivel clevis joints. The maximum number of members at a node is nine (9). The probe part of the module-to-module coupler shown previously will be located externally at each node to provide attachment of another module or experiment pallets.

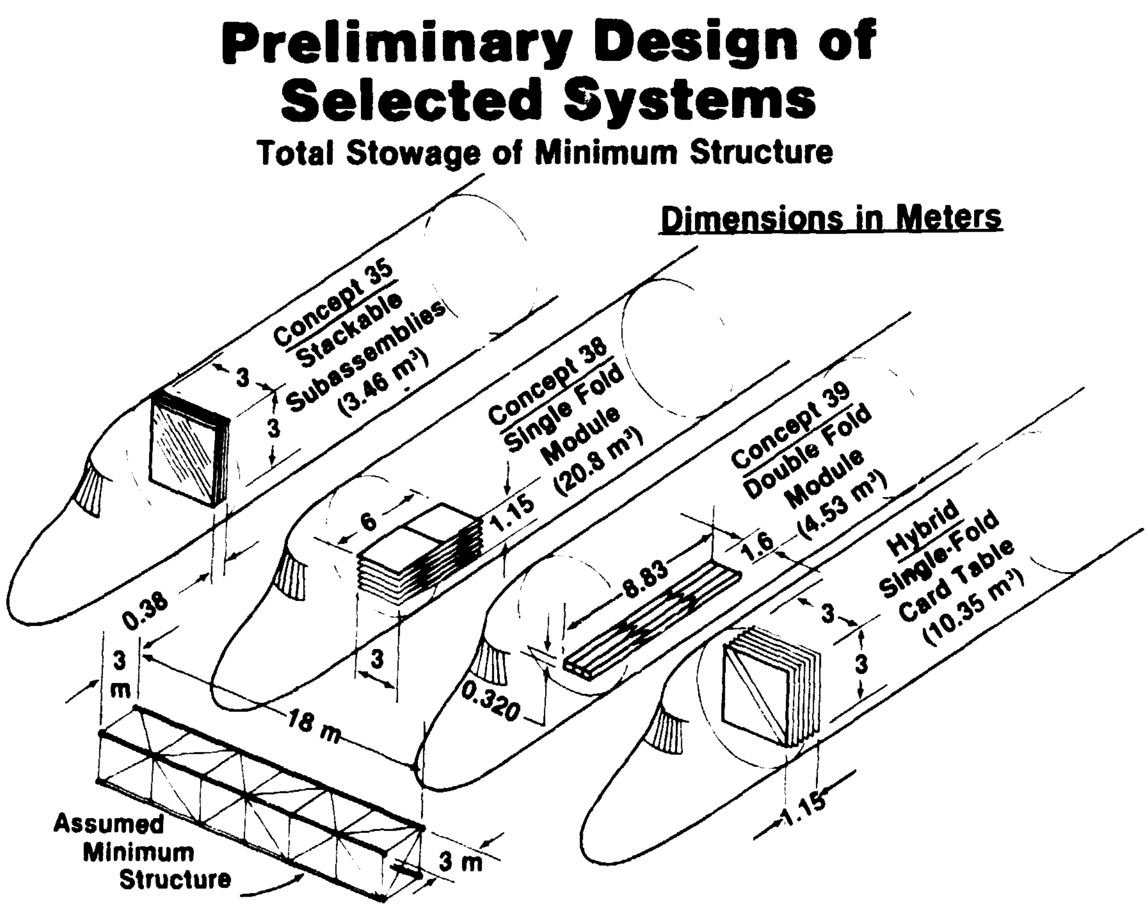






PRELIMINARY DESIGN OF SELECTED SYSTEMS

Packaging is an important aspect in the transportation of space structures. The remaining three (3) concepts studied are different packaging arrangements for the 3m cubic cell. The total packaging volume required to assemble a nominal structure arm, 3m x 3m x 18m, of the Science and Application Space Platform is shown. Concept 35 has a large cross section but is very thin. The longitudinal members are loose and will require additional orbital assembly time. Concept 38 is a single fold configuration and requires the largest volume. Concept 39 stows in a long narrow space. The hybrid configuration is similar to Concept 35 except that it does not have any loose members. Therefore, assembly time is reduced at the expense of cargo volume. These four packaging configurations offer different form factors which may be coordinated with Orbiter cargo manifests.

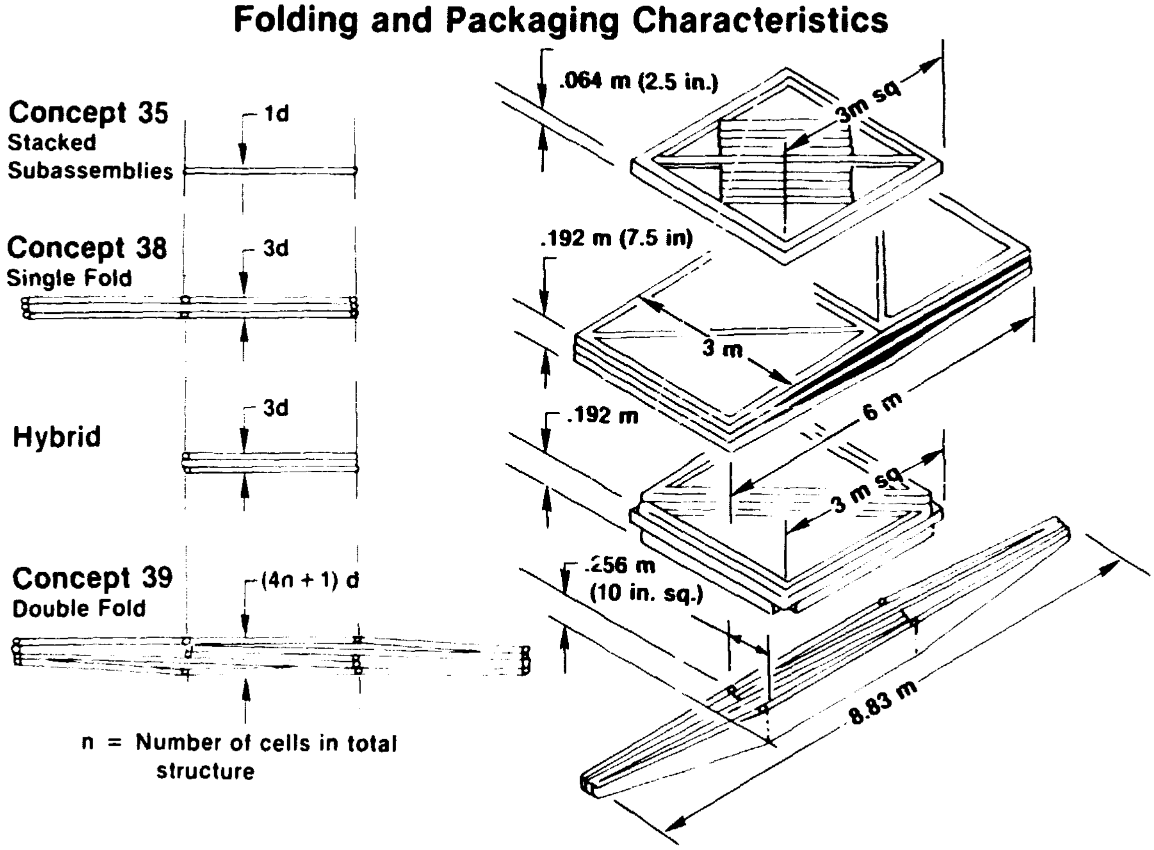


PRELIMINARY DESIGN OF SELECTED SYSTEMS

Additional dimensional details are shown for the four packaging schemes.

Preliminary Design of Selected Systems

Folding and Packaging Characteristics

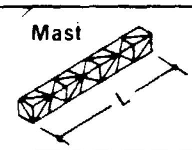
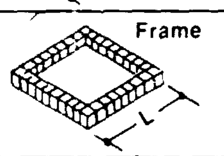
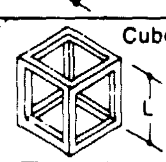
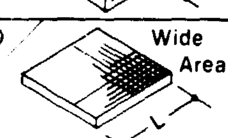


PRELIMINARY DESIGN OF SELECTED SYSTEMS

The results of those four packaging schemes are presented on a comparative basis. The lengths or areas of various types of structures that could be developed with the four configurations are shown. For example, the double fold concept will provide a 3 meter by 3 meter linear type platform 984 meters long if a full cargo bay was available. If the EVA and OMS kits are in the Orbiter then 492 meters of linear platform can be transported. Similar data are shown for a frame, cube, and wide area platform. The double fold element can be configured with 6m elements and still fit within the cargo bay and provide a linear platform 6m x 6m x 984m.

Preliminary Design of Selected Systems

Platform Configuration Options and Size Comparisons 1.5 and 3m Struts

Concept →		35 Subassembly		38 Single Fold		39 Double Fold		Hybrid "Cardtable"	
Strut Size →		3m	1½m	3m	1½m	3m	1½m	3m	1½m
A Mast 	Full Bay	864	1.728	144	288	984	984	288	576
	With EVA & OMS	675	1.350	96	216	492	738	225	450
B Frame 	Full Bay	216	432	36	72	246	246	72	144
	With EVA & OMS	166	338	24	54	123	184	56	112
C Cube 	Full Bay	72	144	12	24	82	82	24	48
	With EVA & OMS	-	12	8	18	41	62	18	38
D Wide Area 	Full Bay	50.9	50.9	20.8	20.8	54.3	38.4	29.4	29.4
	With EVA & OMS	45.0	45.0	17.0	18.0	38.4	33.3	26.0	26.0

* Numbers in table are dimension "L"

PRELIMINARY DEVELOPMENT OF ASSEMBLY TECHNIQUES AND AIDS

Preliminary development of assembly techniques and aids task was required to develop timelines and identify the construction aids and transportation requirements that would be necessary to fulfill the near term applications for the joints and members developed.

Preliminary Development of Assembly Techniques and Aids

Objective: Identify and define steps, procedures, equipment, complexity/timeline estimates for transportation and construction of reference platform using selected design concepts.

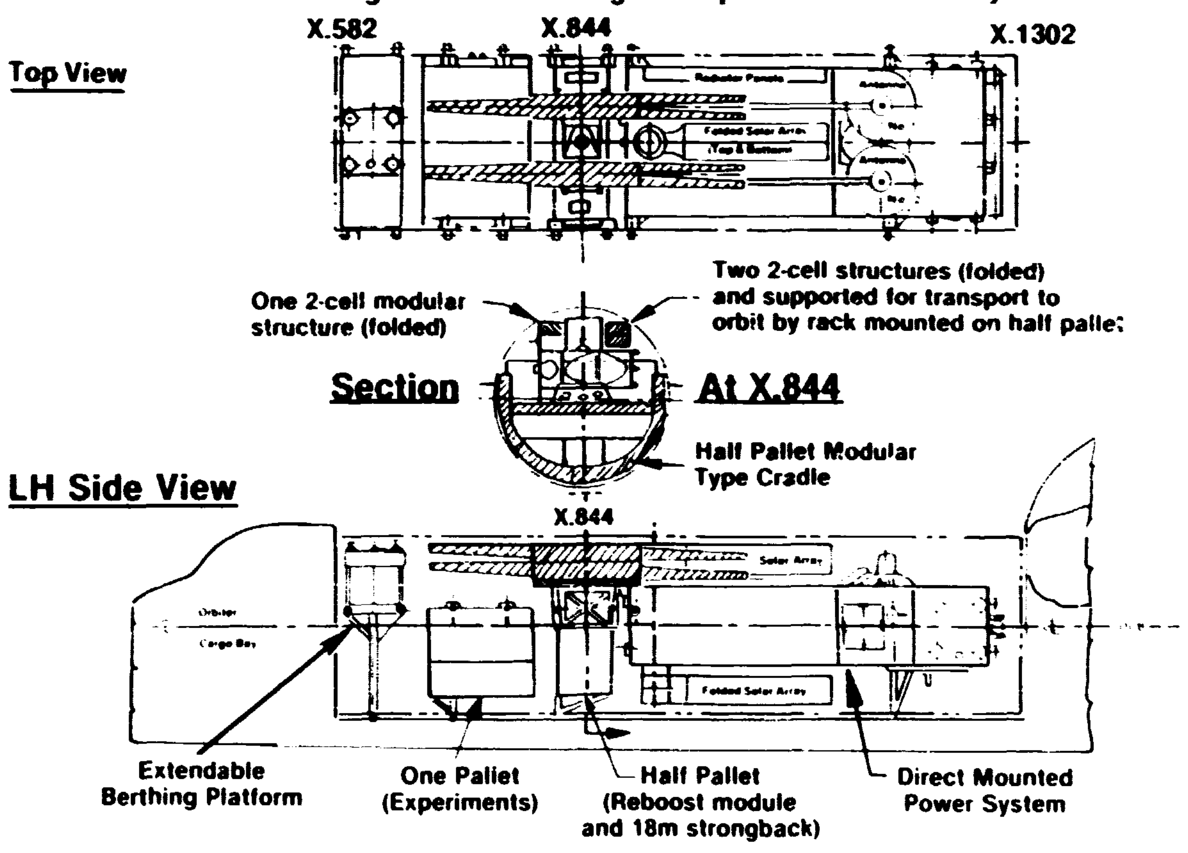
PRELIMINARY DEVELOPMENT OF
ASSEMBLY TECHNIQUES AND AIDS

An example of the double fold double cell module packaging arrangement with the 25 KW Power System is shown below. Other arrangements may also be used.

Preliminary Development of Assembly Techniques And Aids

Typical Orbiter Installation

18m Strongback with Existing Concept — 25 kw Power System

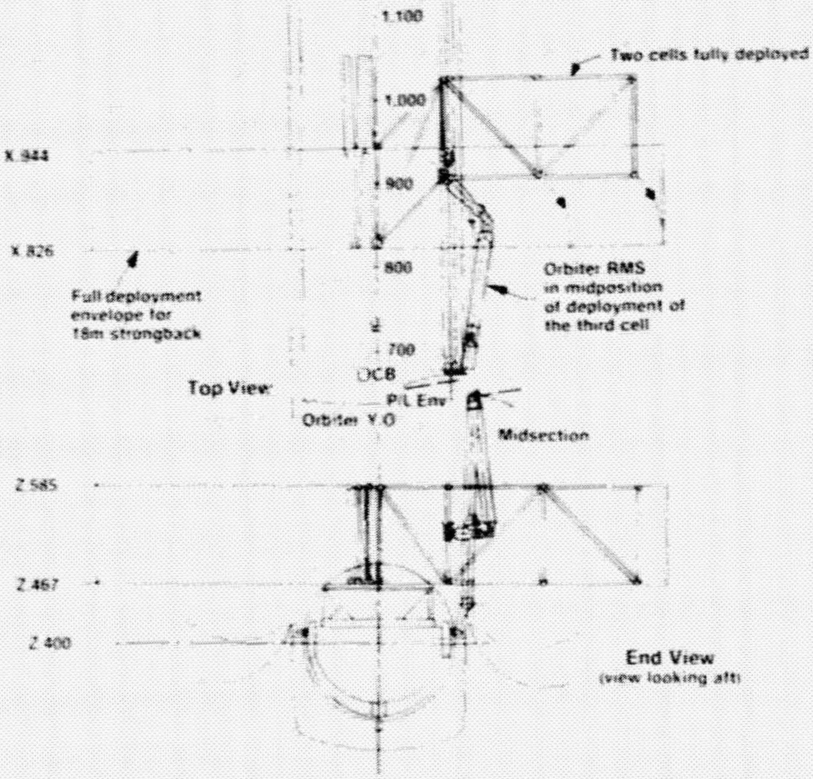


PRELIMINARY DEVELOPMENT OF
ASSEMBLY TECHNIQUES AND AIDS

One (1) 3m x 3m x 18m platform arm is shown being deployed by the RMS from its stowed (collapsed) position. A 16mm movie has been taken of this operation. Deployment feasibility has been verified.

Preliminary Development of Assembly Techniques And Aids

Kinematics of Deployment for an 18m Strongback from Orbiter Cargo Bay

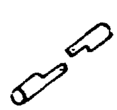
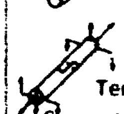
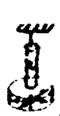
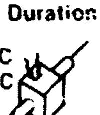


COMPONENT FABRICATION AND TEST

The fourth task was component test and fabrication with the objective being to provide proof of concept. The three joints built will go through an assembly, static, dynamic, and thermal test. Two of the joints have been fabricated; the third is now in fabrication. A ½ size length double cell module with full size joints is being fabricated and will undergo assembly testing.

Component Fabrication And Test

Test Matrix Overview

Test	General Information			Test Specimens		
	Setup	Purpose	Data	1 Full Scale Joint	2 Subscale Deployable Module	
Assembly		• Check Joining and Locking Features. Ease of Operation. Deployment Features	• Clearances • Binding. • Difficulty Factor	X	X	Objective: Demonstrate proof of concept
Static	 Tension Compression Shear Moment Torsion	• Check Joint Integrity. Strength. Stiffness	• Deflection • Rotation • Functional • Binding	X		
Dynamic	 Electro Magnetic Shakers Low-Level Short Duration	• Check Locking And Unlocking Wear. Binding. Looseness	• Clearances Functional	X		
Thermal	Heat °C Cold °C  With and Without Load	• Check Expansion and Contraction. Binding Fit and Function	• Temperature Deformation	X		

The static/thermal test setup for the automatic coupler joint is shown. Tension, compression, shear, moment, and torsion loads were applied at room temperature and -106°C (-160°F).

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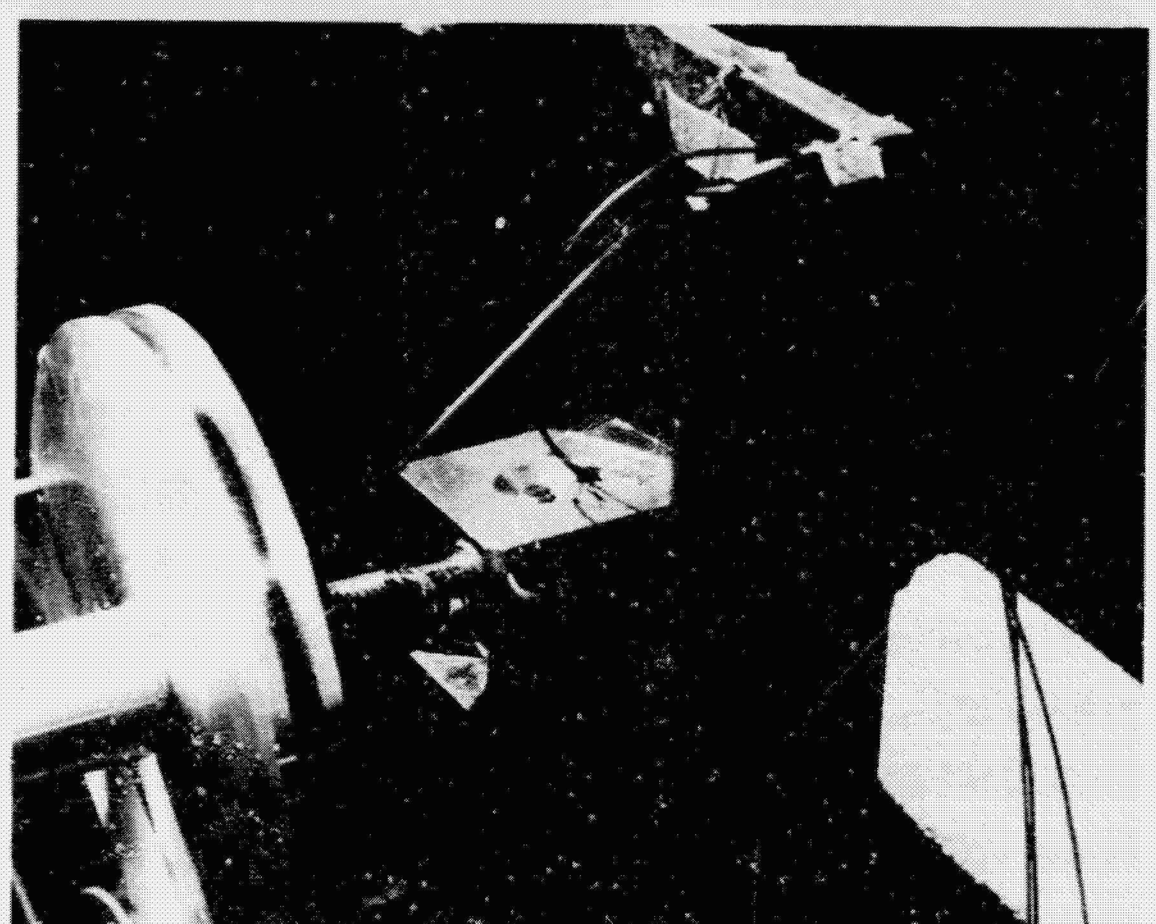


TOLERANCE AND UTILITY ANALYSIS

The purpose of this task is to investigate, in greater detail, the effect of tolerances within a joint relative to an assembly. Considering a long linear platform, what types of limits should be put on joints such that the tolerances would not accumulate to provide an excessively loose fitting or non linear structure? The utility incorporation is not to develop new connectors but merely to incorporate existing connectors into the structural arrangement in some fashion such that their incorporation enhances the assembly and construction and does not become a burdensome item.

Tolerance and Utility Analysis

Objective: To concentrate on the effect of tolerances for systems using selected concepts. To provide means of incorporating state-of-the-art electrical and fluids connectors into candidate joints concepts and wires/lines into members

Results: Effort just begun — completion expected December 1979

PAYLOAD/EXPERIMENT CARRIER
DESIGN STUDY

The payload/experiment carrier design study was primarily intended to develop a carrier to transport the elements or modules developed; but it also needed to be sensitive to other space experiments and to be responsive to the requirements of the Shuttle and the reference Science and Application Space Platform. A modular approach has been developed which emphasizes versatility, light weight, and cost effectiveness plus being accommodative to the interfaces that will be present.

Payload/Experiment Carrier Design Study

Objective: Accomplish conceptual design of carrier structure for elements/modules and space experiments responsive to requirements of shuttle and reference platform.

Approach: Modular design that is

- Versatile
- Lightweight
- Cost effective
- Easy attachment to primary structure
- Clean packaging scheme
- Convenient transportation and handling characteristics

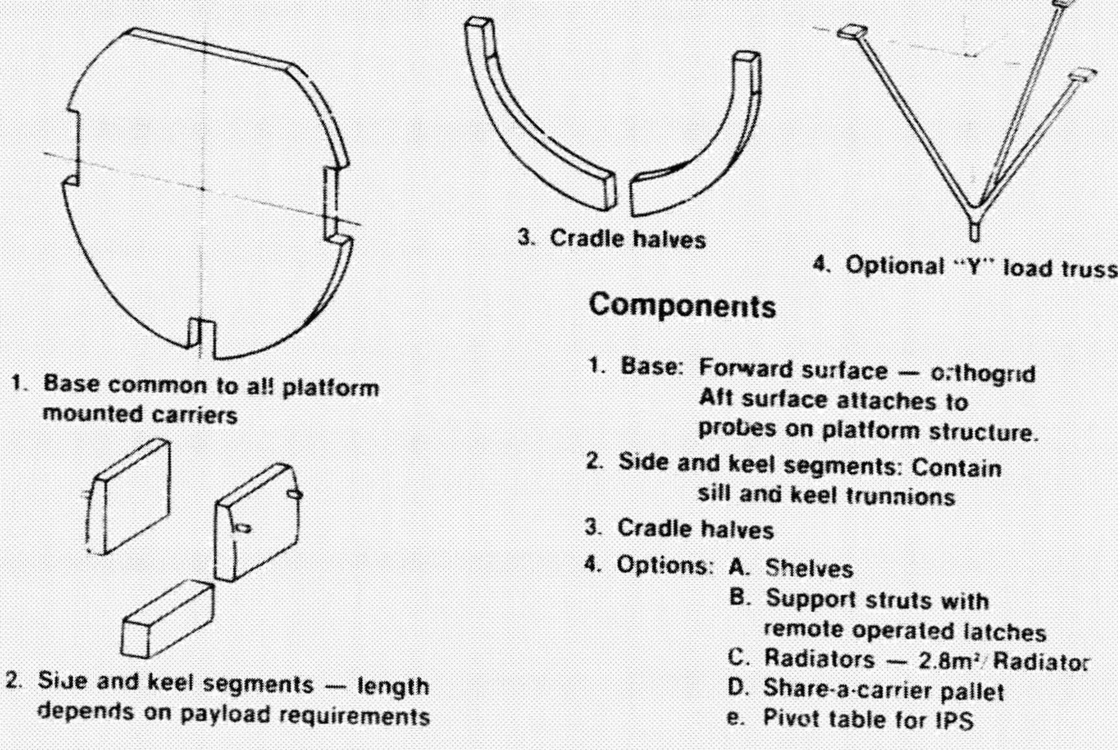
And will accommodate

- Interfaces and integration — thermal, power, data
- Experiment requirements — mounting, viewing

PAYLOAD CARRIER SYSTEM

The modular system is basically a thin wafer type of base/platform that fits into the Orbiter in vertical fashion. It has the side and keel segments of variable lengths. Cradle halves or a "y" load truss can be used if necessary or for the larger experiments. From these basic components a variety of carrier configurations can be constructed to meet the structural and experiment requirements.

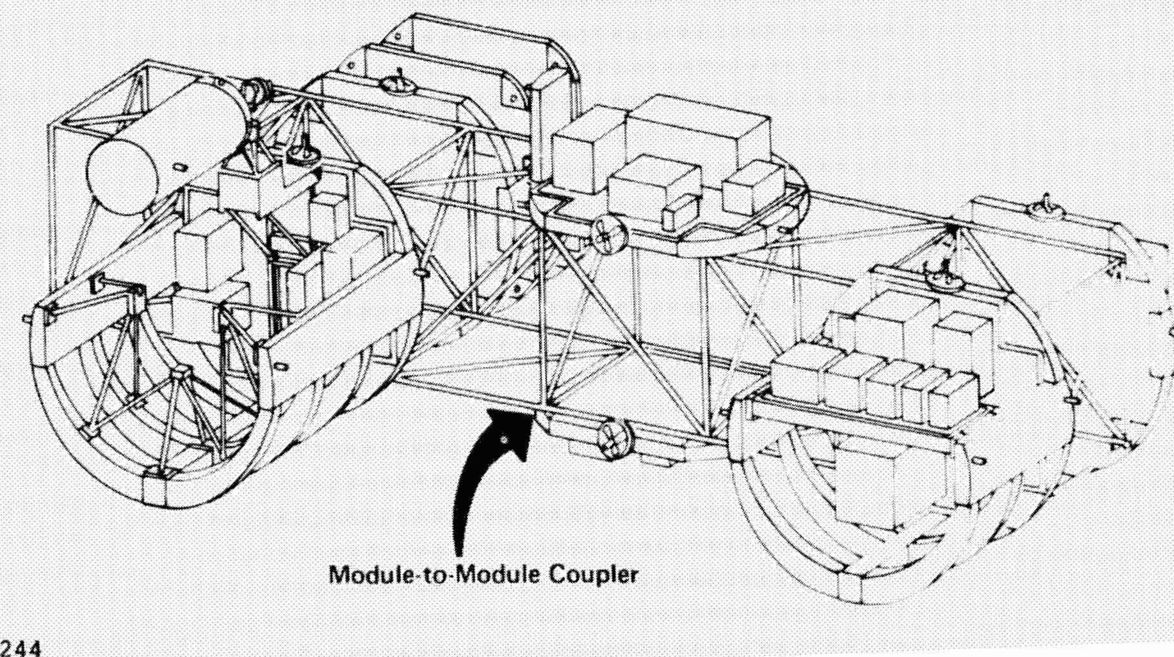
Payload Carrier System



STRONGBACK/CARRIER COMBINATION

An 18 meter platform arm is shown supporting a family of experiments. The smaller experiments are on the thin wafer sections. With the optional keels, sides and cradles, larger payloads can be supported. The module to module coupler is shown connecting the experiment carrier to the platform. Each carrier has an RMS pickup attachment for handling purposes.

Strongback/Carrier Combination

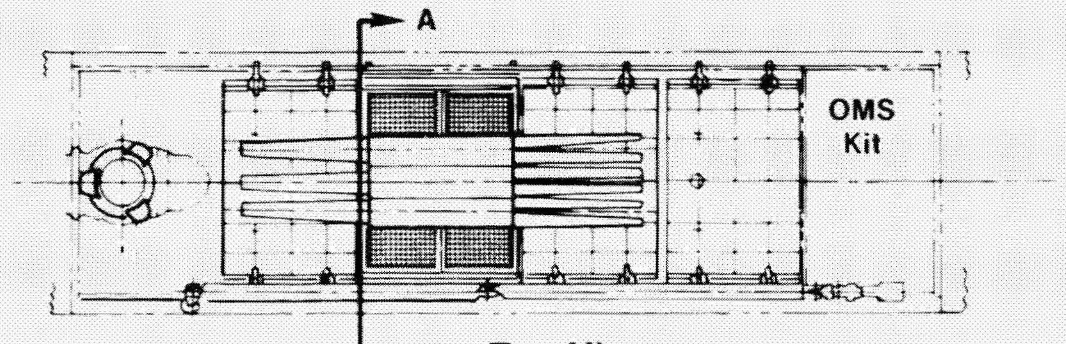


TYPICAL ORBITER INSTALLATION

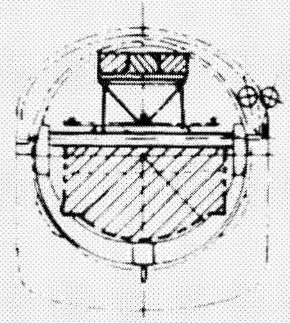
Three double cell double fold modules are connected to provide 18 m total length and installed in the Orbiter bay with three other experiments. Deployment of this 1/10 scale platform arm was shown in 16 mm film strip.

Typical Orbiter Installation

18 m Strongback with Three 1984 Payload Concepts



Top View



Section A-A

Stowage space available for strongback to PS mounting adapters(s) and other accessories

KEY SUMMARY ITEMS

Previous work has been reviewed and the effort has been directed primarily toward near term applications, such as the smaller linear or strongback type of platforms. Seventy-two joint and member ideas have been evaluated with the most promising concepts being selected by a figure of merit evaluation. Two of the joints have been fabricated and the other one is in fabrication. Four structural modules are being developed. The double cell double fold configuration will be fabricated in a ½ length size full joint module. The double fold module is a promising concept from a packaging point of view because it will more than adequately supply the length of the platform arm that is needed for the near term.

Key Summary Items

- All previous work reviewed
- Application of joints and elements directed toward 1985-1990 LEO platforms
- Seventy-two (72) joining ideas and thirty-eight (38) member ideas were generated
- Most promising concepts selected on FOM evaluation
- Two (2) promising strut joints designed and fabricated
- One (1) module-to-module coupler joint designed and in fabrication
- Multicell deployable module designed with ½ length struts and full size joints — in fabrication
- Double-fold module is promising, considering packaging/ assembly requirements