A MODULAR APPROACH TOWARD EXTREMELY LARGE APERTURES

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STUDY OBJECTIVES

A nine month study entitled "Development of a Deployable Module Concept for Large Reflector Application" was undertaken by Lockheed Missiles and Space Company, Inc., in September 1979. This contract was originated by Langley Research Center as a subtask of an ongoing contract in support of the development of Large Space Structures Concepts.

The subtask objectives are summarized in Figure 1. LMSC was to design a large erectable antenna using a deployable modular approach and characterize the performance of such antennas. In addition, the module deployment kinematics were to be verified by construction of a working subscale demonstration model, and on-orbit antenna assembly scenarios were to be investigated.

- DESIGN A DEPLOYABLE MODULAR STRUCTURAL ELEMENT FOR ANTENNA APPLICATIONS
- CHARACTERIZE PERFORMANCE
- VALIDATE KINEMATICS
- INVESTIGATE ORBITAL OPERATIONS

Figure 1

The final product envisioned from the study was a large parabolic reflector to be erected in lower earth orbit from up to 330 separate deployable modules transported by one STS launch. This concept is overviewed in Figure 2.

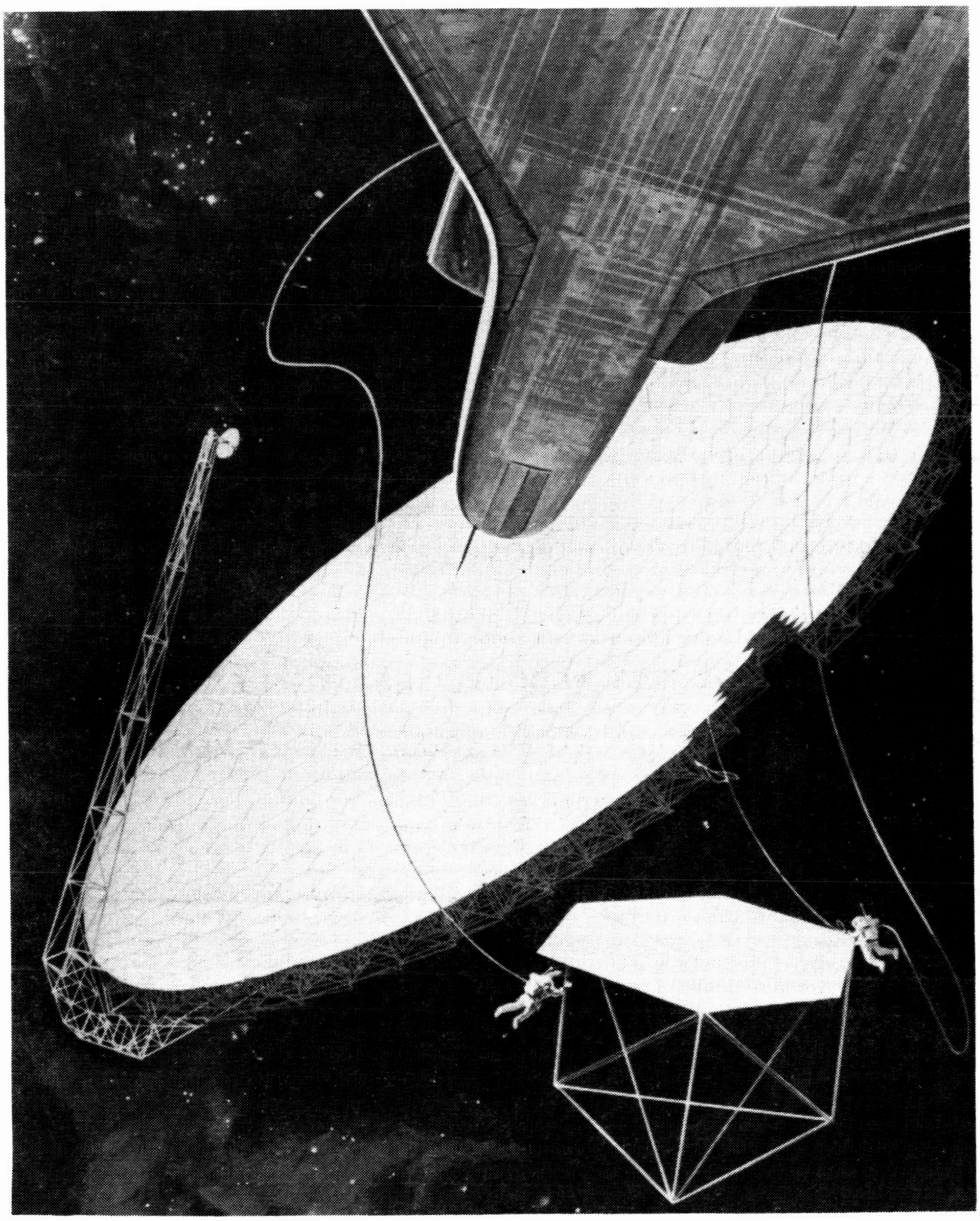

Figure 2

DESIGN REQUIREMENTS

The design constraints established for the study are listed in Figure 3. Each module was to be an autonomous deployable unit, attached to neighboring modules through three attachment points. Each module was to provide a hexagonal RF reflective surface element, independent of but adjacent to neighboring elements. The modules were to provide minimum stowed volume (maximize packing efficiency) and be capable of being deployed by an external, plug-in deployment power device.

- EACH MODULE AN AUTONOMOUS STRUCTURE
- HEXAGONAL SURFACE ELEMENT
- ORBIT DEPLOYMENT ACCOMPLISHED WITH EXTERNAL AID
- THREE POINT MODULE TO MODULE ATTACHMENT
- MINIMIZE STOWED VOLUME

Figure 3

DESIGN APPROACH

The design approach selected to satisfy the foregoing requirements consists of a reflective mesh surface supported by a small diameter (1.27 cm) thin wall (.4 mm) tubular framework. Several of the tubes contain spring powered, latching joints which allow them to be folded to reduce the stowed package size. A single central jackscrew controls all of the deployment motions, acting as both the slider link of a four bar linkage for the upper truss and as a cable reel to deploy cables which control the deployment motions of the lower structure elements. The stowed module is basically a passive device, in that external mechanical power must be supplied by a motor for deployment to occur.

• SURFACE	– FOLDING HEXAGONAL TRUSS PLATE
• FRAME	– FOLDED TRIANGULAR TRUSS
• STRUCTURE	– 1.27 CM DIAMETER, 0.4 mm THICK GRAPHIC EPOXY TUBES
• JOINTS	– SELF ACTIVATING AND LOCKING WITH TWO DEGREES OF FREEDOM
• DEPLOYMENT CONTROL	– CENTRAL JACK SCREW WITH STRUCTURAL AND CABLE SYNCHRONIZATION
• DEPLOYMENT POWER	– EXTERNAL PLUG IN MOTOR

Figure 4

MODULE DESIGN OVERVIEW

Figure 5 describes the basic components of a single module. An upper hexagonal truss frame supports the mesh, and structural depth is provided by a triangular lower frame cross braced to the upper frame. The folded truss elements use spring powered latching joints which provide continuous column stiffness in the deployed position. Deployment is effected by a central jack-screw in the upper space frame which opens the hexagonal frame through a four-bar linkage and simultaneously pays out cables which control the spring powered deployment motions of the lower frame members. The jackscrew is powered by a separate, plug-in motor unit which is used to deploy all individual modules.

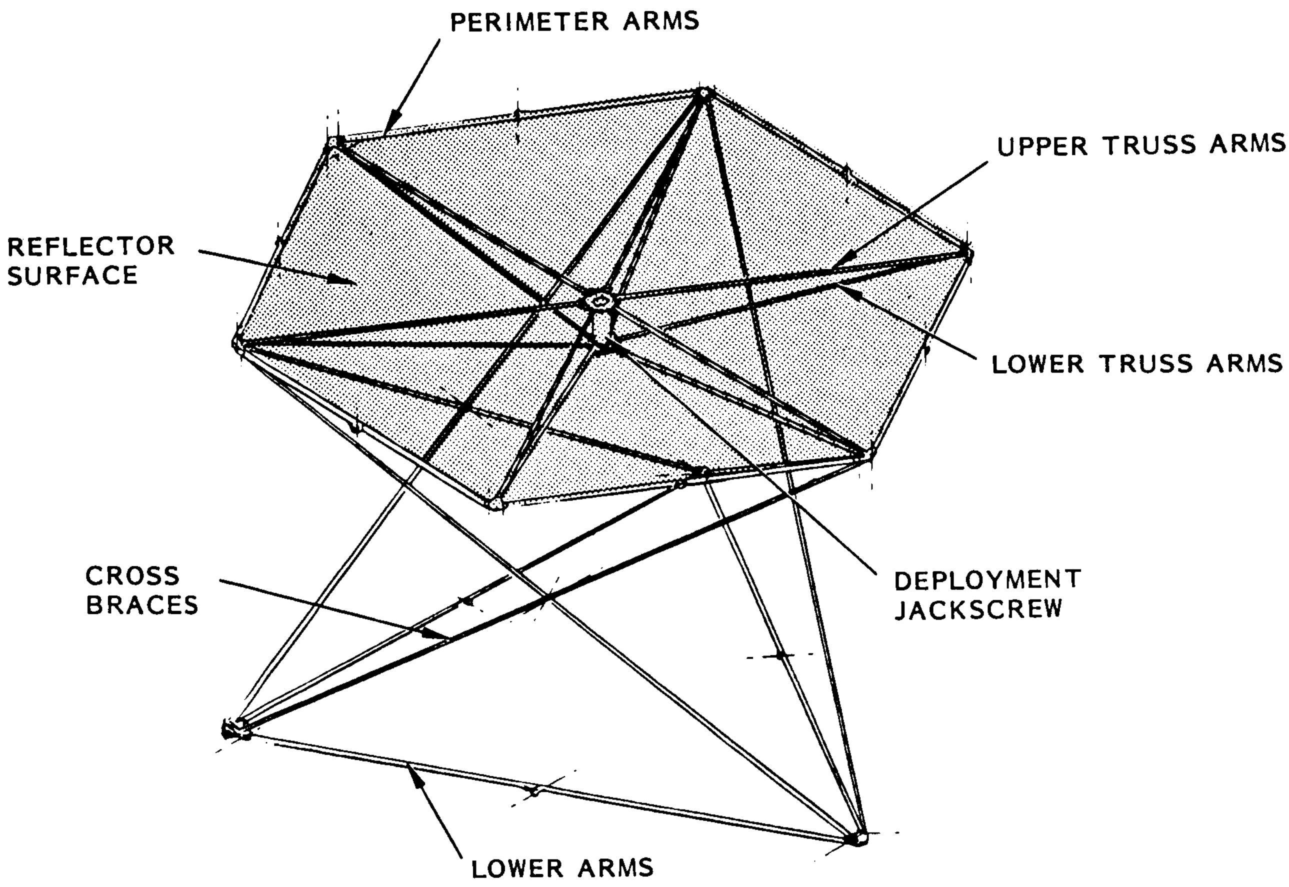

Figure 5

Figure 6 shows the subscale demonstration model in the stowed position. The stowed package is approximately 25 cm in diameter by 100 cm long. The separate deployment motor housing can be seen as a small rectangular box extending below the module.

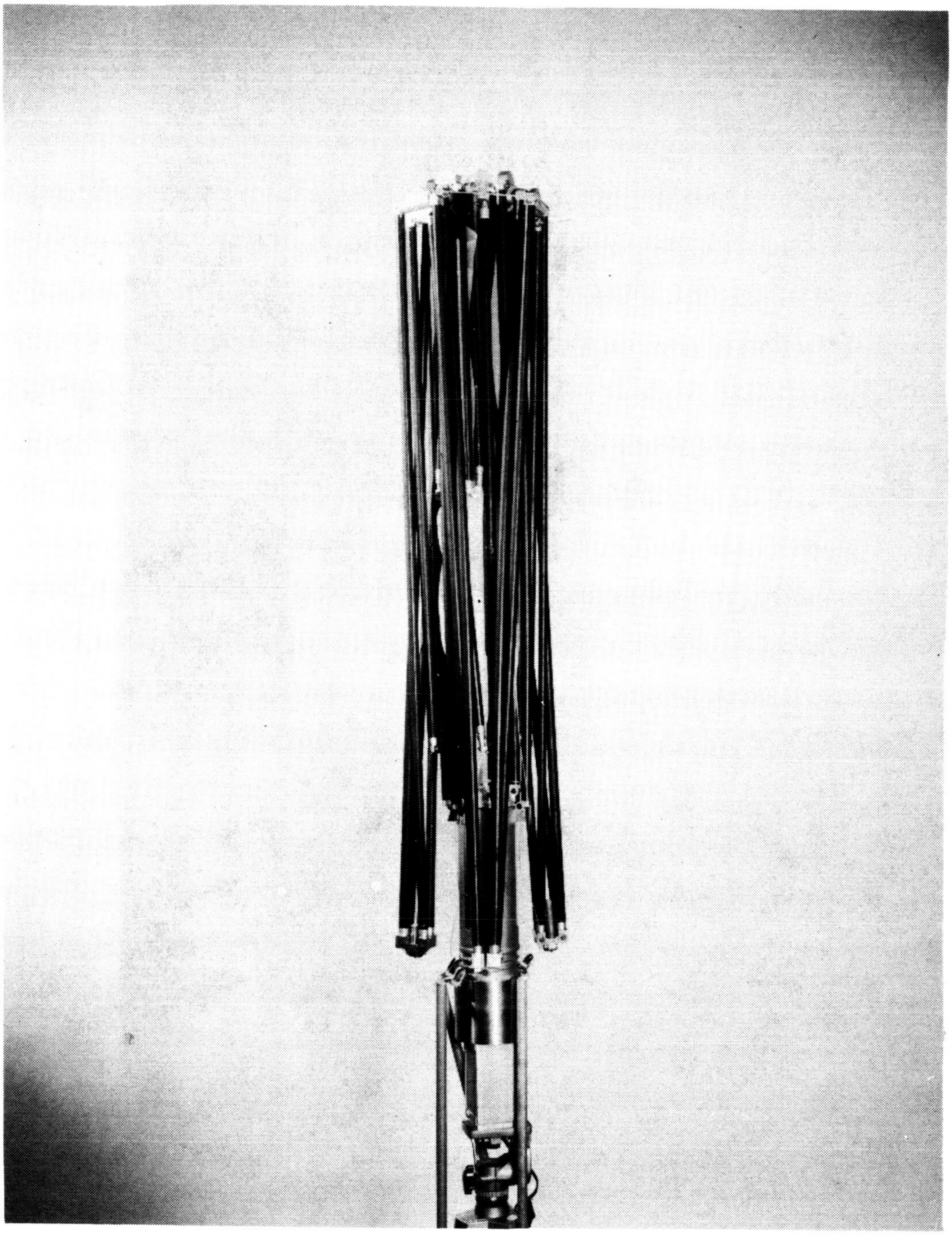

Figure 6

Figure 7 shows the demonstration model early in its deployment cycle. The cross braces are moving outward and upward and the hexagonal truss is beginning to open.

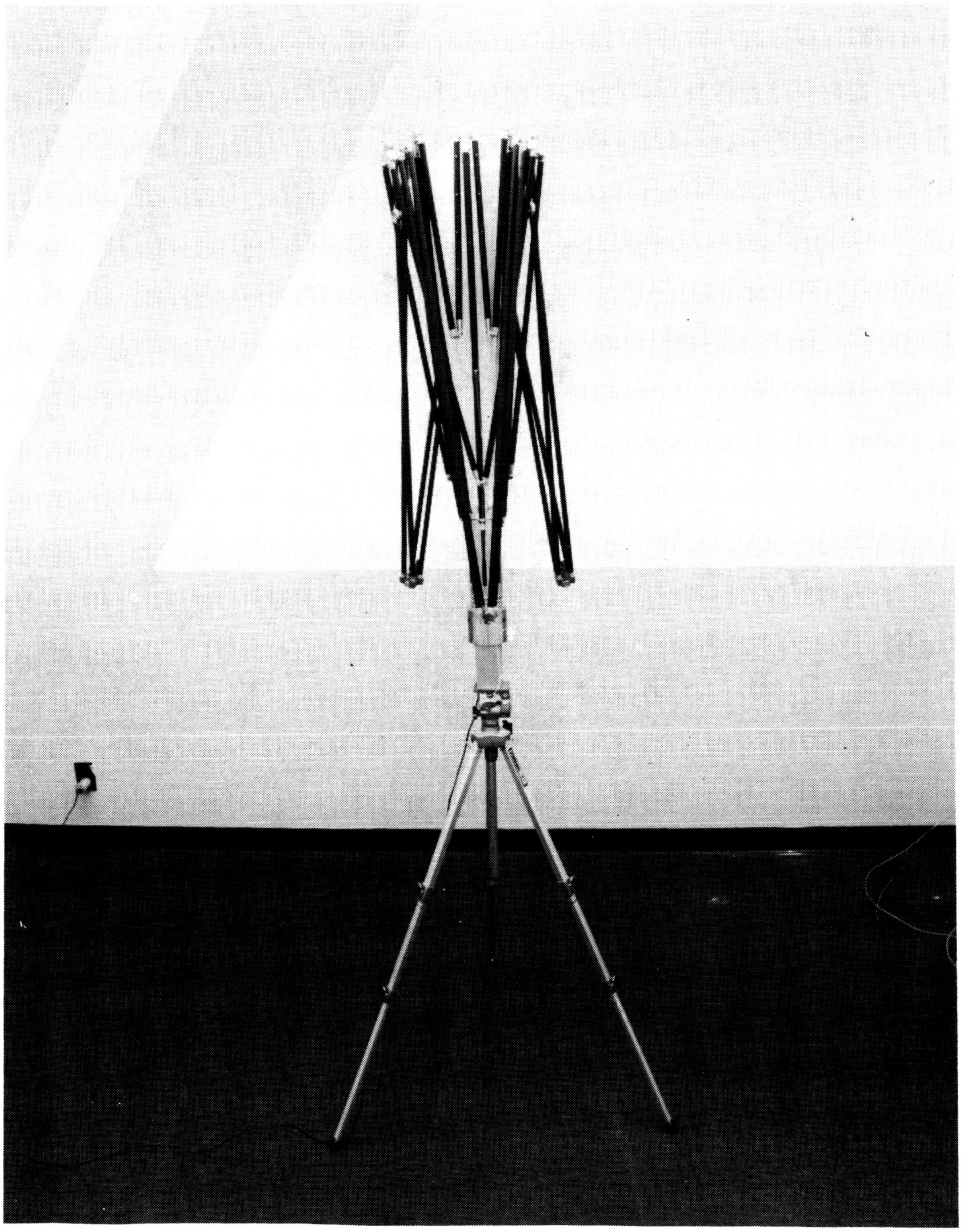

Figure 7

Figure 8 shows the model further along in its deployment motion. The upper surface has opened substantially and the cross brace center joints have reached the peak of their upward swing.

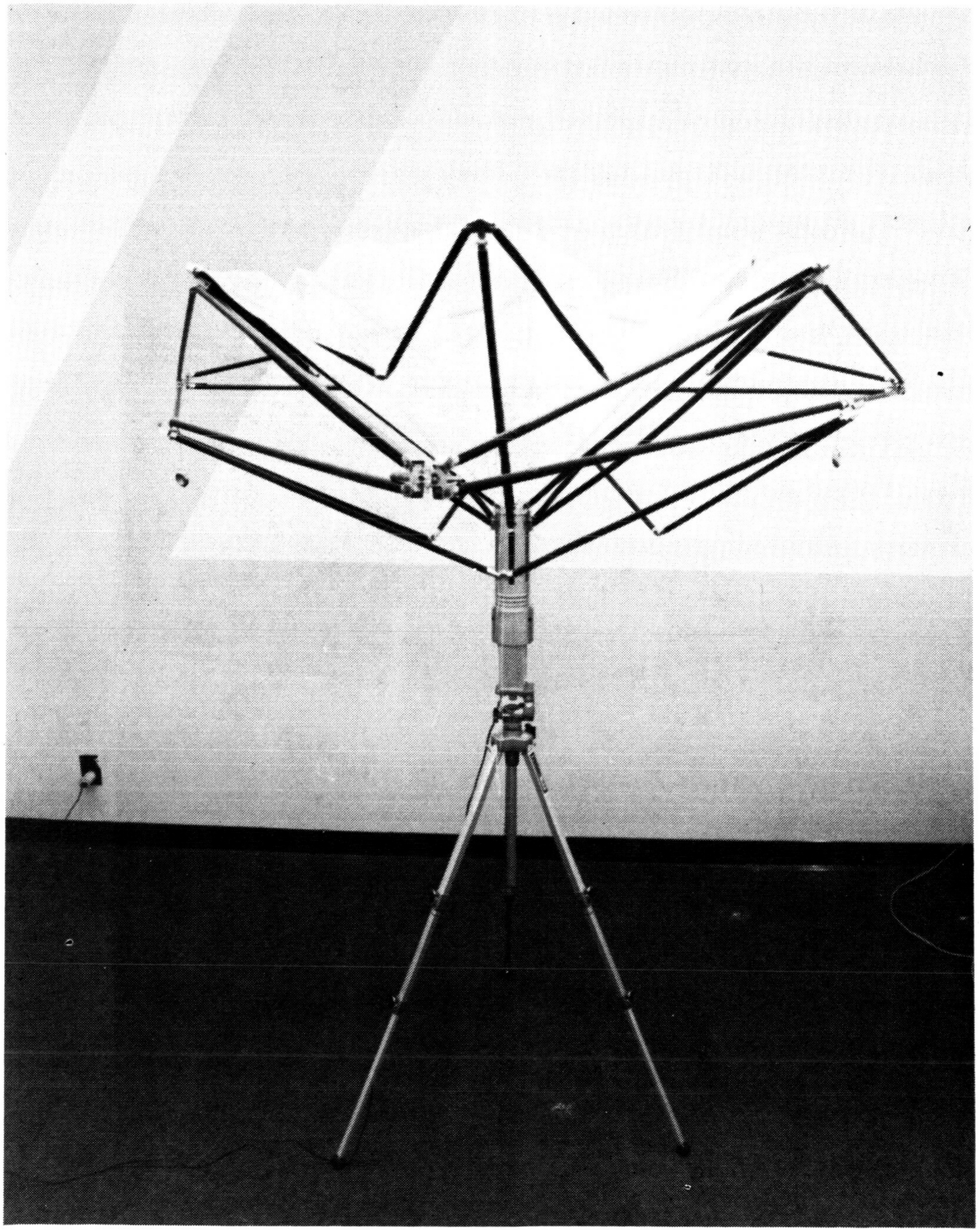

Figure 8

Figure 9 shows the model still further along in its deployment. The cross brace lower joints are separating from the upper joints deepening the structure.

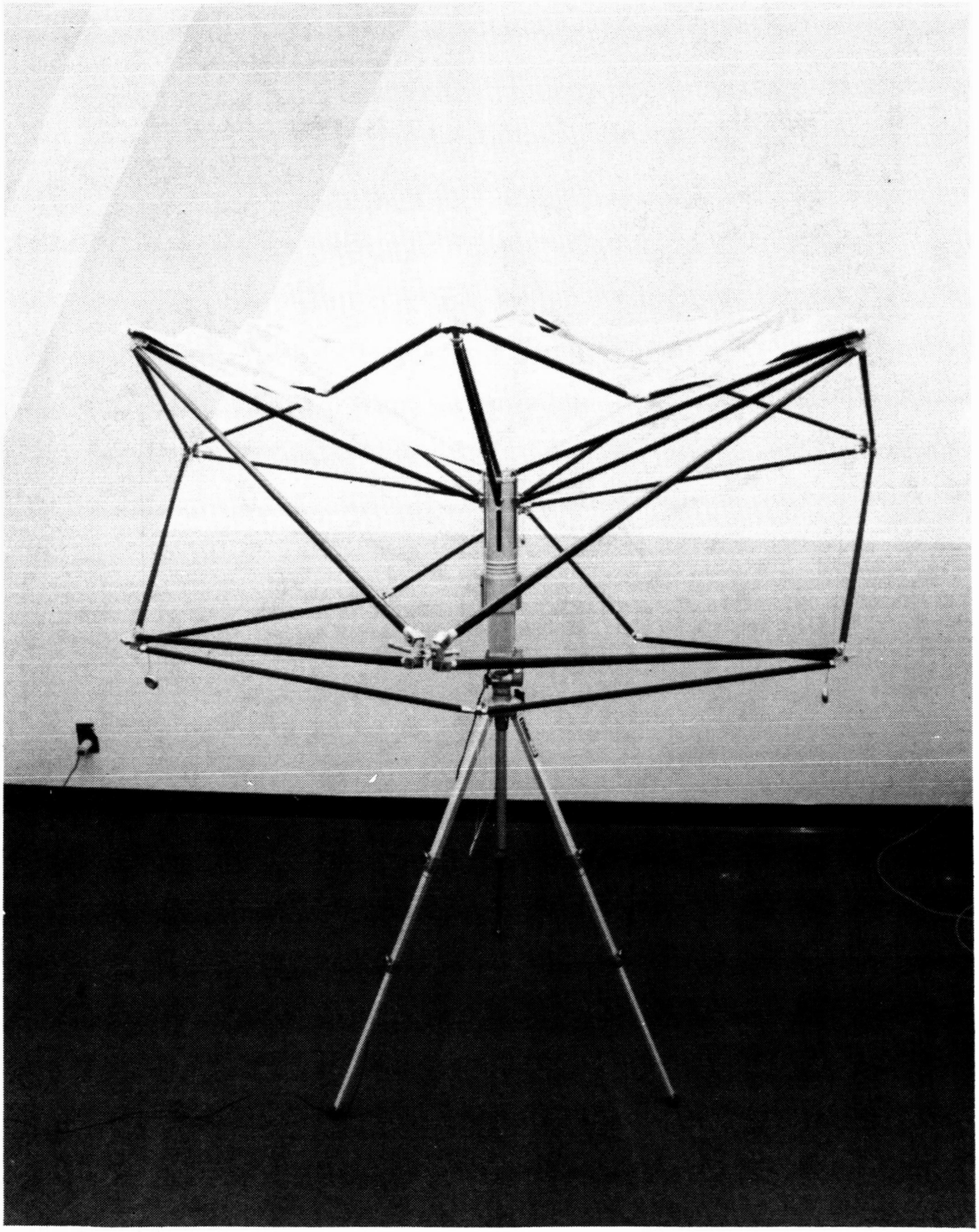

Figure 9

The fully deployed module is pictured in Figure 10. This demonstration model measures approximately 160 cm across the corners of the hexagonal reflector surface and stands approximately 135 cm high. The tubing size (1.27 cm diameter) and therefore joint sizes are full scale in the model. For a full scale module, however, the tube lengths are increased to the full length of the STS Orbiter cargo bay, resulting in a flight module measuring 28 meters across the corners of the hexagonal surface by 24 meters deep.

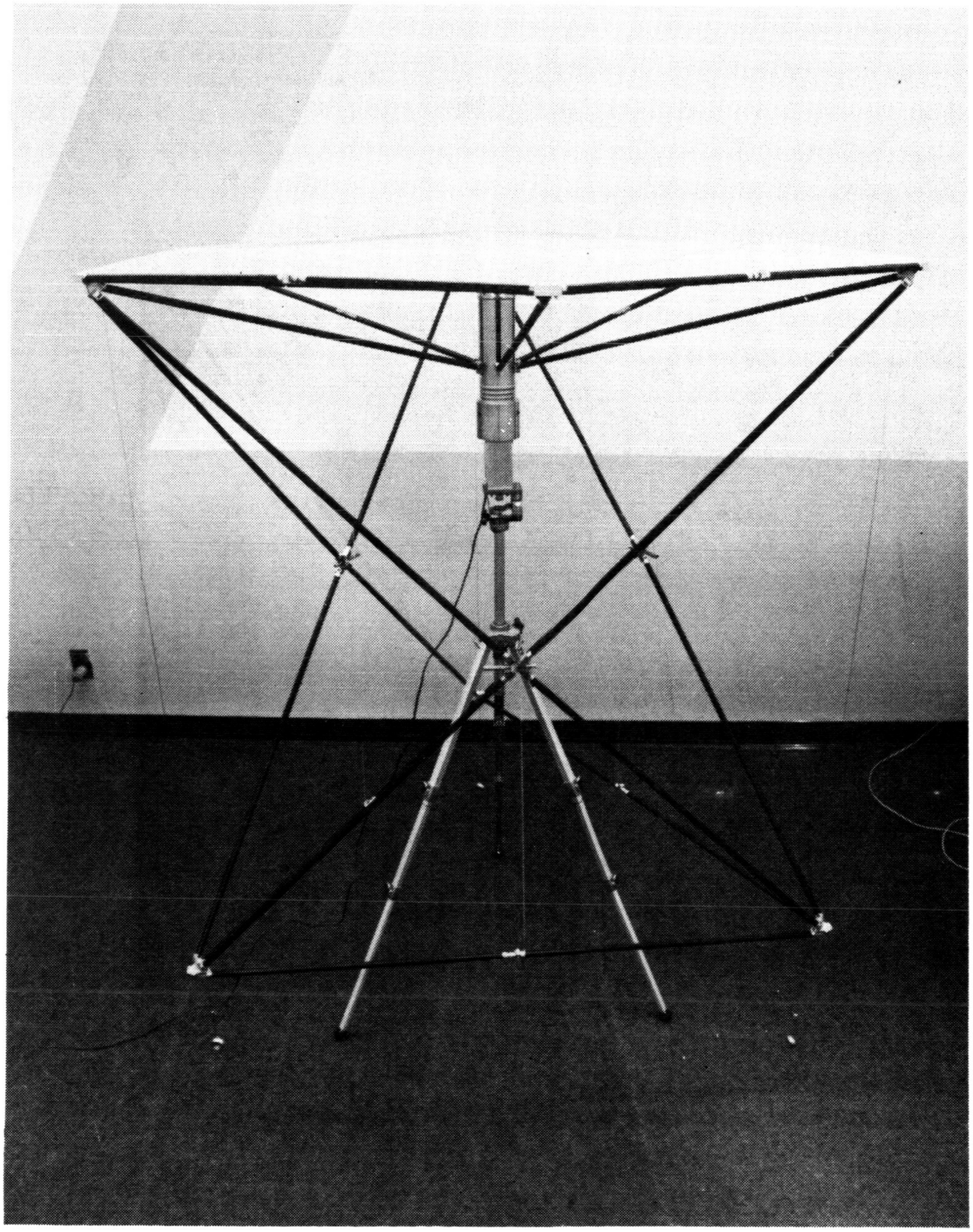

Figure 10

Figure 11 shows the mass of individual modules of various sizes. As the module size increases, the essentially parasitic mass of the module structure and the deployment mechanism becomes less and less significant and the module mass becomes predominantly the mass of the reflective mesh.

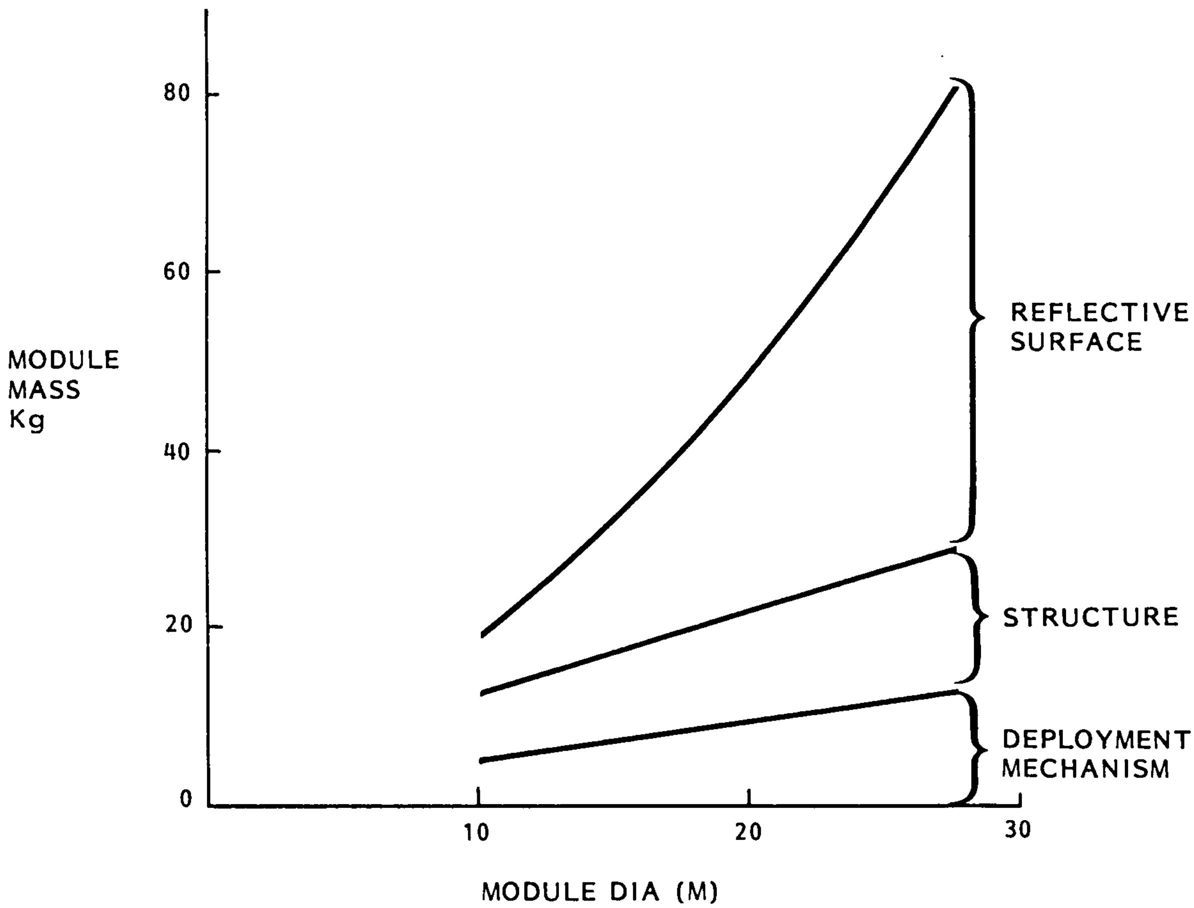

Figure 11

Figure 12 demonstrates this effect more clearly. For small modules (10 meters in diameter) the reflective mesh surface, which is for an antenna reflector the useful portion of the module, amounts to a little over one third of the total mass of the module. For a 28 meter diameter module, however, the mesh surface comprises almost two thirds of the mass of the module.

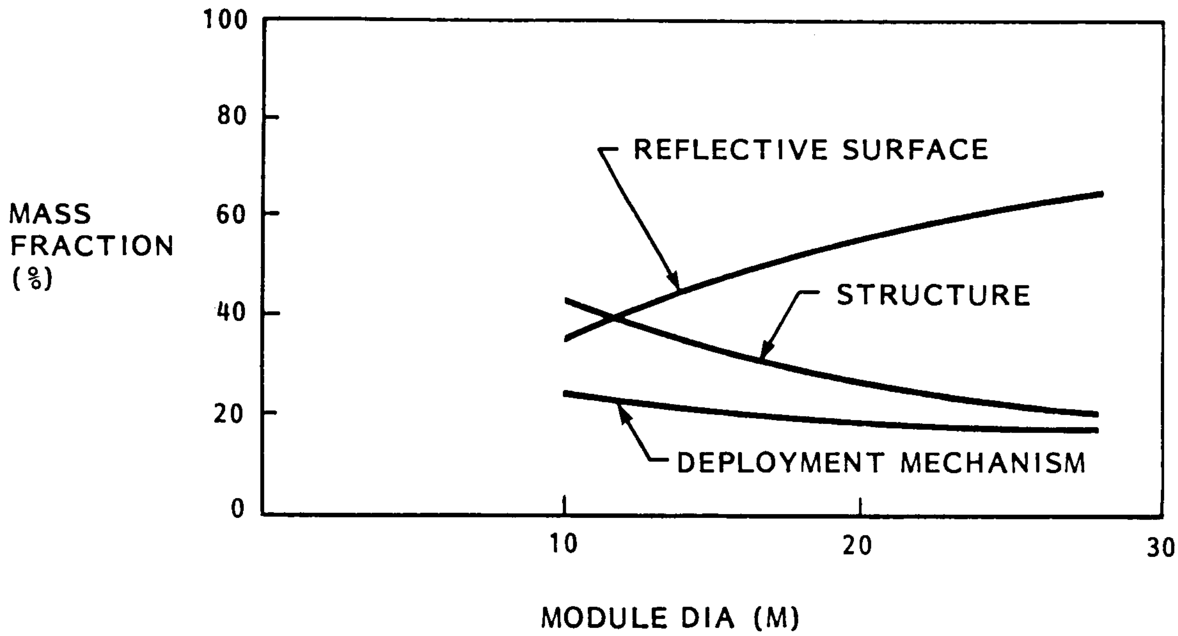

Figure 12

DEPLOYABLE MODULAR ANTENNA APPLICATION

The structural efficiency of modular antennas is fully realized in large aperture uses at moderate to mm wavelength RF frequencies. Modular antennas can be efficiently utilized through the majority of currently projected radiometry and ODSRS reflector applications when multiple shuttle flights are considered. Even with a single shuttle, the modular approach yields a significant potential for performance improvement over the current projections for mesh deployables as can be seen in Figure 13.

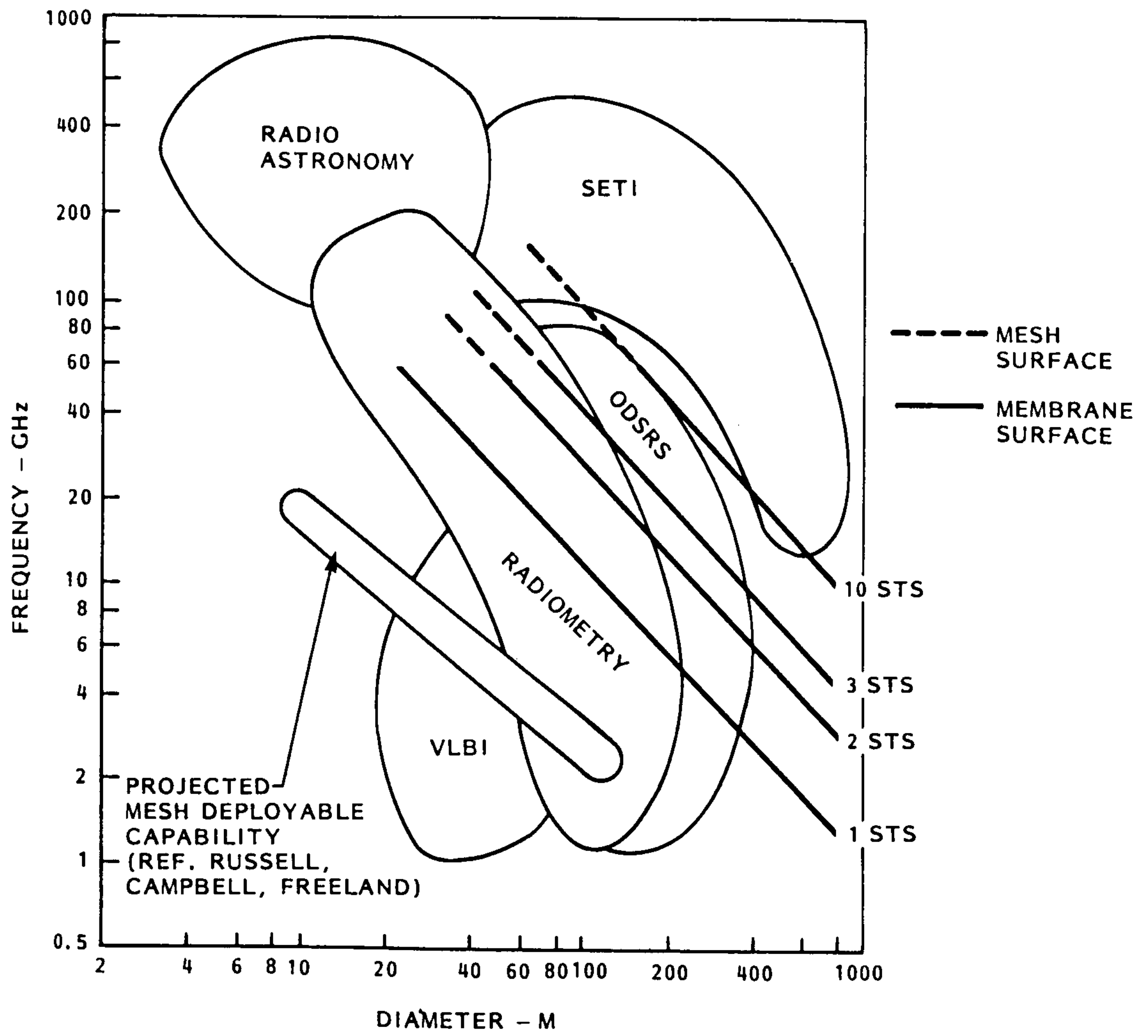

Figure 13

MODULAR ANTENNA ASSEMBLY METHODS

Figure 14 summarizes the various reflector assembly scenarios investigated during the study.

Techniques which were examined ranged from those requiring present technology STS operations with no EVA to large aperture techniques requiring development of a self contained, automated free flying assembly satellite.

- STS CONTAINED WITH 2 RMS
- RMS/ARTICULATED BOOM FIXTURE
- FORMATION FLYING SATELLITE
- FREE FLYING AUTOMATED SATELLITE

Figure 14

Reflectors of moderate size (up to approximately 70 m diameter) can be assembled directly from the Orbiter cargo bay using 2 RMS arms. One arm is used to hold and position the partially completed reflector and the other arm is used to deploy each individual module and attach it to the assembly. The entire operation can be controlled by the payload specialist working at the aft flight deck of the Orbiter. This concept is overviewed in Figure 15.

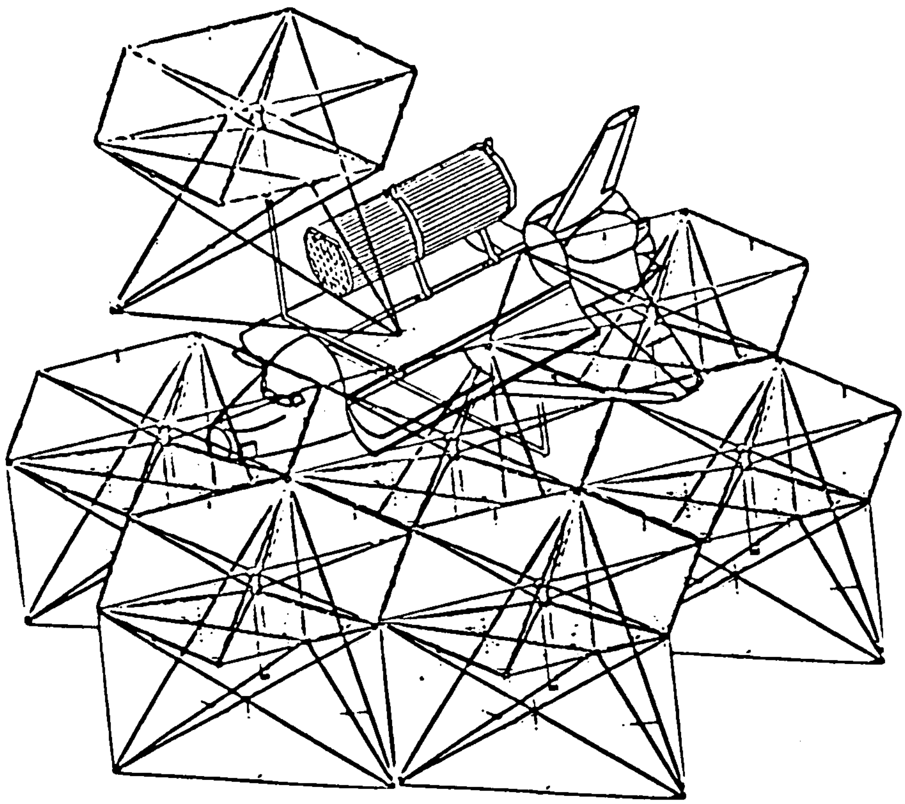

Figure 15

Figure 16 depicts assembly of a larger reflector using an articulated, extendable boom to hold the reflector for assembly. This boom is operated from inside the orbiter and is used to rotate and position the reflector to receive each module. The modules are deployed and assembled to the reflector by the Orbiter RMS. Reflector apertures up to approximately 310 meters in diameter can be assembled in one launch using this approach.

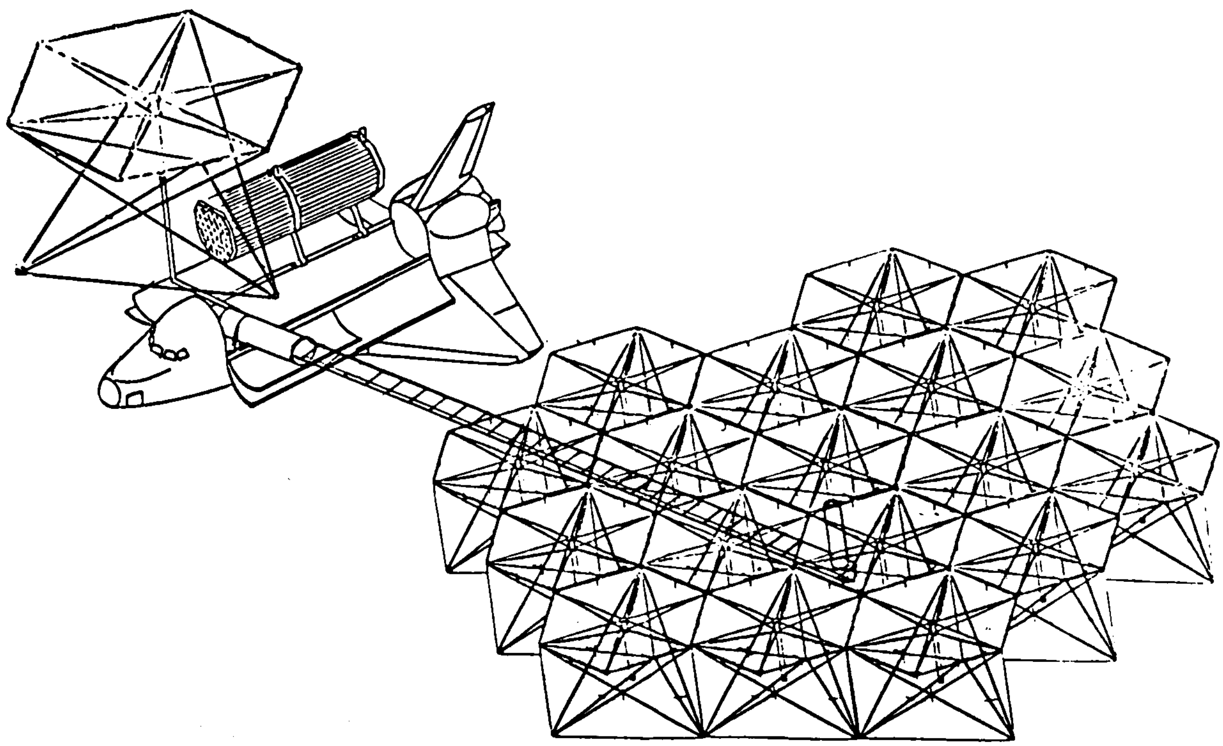

Figure 16

Large aperture antennas can be assembled only by using techniques which allow multiple resupply by the STS. One such technique is shown in Figure 17. A free flying satellite is carried to orbit with the first set of modules. After these modules are installed, the Orbiter releases the satellite and returns to Earth. Subsequent Orbiter flights rendezvous with the satellite to deliver and install additional modules.

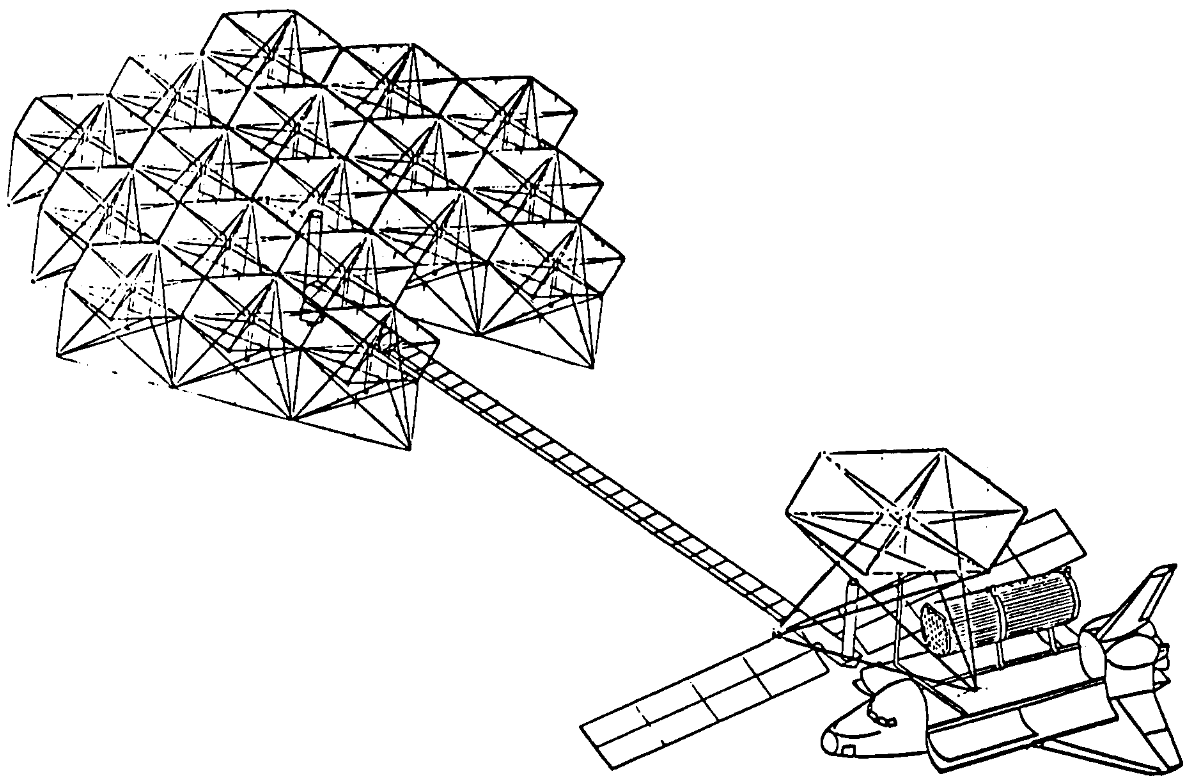

Figure 17

Figure 18 describes another reflector assembly approach for apertures requiring multiple STS launches. In the scheme, the satellite is a totally automated, self contained assembly platform. The STS ferries cargo loads of modules to orbit and delivers them to the satellite. Positioning equipment, permanently mounted on the satellite, removes the modules from their transport cannister, deploy them and attach them to the reflector.

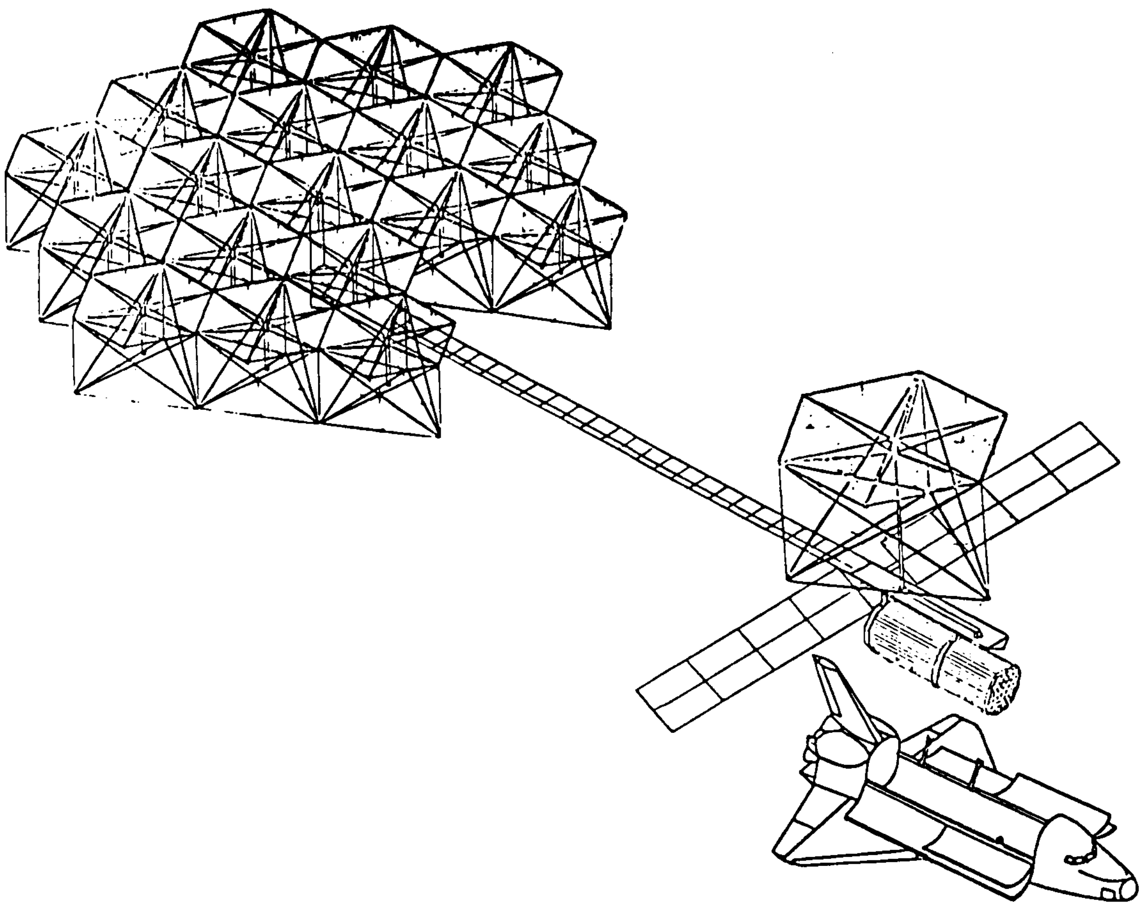

Figure 18

SIZE LIMITS OF ASSEMBLY TECHNIQUES

Figure 19 summarizes the reflector size limitations of the various assembly techniques. The approach using the RMS arms from the shuttle Orbiter is limited by the reach of the two arms, allowing a maximum size reflector of approximately 73 m diameter. The articulated boom case is limited in size by the number of modules that can be carried in the Orbiter cargo bay, with part of the volume taken up by the stowed assembly boom. The assembly satellite cases are essentially limited in size only by a number of shuttle launches devoted to the task.

- STS CONTAINED – 73 M DIAMETER
- RMS/BOOM – 310 M DIAMETER
- FORMATION SATELLITE – UNLIMITED
- AUTOMATED SATELLITE – UNLIMITED

Figure 19

STUDY CONCLUSIONS

The conclusions reached during the study are summarized in Figure 20. Modular antenna construction can provide a significant increase in reflector aperture size over deployable reflectors. The modular approach allows reflective mesh surfaces to be supported by a minimum of structure. The kinematics of the selected deployable design approach have been validated by the subscale demonstration model. Further design refinements on the module structural/joints and design optimization on intermodule joints are needed.

- MODULAR CONSTRUCTION PROVIDES A SIGNIFICANT INCREASE IN APERTURE SIZE
- APPROACH YIELDS A MINIMIZATION OF STRUCTURAL WEIGHT
- KINEMATICS ARE VALID
- JOINT AND INTER MODULE ATTACHMENT REQUIRE ADDITIONAL ACTIVITY

Figure 20

AREAS FOR FURTHER CONSIDERATION

The study concluded that work in two additional technology areas would be beneficial in developing larger reflector apertures. These study areas are summarized in Figure 21. The first area is the development of a larger deployable element, perhaps seven individual modules packaged and interconnected to be deployed as a single unit. These large "building block" elements would then be assembled in essentially the same manner as the single modules.

The second area for research is the development of an active reflective surface, that is, surface which automatically adjusts itself on orbit to compensate for mechanical assembly tolerances and/or reflector distortions due to thermal gradient or positioning dynamic effects.

DEVELOPMENT OF A MODULAR BUILDING BLOCK

- 100 M DIAMETER BASIC ELEMENT
- MULTIPLE MODULE INTERCONNECTED
- DEPLOYED WITH SINGLE ACTUATOR
- ABILITY TO INTERCONNECT WITH OTHER 100 M ELEMENTS TO OBTAIN DESIRED SIZE

DEVELOPMENT OF ACTIVE SURFACE ELEMENT

- PRECISION HEXAGONAL SURFACE ELEMENT
- ORBITAL ATTACHMENT TO SUBSTRUCTURE
- ATTACHMENT THROUGH ACTIVE CONTROL ACTUATORS

Figure 21

REFERENCE

Russel, R.; Campbell, T.; and Freeland, R.: A Technology Development Program for Large Space Antennas. Paper No. IAF-80A33, 31st International Aeronautical Congress of the International Astronautical Federation, Sept. 1980.