SEQUENTIAL DEPLOYMENT OF TRUSS STRUCTURES

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DESIGN CONCEPTS FOR LARGE ANTENNA REFLECTOR STRUCTURES

During the past year, Astro has been working on the design and analysis of truss-type reflector structures using expandable mesh as an rf reflecting surface. This work, which is supported by a contract from Langley Research Center, is motivated by the excellent accuracy and stiffness performance indicated by previous analyses of these types of structures.

In order to achieve the objective, a number of ground rules were established which are aimed at simplifying the mechanization of the truss configuration. Most of these ground rules are being used in our work on spaceflight hardware systems. They have proven to be very helpful in keeping the development, fabrication, and test costs of deployable structures under control. The only new one arising from the current application is that of mesh attachment. It is desired to fasten the mesh directly to the surface struts of the truss and avoid intricate systems of shaping wires, tie-downs, or harnesses.

OBJECTIVE

CONCEIVE AND DEFINE A SPACE-DEPLOYED/ASSEMBLED REFLECTOR ANTENNA STRUCTURE UTILIZING STOWABLE MESH AS THE REFLECTING SURFACE

GROUND RULES

- SEQUENTIAL DEPLOYMENT
- METRIC DEPLOYMENT WITH CANISTER-MOUNTED ACTUATORS
- AUTOMATED DEPLOYMENT WITH ON-OFF CONTROL
- EFFICIENT PACKAGING
- NO ADJUSTMENTS AFTER FABRICATION
- SIMPLE MESH ATTACHMENT

Figure 1

TETRAHEDRAL TRUSS STRUCTURE

The geometry investigated most intensively has been the triangular tetrahedral truss shown here. A square-type truss having the same topology has also been investigated.

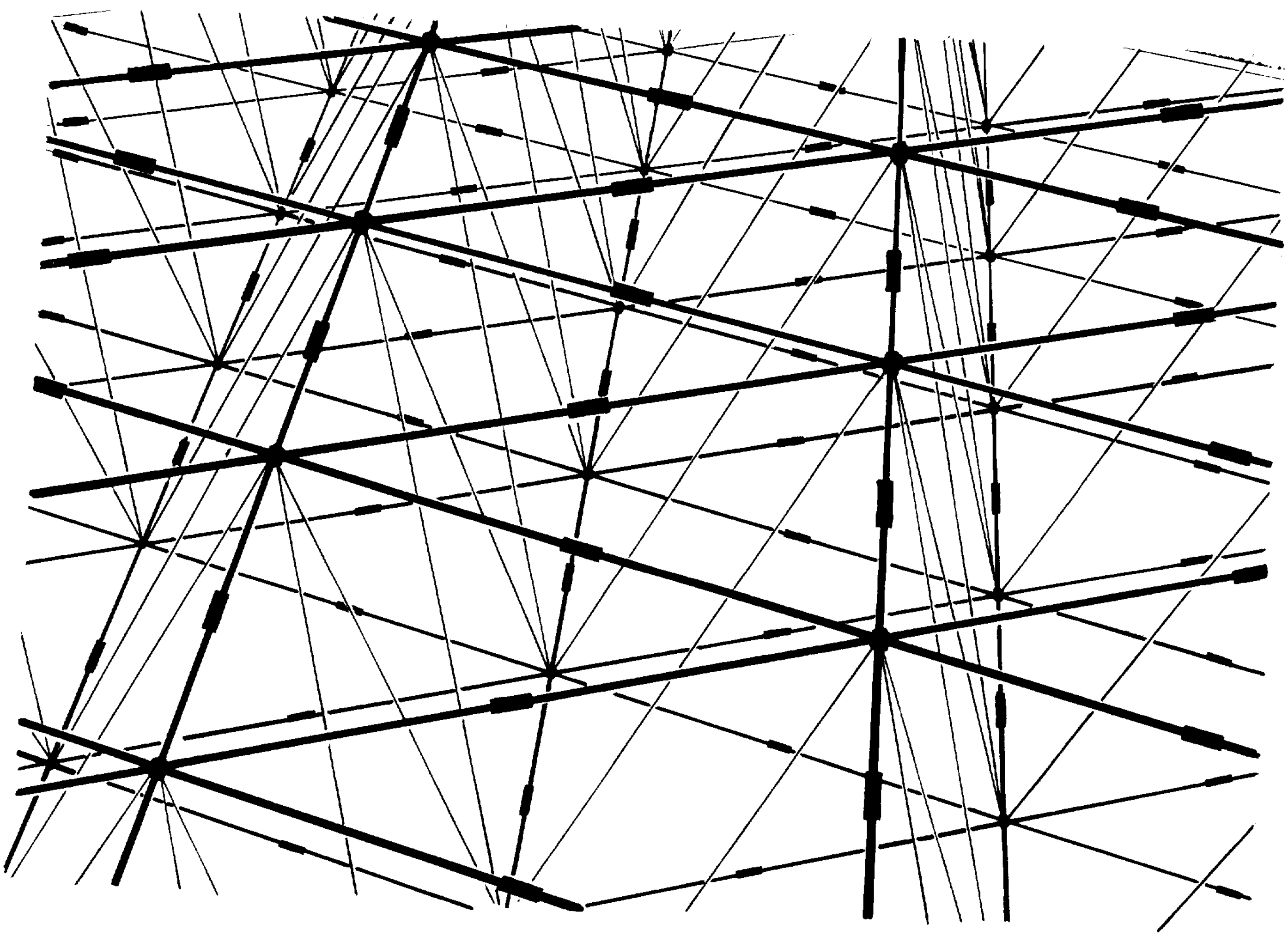


Figure 2

TETRAHEDRAL TRUSS NOMENCLATURE

The tetrahedral truss is composed of surface struts and core members. In the particular deployable form invented in this contract, the entire truss is viewed as being made up of a number of parallel truss "ribs" connected to each other by interrib struts and members as shown on this figure.

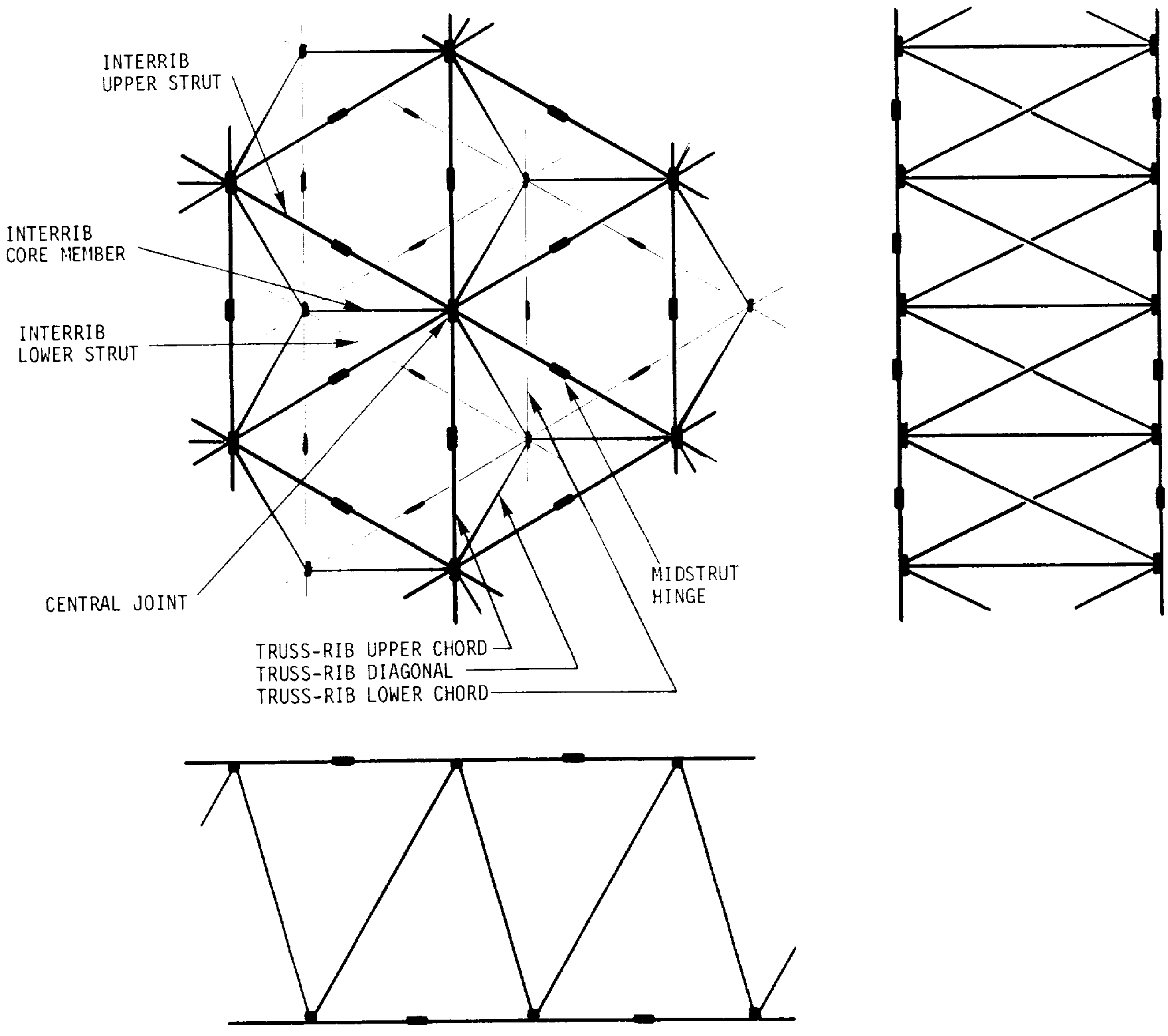


Figure 3

PARTIALLY DEPLOYED STRUCTURE

In this new concept of deployment, the truss ribs are deployed first along their length, and then the interrib members are deployed. This sketch shows five deployed truss ribs still packaged together with fully deployed structure on either side. These fully deployed trusses have high stiffness and the truss ribs sandwiched between them are well-controlled simply by controlling the positions of the two fully deployed portions. The positioning of the fully deployed portions is accomplished by deployment mechanisms at the two boundaries of the structure.

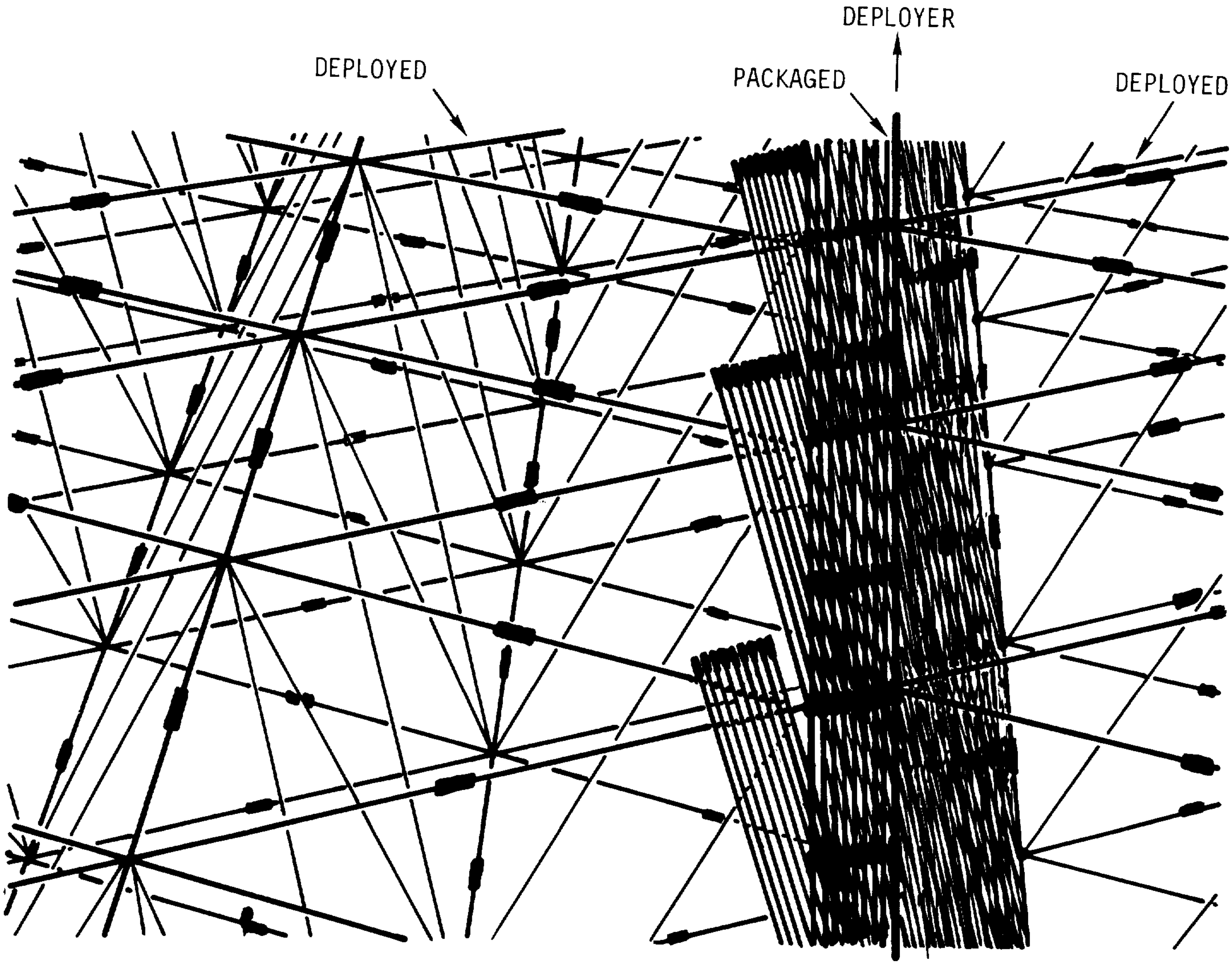


Figure 4

MID-DEPLOYMENT

The deployment mechanisms are indicated in this figure by the small half circles. Appropriate actuators will grasp the fully deployed portions, move them apart, and allow the required amount of fully packaged truss to leave the deployment mechanism.

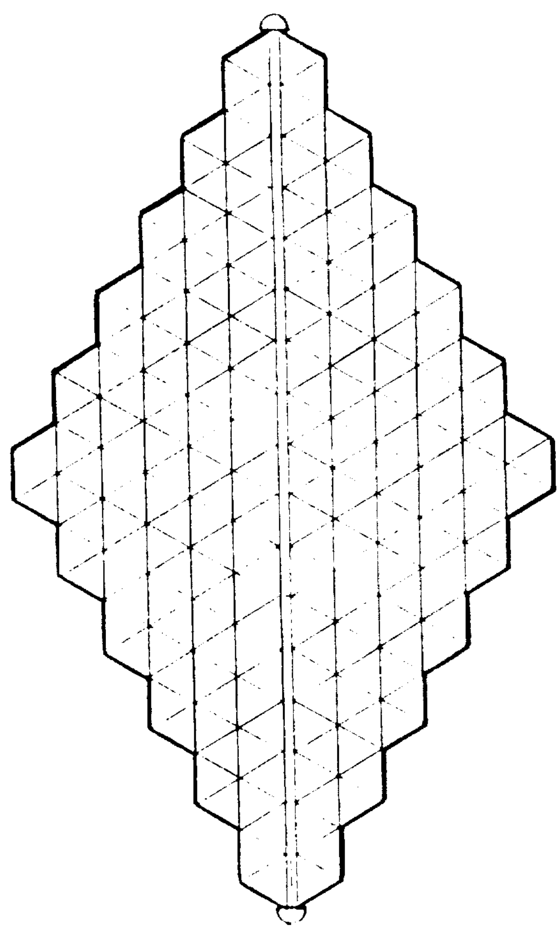


Figure 5

TRUSS RIB WITH INTERRIB ELEMENTS

A fully deployed single truss rib with its associated interrib elements is shown in this figure. Of course, the rib itself packages neatly by allowing midstrut joints to fold outwards allowing the diagonals to lie alongside each other. The difference between the present packaging method and the "standard method," which involves synchronous deployment, is the manner in which the interrib elements are packaged.

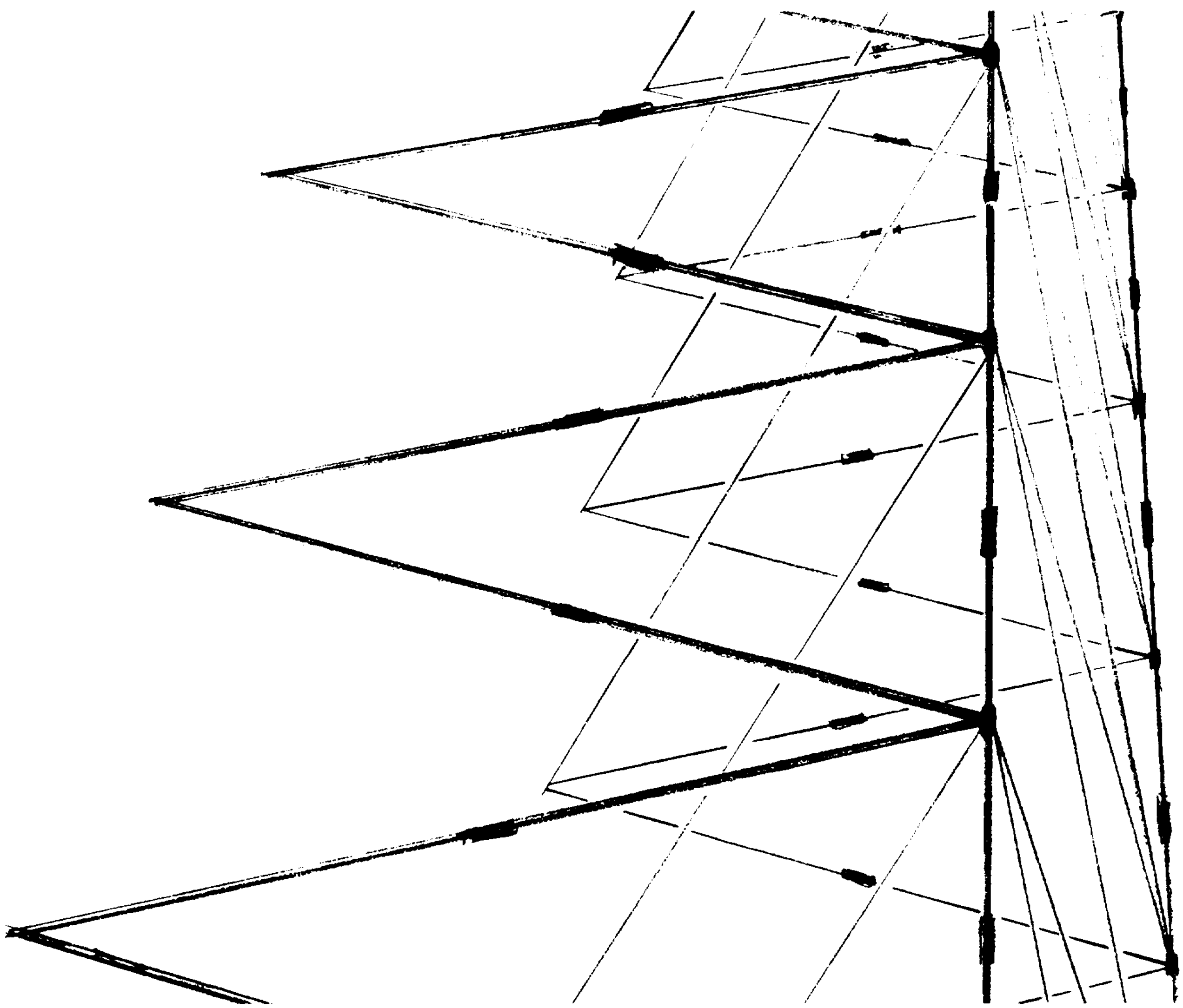
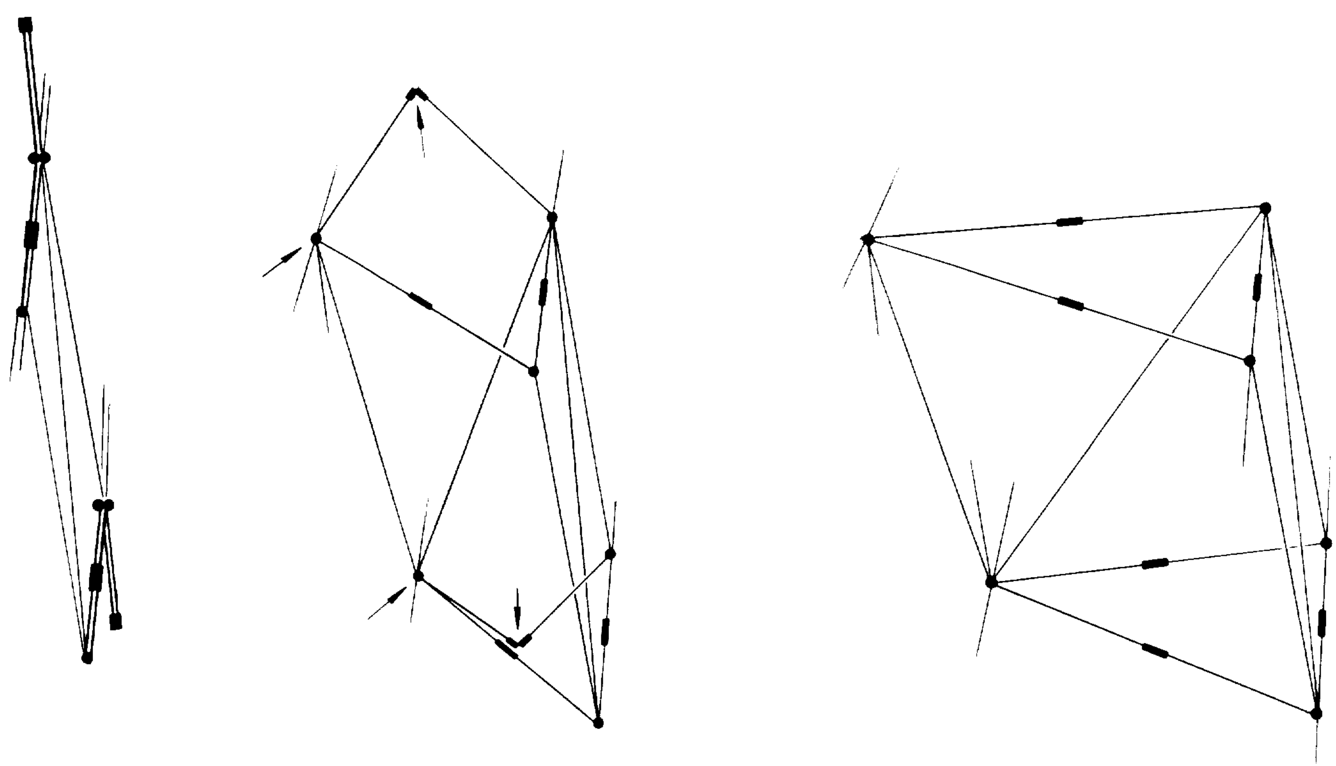


Figure 6

SECOND-STAGE DEPLOYMENT

This sketch shows the deployment of the interrib elements. Note that only one of the interrib struts on each surface is folded outward. The other surface strut folds over against the appropriate truss chord. It is this action which allows sequential deployment.



(a) STOWED (b) PARTIALLY DEPLOYED (c) DEPLOYED

Figure 7

CENTRAL JOINT

The previously described type of deployment requires specially designed joints. The central joint at which nine members intersect is a particularly tough design problem. After a considerable amount of effort, we have been able to design the joint shown here which has all the proper articulations and incorporates buttresses as necessary to stabilize the joint when fully deployed. Note that all motions are single hinge-type rotations.

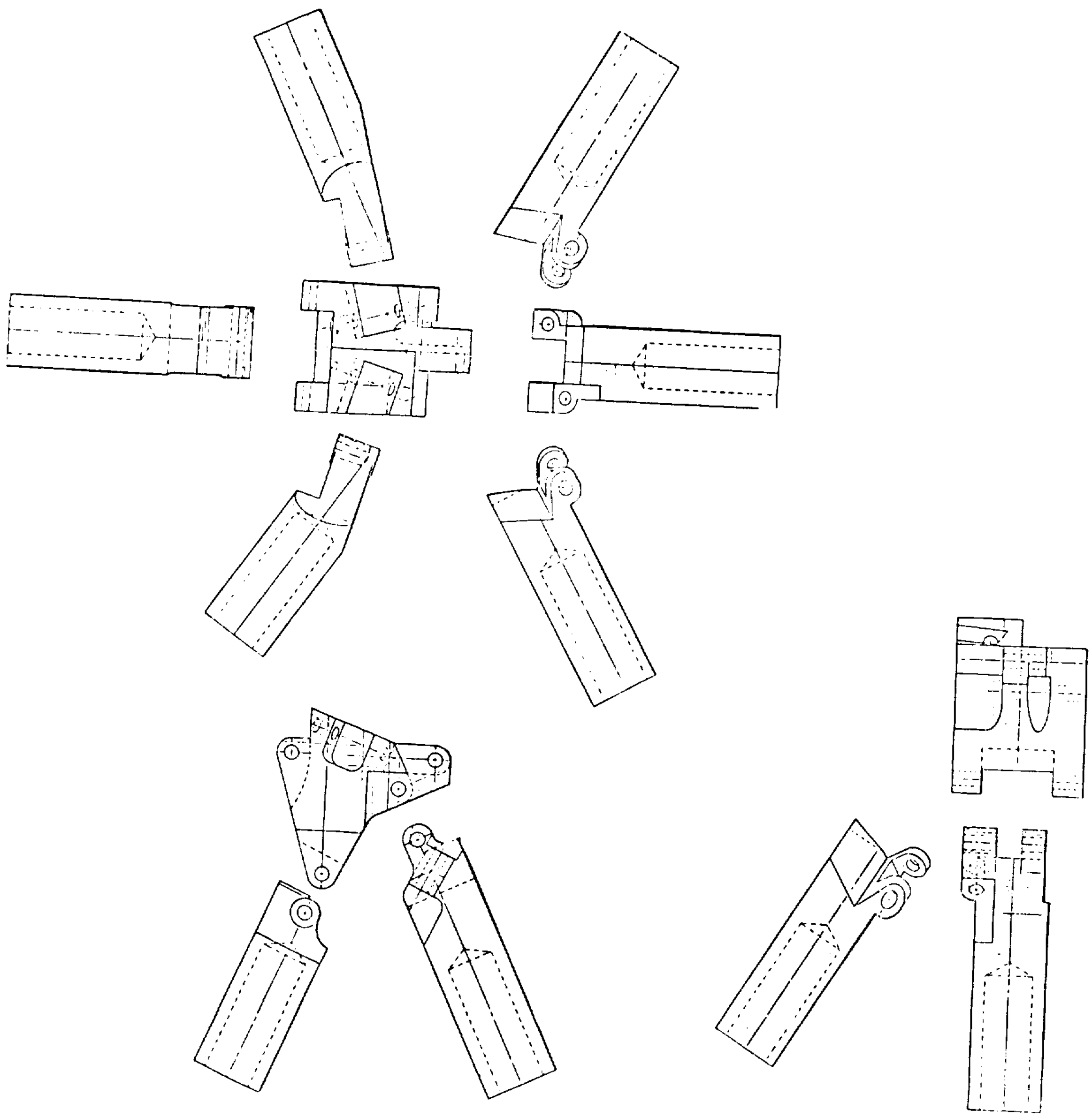
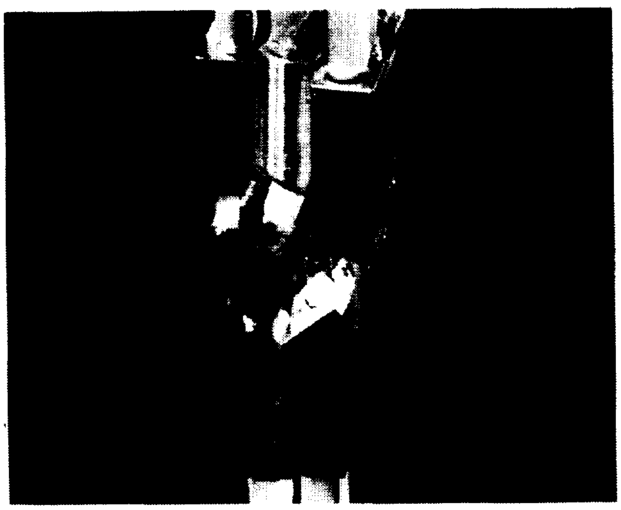


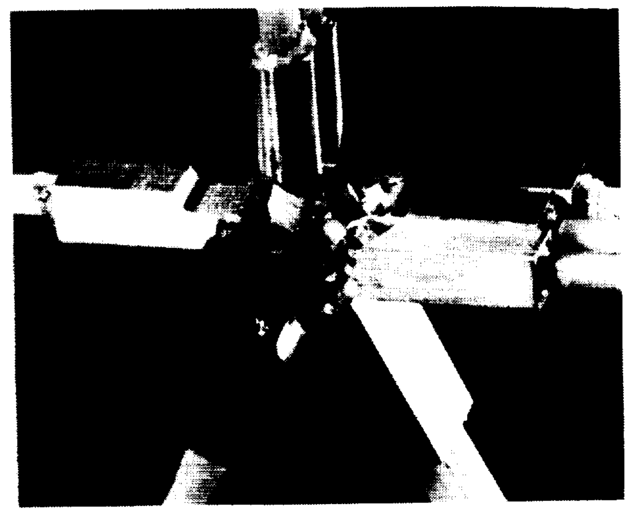
Figure 8

NINE-MEMBER CENTRAL JOINT

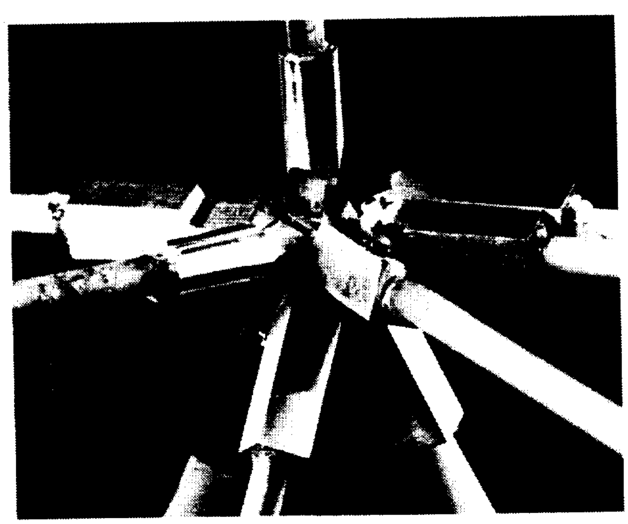
The first example of the nine-member central joint in hardware form is shown in the photographs here. The various stages of deployment of this joint are shown.



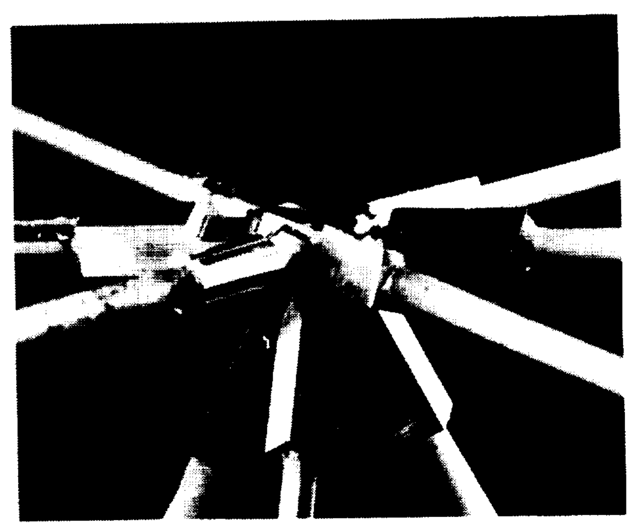
(a) STOWED



(b) FIRST-STAGE DEPLOYMENT



(c) ONE-SIDE SECOND-STAGE DEPLOYMENT



(d) FULLY DEPLOYED

Figure 9

MIDSTRUT HINGE

The midstrut hinge is a refinement of a design which has already been flight proven on the Seasat Synthetic Aperture Radar Extendible Support Structure. The main problem solved here was to squeeze the packaged hinge into a cross-sectional area no larger than the members to which it is attached.

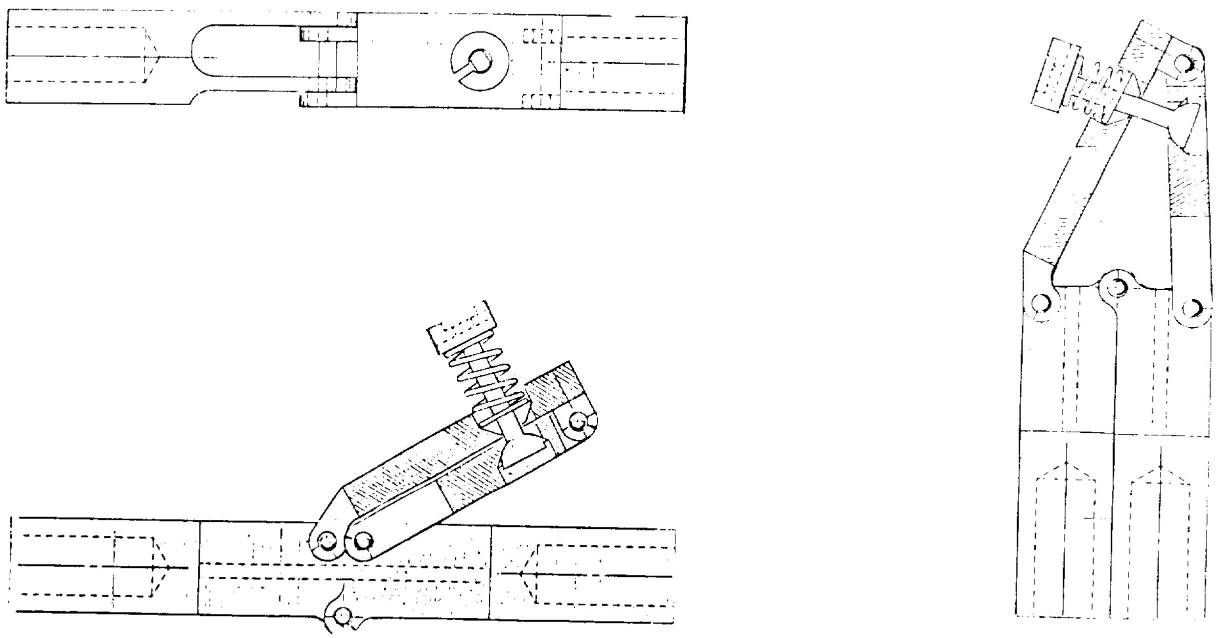
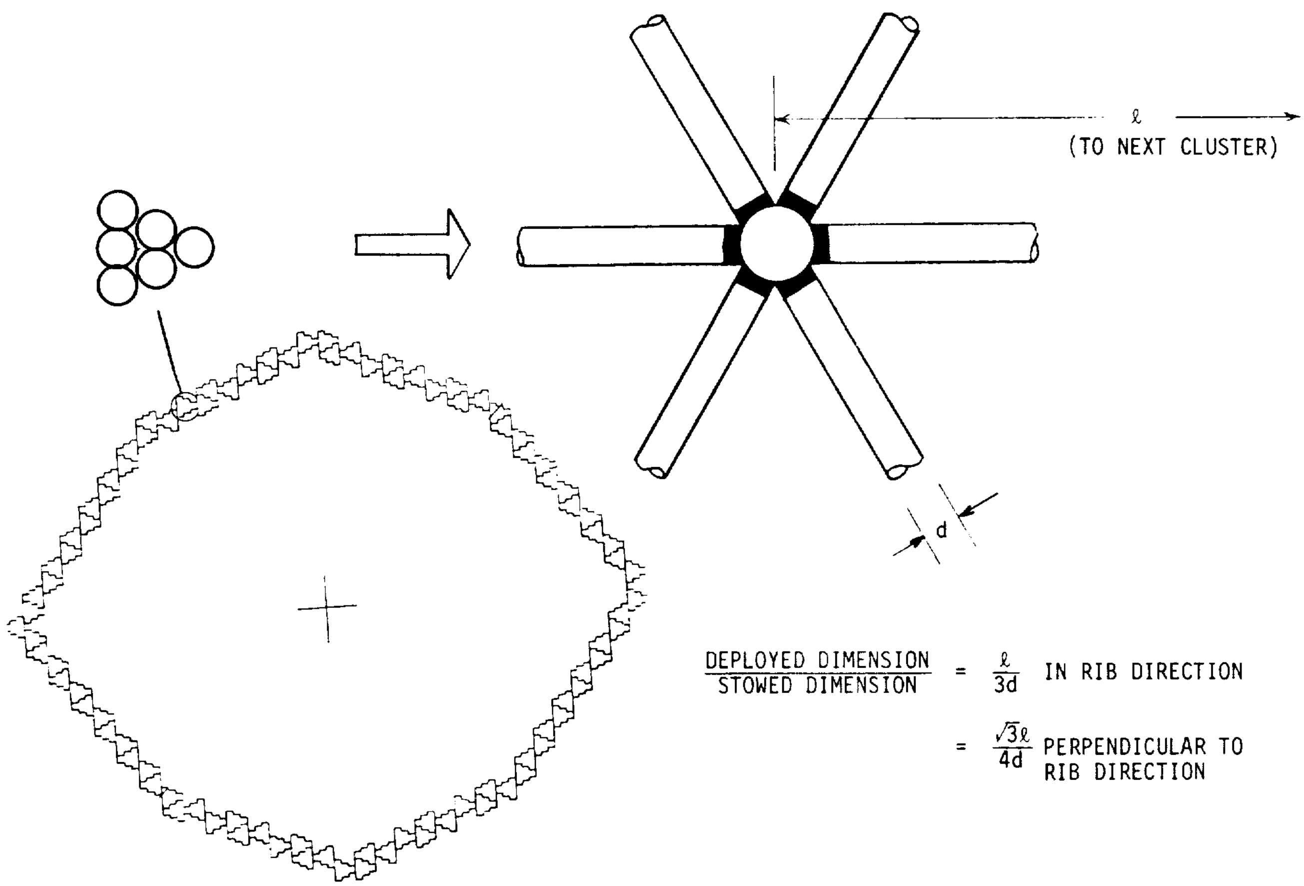


Figure 10

PACKAGING EFFICIENCY

Each of the nine-member joints package into a triangular cluster shown here. The ratio of deployed-to-stowed dimensions is determined by tightly packaging these clusters together. Note that for a circular deployed structure the package is smaller in the direction perpendicular to the rib than it is in the direction parallel to the rib. These packaging ratios are correct for flat truss surfaces. For doubly curved truss surfaces, there may be a necessary increase in package size caused by the requirement to adjust member lengths so as to achieve the designed geometry both deployed and packaged. The amount of increased package size has been studied for a spherical truss surface. Several different strategies of laying out the structure on the spherical surface have been studied, and one has been selected which minimizes the penalty in package size.



$$\frac{\text{DEPLOYED DIMENSION}}{\text{STOWED DIMENSION}} = \frac{\ell}{3d} \text{ IN RIB DIRECTION}$$

$$= \frac{\sqrt{3}\ell}{4d} \text{ PERPENDICULAR TO RIB DIRECTION}$$

Figure 11

PACKAGED SIZE FOR SPHERICAL SURFACE

The package size along and perpendicular to the truss rib directions for a spherical surface are shown here. The package size is nondimensionalized with respect to the theoretical values in the truss rib direction for zero curvature. The abscissa is the ratio of focal length to diameter. The smaller the value of F/D, the more curved the surface is. With the particular strategy used, the increase in package size due to curvature along the truss rib is gradual and is caused by the fact that the size of the surface triangles tends to get smaller as the surface slope increases. In the cross-rib direction, the geometry dictates inequalities in the deployed and packaged lengths of the interrib core members. These length inequalities are adjusted by appropriately moving the hinge locations. As long as this relocation allows the hinge to stay within a member, no packaging penalty is incurred. However, for slender members at low enough F/D, the hinges must go outside of the member and therefore start dominating the package size. Thus, for a very slender member there may be significant penalty due to curvature. However, for a slenderness of say 100, very little penalty would be expected.

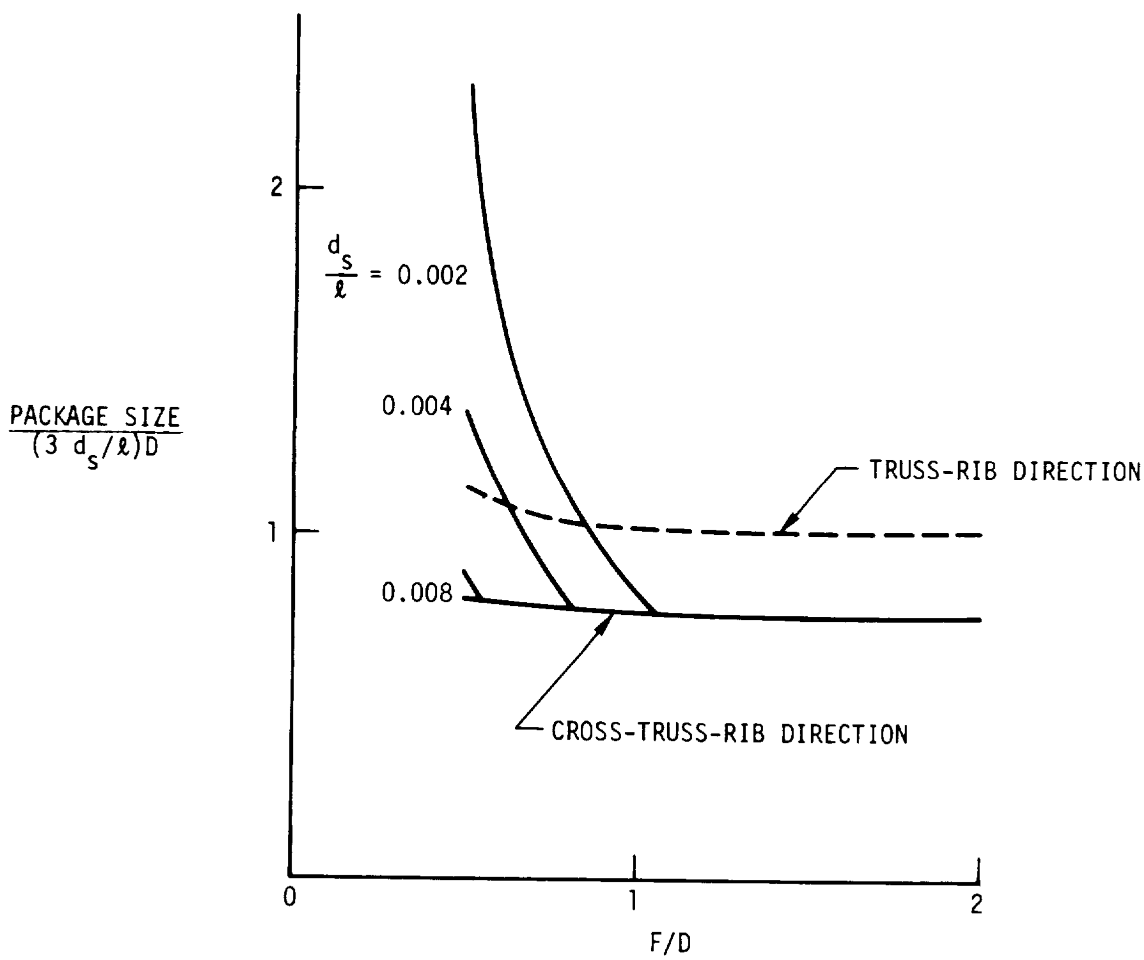


Figure 12

SEQUENTIALLY DEPLOYABLE TRUSS ANTENNA STRUCTURES FOR SPACE

The accomplishments to date, the work planned next year, and what we recommend for the following year are shown here. It is the long-range intent of the effort to make the sequential deployable truss antenna available to potential users.

PROGRAM SCHEDULE

ACCOMPLISHMENTS	PLANNED 1982	RECOMMENDED 1983
SEQUENTIAL DEPLOYMENT CONCEPT, GENERALIZED EXAMPLES	CONSTRUCT MEDIUM-SCALE DEPLOYABLE MODEL (1-m STRUT LENGTH) FROM 1/2-INCH-DIAMETER GRAPHITE-COMPOSITE TUBING SUITABLE FOR TESTING	AUGMENT MEDIUM-SCALE MODEL TO INCLUDE TRUSS RIM AND MORE BAYS
GENERALIZED TETRAHEDRAL TRUSS TRIANGLE TO SQUARE	DETERMINE GEOMETRY FOR PARABOLOIDAL SURFACE	INTEGRATE SIMULATED MESH WITH MODEL
DESIGN FOR MESH FACETING ACCURACY	DETERMINE METHODS FOR INTEGRATING REFLECTOR MESH WITH STRUCTURE	DETAIL DESIGN AND FABRICATE OPERATING DEPLOYER AND INTEGRATE WITH AUGMENTED MEDIUM-SCALE MODEL
HINGE-GEOMETRY ANALYSIS	DESIGN HINGE GEOMETRY FOR TRUSS-RIM POINTS	BUILD A FULL-LENGTH DEPLOYABLE TRUSS SEGMENT WITH CURVED-SURFACE GEOMETRY
CONCEPT DEMONSTRATION MODEL	DESIGN DEPLOYER (PRELIMINARY)	PERFORM SUPPORTING ANALYSIS
PACKAGE SIZE AND WEIGHT ANALYSIS	BUILD DEPLOYER VISUALIZATION MODEL	
SHELL VIBRATION ANALYSIS	PERFORM SUPPORTING ANALYSIS	
HIGH-FIDELITY MODEL DESIGN AND CONSTRUCTION		
GEOMETRICAL DETERMINATION FOR SPHERICAL SURFACES		

Table 1