DEVELOPMENT OF THE 15-METER HOOP/COLUMN ANTENNA SYSTEM

T. G. Campbell,
D. H. Butler, and
K. Belvin
NASA Langley Research Center
Hampton, Virginia

and

B. B. Allen
Harris Corporation
Melbourne, Florida

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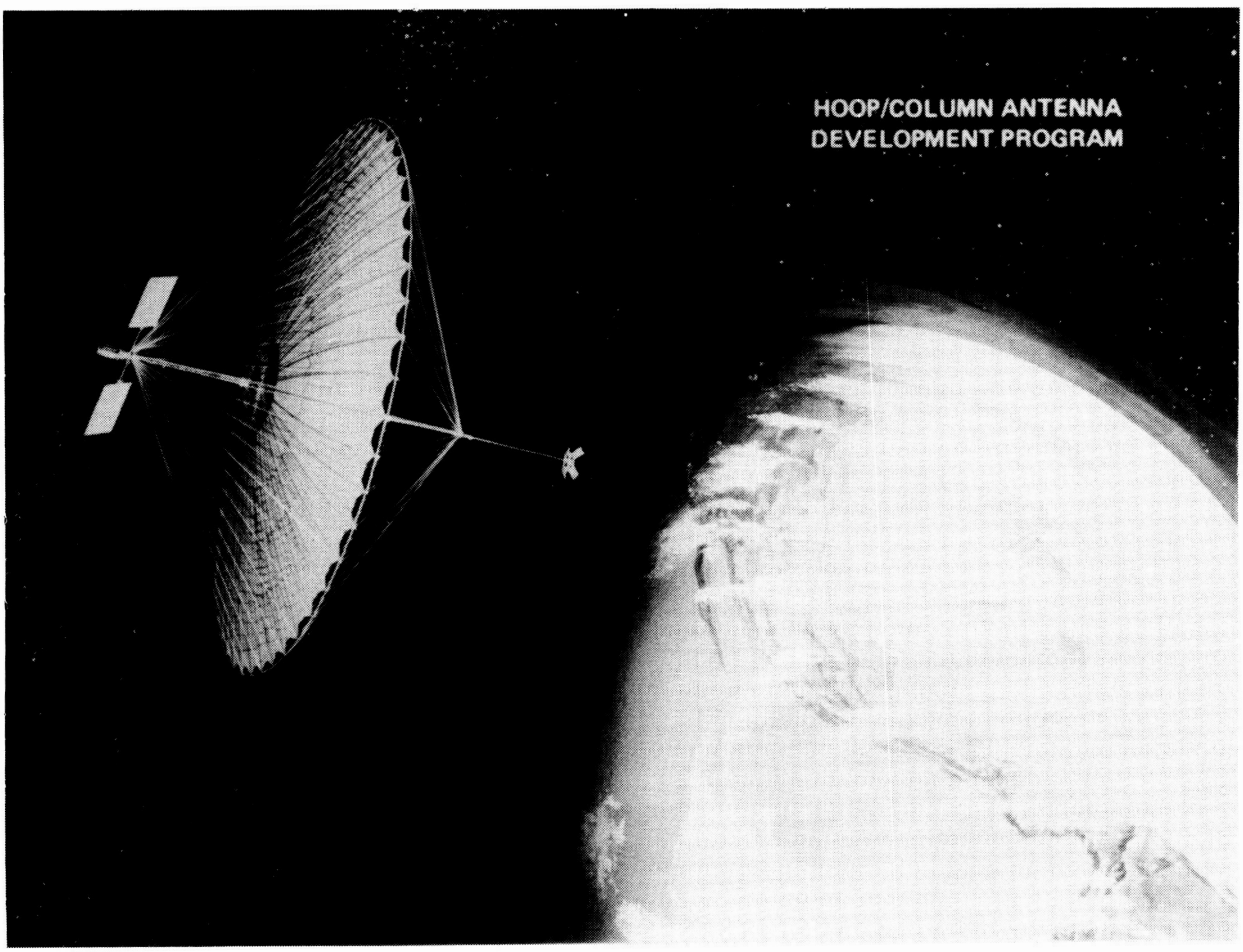
INTRODUCTION

The development of the 15-meter hoop/column antenna system is presented. The 15-meter deployable structure is discussed along with the multiple-beam feed system development and the structures and RF testing planned in 1985. These topics are presented in accordance with the presentation agenda listed below.

- **OVERVIEW OF ANTENNA DEVELOPMENT ACTIVITIES**
- **DEVELOPMENT OF 15-METER REFLECTOR AND KINEMATIC DEPLOYMENT TESTS**
- **PRELIMINARY MODAL SURVEY TEST RESULTS AND FUTURE STRUCTURAL-DYNAMICS TESTS**
- **RADIO FREQUENCY SUBSYSTEMS AND NEAR-FIELD TESTING**
- **CONCLUDING REMARKS**

HOOP/COLUMN ANTENNA CONFIGURATION

The hoop/column deployable antenna concept is shown here in an artist's rendering in a space application. This antenna concept is a symmetrical, cable-stiffened structure which is amenable to different reflector configurations: parabolic, spherical, and planar.



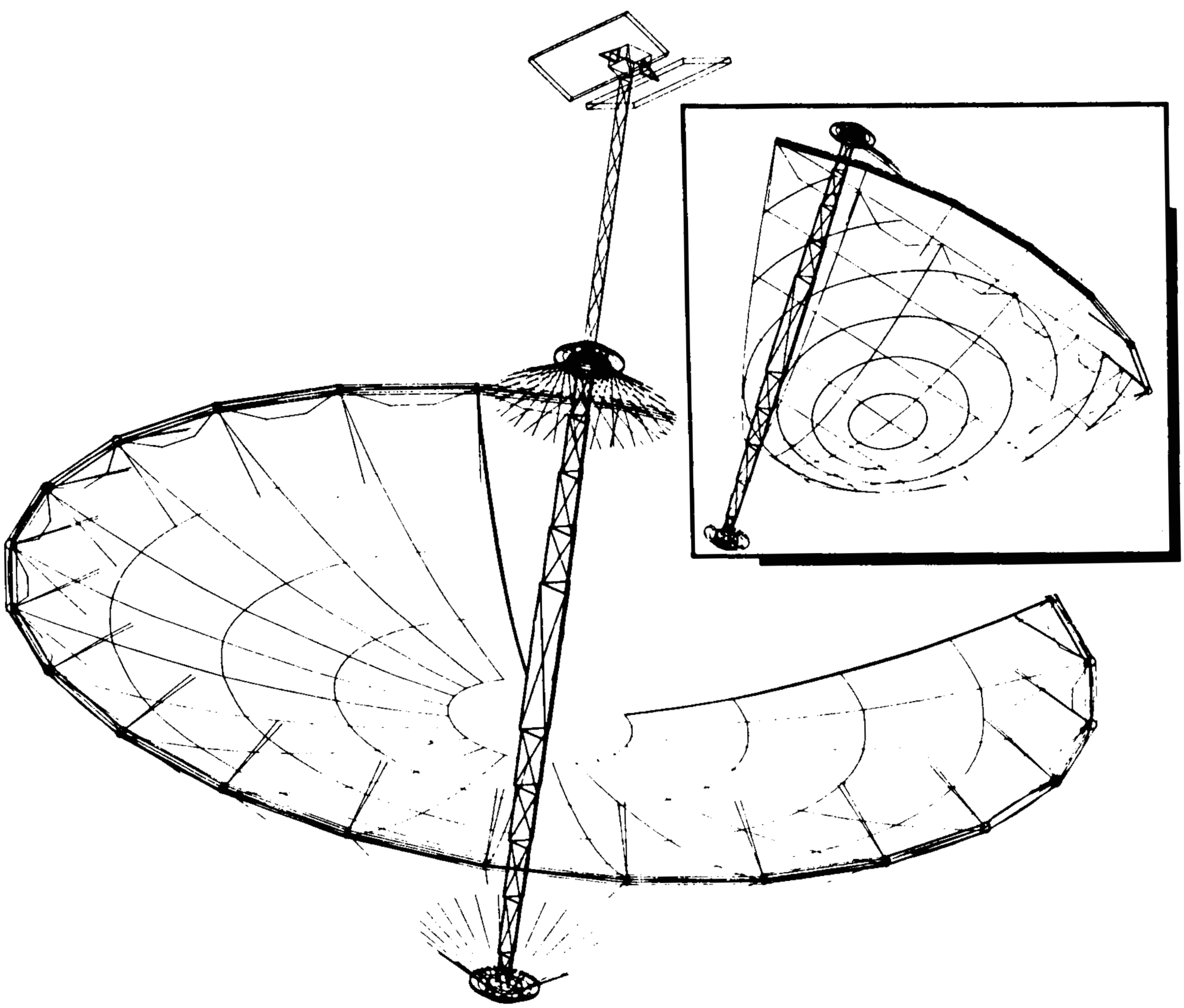
TECHNOLOGY DEVELOPMENT OBJECTIVES

Since the beginning of the hoop/column technology development program in 1979, there have been numerous accomplishments ranging from structure development, mechanisms, and materials. A listing of the technology thrusts for the hoop/column large space antenna program is pesented below.

- HOOP/COLUMN WILL BE THE FIRST TO DESIGN, ANALYSE, FABRICATE, AND VERIFY A 3 DIMENSIONAL, NON-LINEAR MESH REFLECTOR SURFACE.
- DEVELOPMENT OF A TRIANGULAR TRUSS, TELESCOPING COLOMN THAT IS SELF DEPLOYING (I.E., NO ROBOTICS REQUIRED)
- DEVELOPMENT OF COLUMN LATCHES THAT WILL SUBSTANTIALLY REDUCE (IF NOT ELIMINATE) NON-LINEAR JOINT BEHAVIOR RESULTING FROM CLEARANCES.
- THE 15 METER MODULE WILL VERIFY INTEGRATION OF 100M POINT DESIGN KINEMATIC CONCEPTS WITH THE DEMONSTRATED 50 METER SURFACE CONTOUR TECHNOLOGY.
- THE 15 METER MODULE CAN BE USED AS A LOW LEVEL VIBRATION TEST ARTICLE TO VERIFY STRUCTURAL/DYNAMIC CALCULATIONS ON A RELATIVELY LARGE PRETENSIONED STRUCTURE.
- MATERIALS DRIVEN IN CABLES AND CORD TAPE TECHNOLOGY.
- FINITE ELEMENT MODLE DEVELOPMENT AND UTILIZATION FOR STUDY OF LARGE TENSION/STABILIZED STRUCTURES.
- A TECHNOLOGY DRIVER FOR THE MULTIPLE BEAM FEED PROGRAM OF OAST.

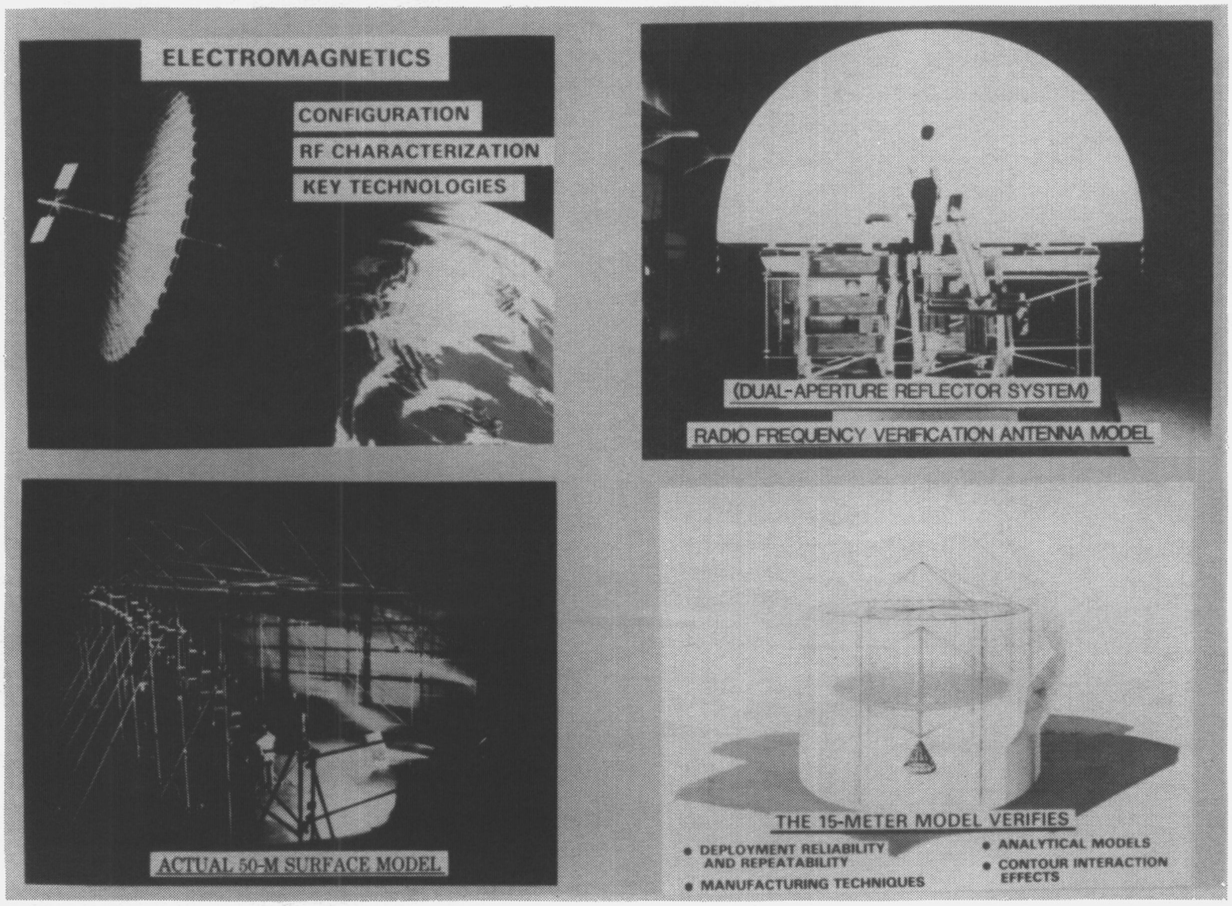
MULTIPLE-APERTURE CONFIGURATION FOR MULTIPLE-BEAM ANTENNA SYSTEMS

A very important objective in the development of large space antenna technology is the capability for multiple-beam antenna systems. Since the hoop/column structure is symmetrical, the capability for providing an offset-fed reflector geometry is manifested through a multiple-aperture configuration contained by the hoop space frame. Shown in the figure below is the quad-aperture surface configuration for the 15-meter antenna. Each quad-aperture is an offset-fed parabolic reflector with each vertex offset from the centerline of the structure. The overall intent with this approach is to demonstrate the performance of offset mesh reflector systems for single-aperture and multiple-aperture applications.



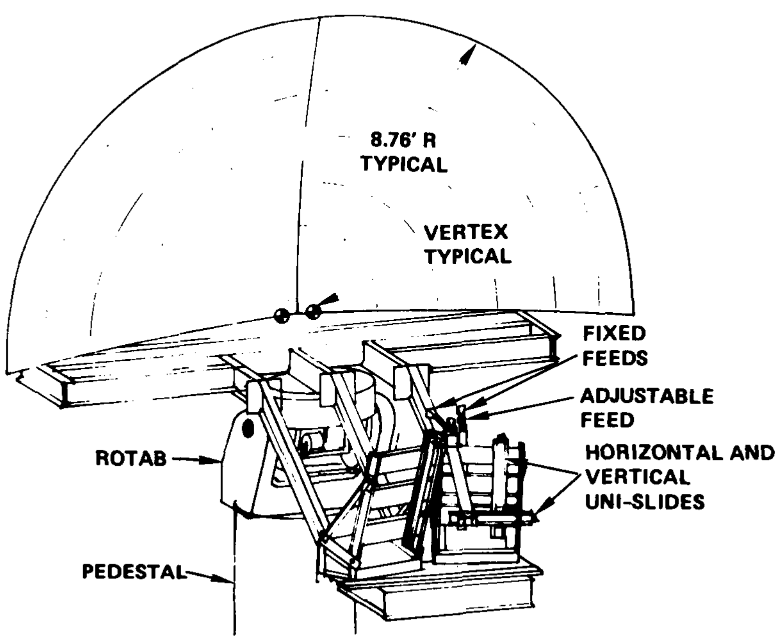
ENGINEERING MODELS OF THE HOOP/COLUMN ANTENNA

Before the development of the 15-meter deployable antenna structure was initiated, large-scale engineering models were fabricated, tested, and evaluated. These models included hoop hinge models, telescoping mast models, and mesh management test models. The larger scale models are shown in the figure below: the radio frequency verification mode (RFV) and the static surface model of the 50-meter-diameter antenna. These models indicate stages of development leading to the final stage, the fabrication and test of a complete 15-meter deployable antenna.



RADIO FREQUENCY VERIFICATION (RFV) MODEL

Shown below is a drawing of the RFV model that was used to demonstrate the feasibility of using the 15-meter antenna in a quad-aperture antenna configuration. The RFV model was designed to simulate two separate and adjacent parabolic offset-fed reflectors. Separate feed systems are used to illuminate each reflector and the capability for feed adjustment (to scan the beam) is provided. The test results using the RFV model demonstrated the need for feed aperture synthesis in an attempt to reduce the parasitic sidelobe radiation. Aperture synthesis analysis has been conducted and applied to the RFV test results, and the parasitic side lobe level has been reduced from 19 dB to 30 dB.



OBJECTIVES:

- **EVALUATE RF PARAMETERS CRITICAL TO THE MULTIBEAM QUAD-APERTURE ANTENNA PERFORMANCE**
- **PROVIDE VERIFICATION OF CRITICAL PARAMETERS THROUGH TEST AND ANALYSIS**
- **VERIFY ANALYTICAL METHODS**

TEST RESULTS USING THE STATIC SURFACE

Another significant milestone in the development of the hoop/column antenna was the construction and test of a four-gore segment of a 50-meter-diameter antenna. The boundary condition around the reflector test sections was provided by the aluminum scaffolding structure. The fabrication methods for the reflector surface and rear cord trusses were identical to the "build-to-dimension" techniques which would be implemented for a 50-meter class structure. The surface accuracy and defocus test results are listed in the table below.

(INCHES)

	PRETEST GOAL	MEASURED	TRANSLATED TO 100-METER	REQUIRED ON 100-METER
SURFACE ACCURACY RMS	0.083*	0.102	0.256	0.300**
DEFOCUS	1.554	0.556	4.622	10.000

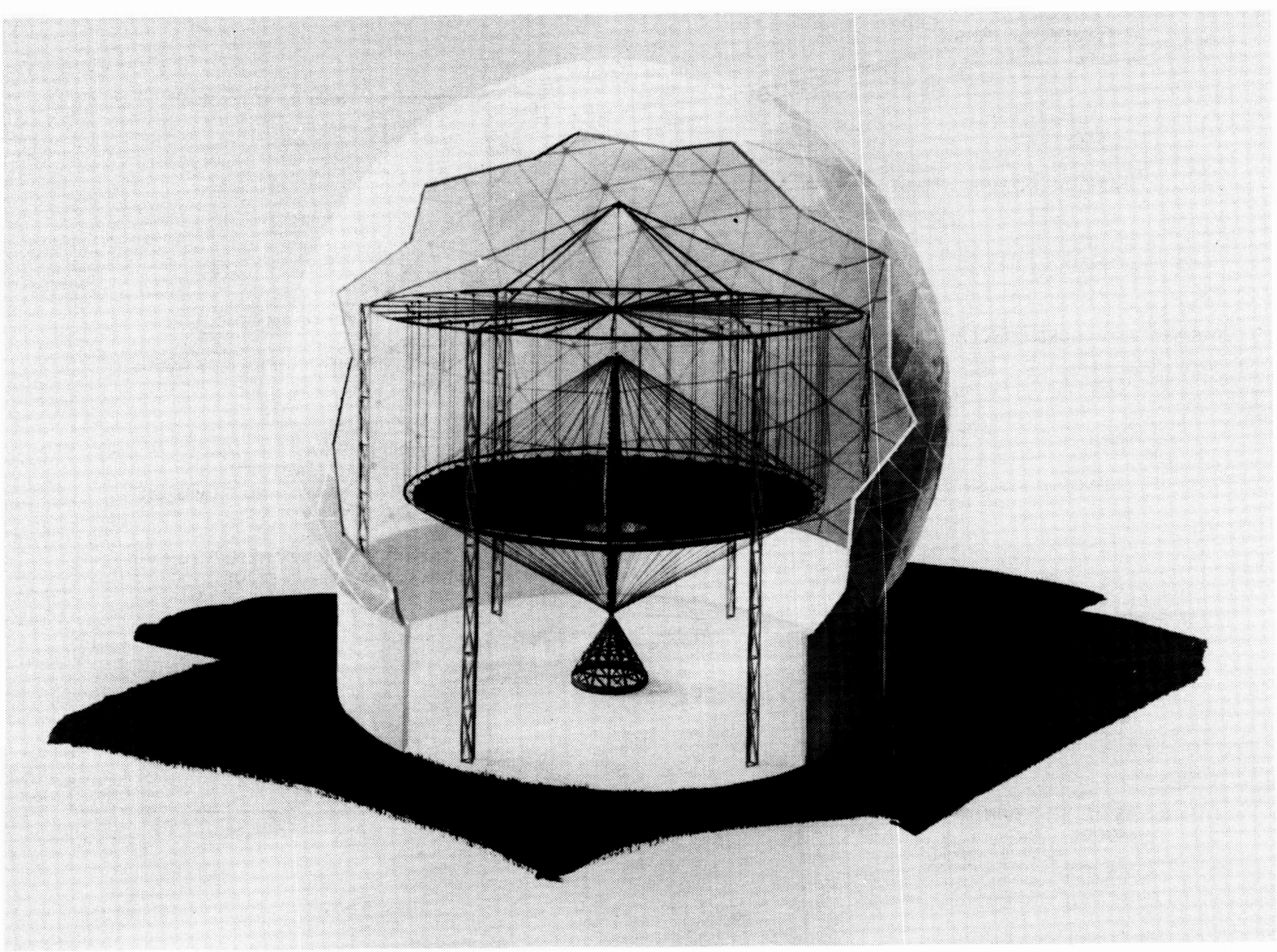
* THE PRETEST SURFACE ACCURACY GOAL WAS NOT REALIZED BECAUSE IT DID NOT REFLECT UNCERTAINTIES DUE TO:

- WEIGHT
- THERMAL GRADIENTS
- BOUNDARY VARIATIONS

** SURFACE ACCURACY REQUIREMENT OF 100-METER IS BASE ON A $\lambda/80$ QUALITY.

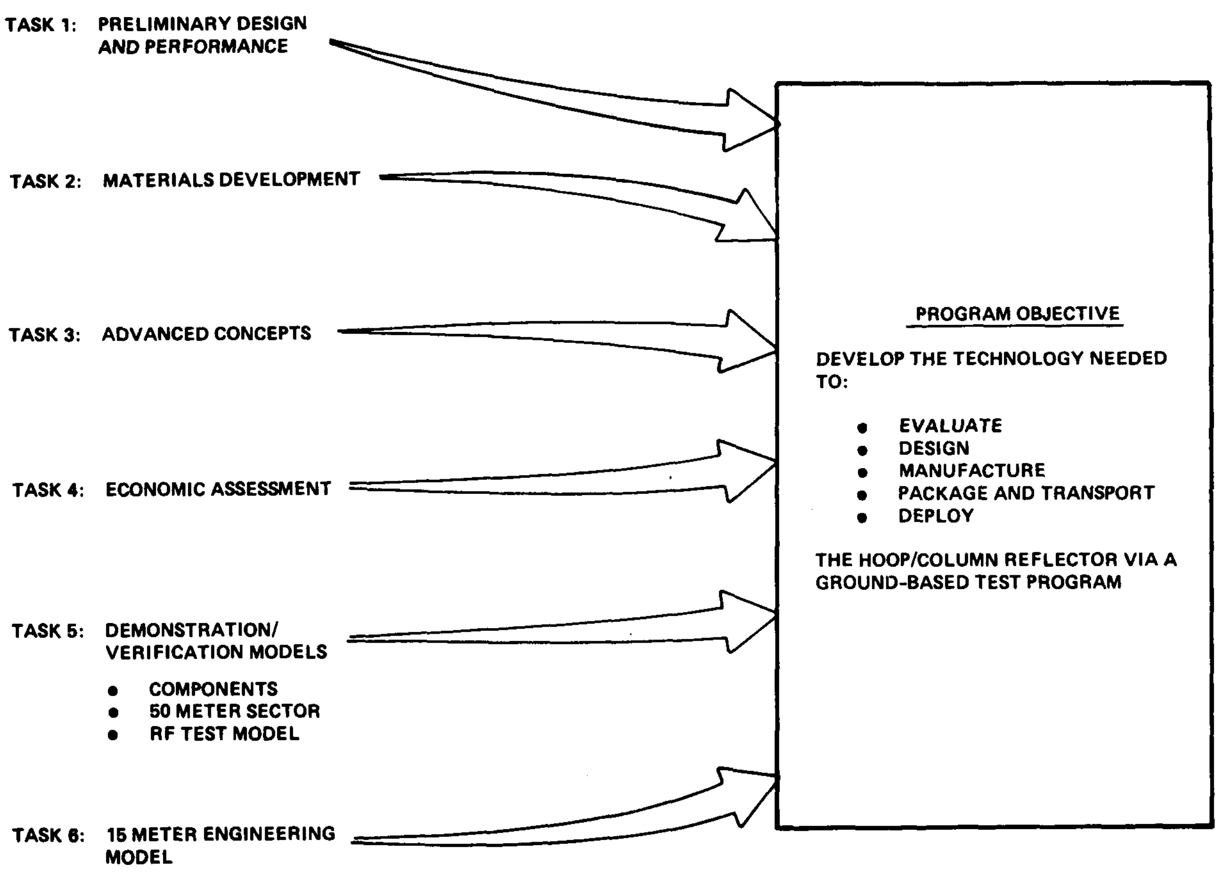
CONFIGURATION OF THE 15-METER ANTENNA STRUCTURE

The final development activities are the development and test of the 15-meter deployable antenna shown in the figure below. The antenna is positioned and deployed under the counterbalance system in the radome facility at the Harris Corporation. The structure will be deployed and surface tested prior to the installation of the feed system for the RF tests. The 15-meter model will be capable of deployment and stow cycles, repeatability, and surface characterization measurements.



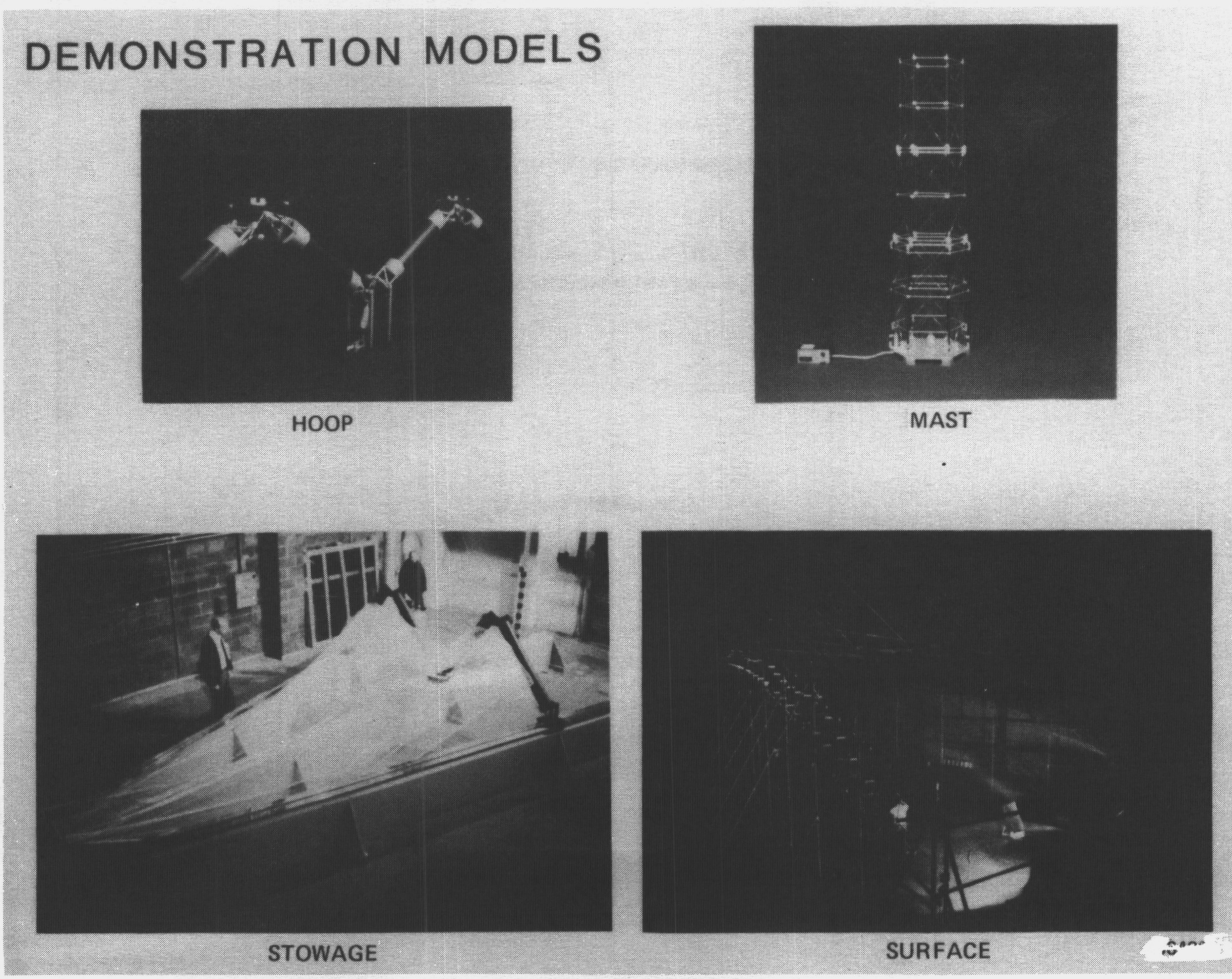
TASK DESCRIPTIONS AND PROGRAM OBJECTIVE

The program consists of six tasks, each of which supports the primary objective which is to develop the technology necessary to evaluate, design, manufacture, package, transport and deploy the hoop/column reflector.



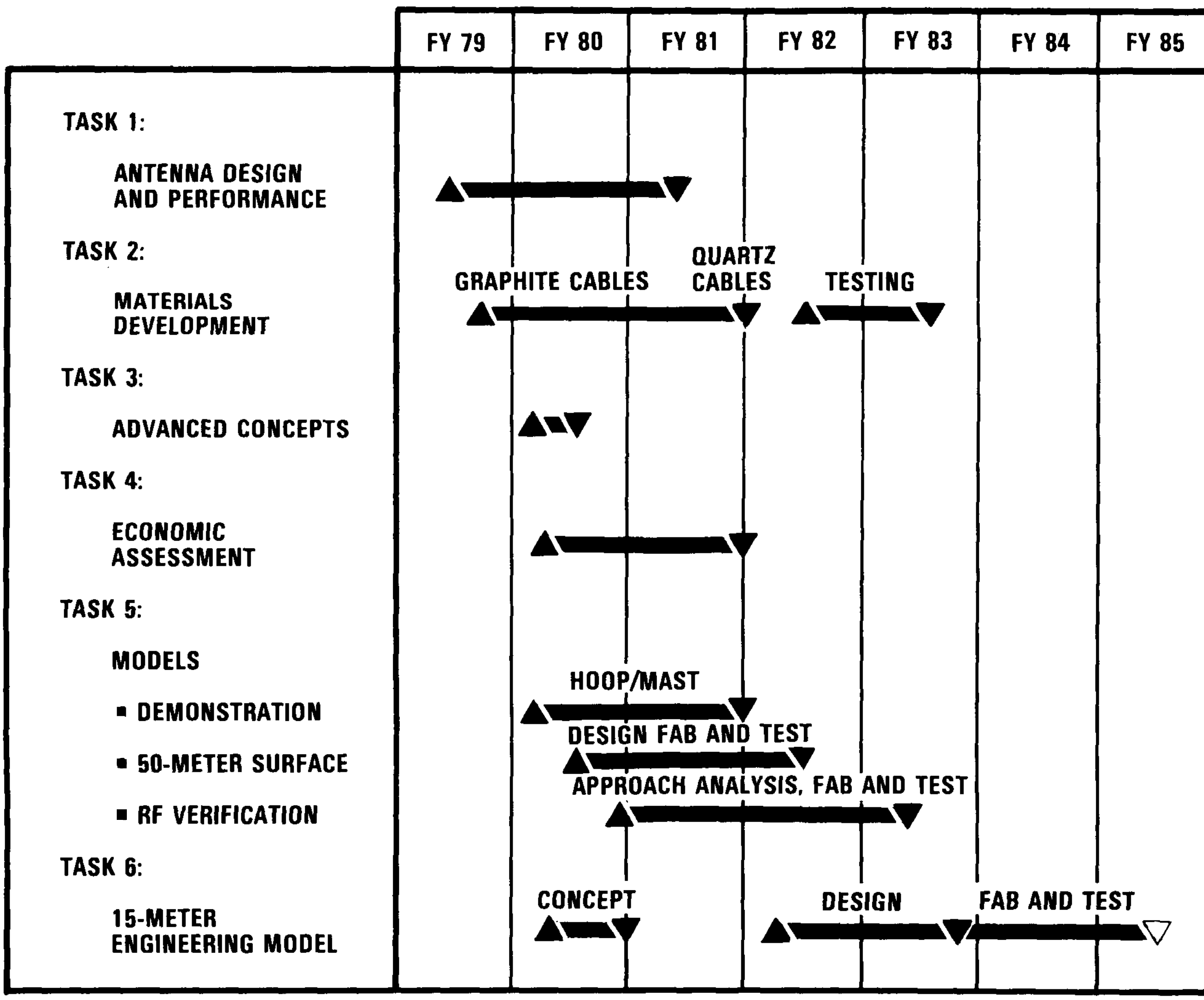
DEMONSTRATION MODELS

Engineering models have been successfully completed and tested. The hoop model and mast model verified the kinematics of these major components. A mesh stowage model demonstrated a method of folding and managing the mesh. The 50-meter surface model confirmed our analytical and manufacturing techniques.



SCHEDULE SUMMARY

All tasks have been successfully completed with the exception of task 6 which is ongoing. Each of the 6 tasks is discussed in the following pages.



15-METER MODEL REQUIREMENTS

Specific requirements of the model are described below. The model is designed and fabricated in the same manner as a much larger antenna.

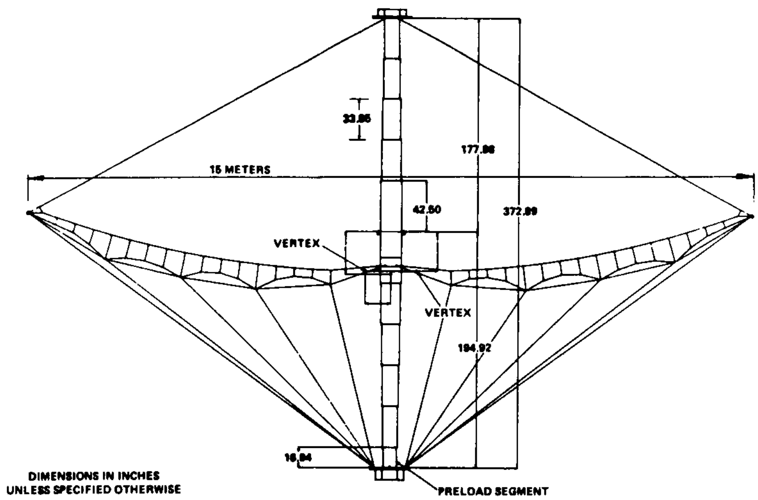
- 15-meter hoop diameter
- Direct scale-down of 100-meter hoop/column point design where practicable
  - Cost constraints
  - IG constraints
  - Load constraints
- Cup-up deployment/restow capability
- All deployment/restow operations hands-off WRT structure
- Without counterbalance—IG cup-up surface rms = 0.069 inch
- Frequency = 2 to 12 GHz
- Provide interfaces for ground handling fixtures and 250-pound feed mast

RF near-field test requirements

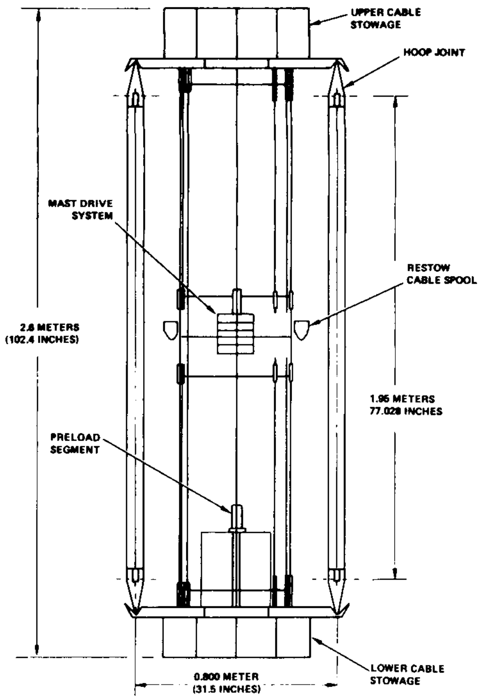
15-METER MODEL - SIDE VIEWS

Key geometry features are shown in the figures below. The model, which is less than a meter in diameter when stowed, deploys to a diameter of 15 meters.

OPEN

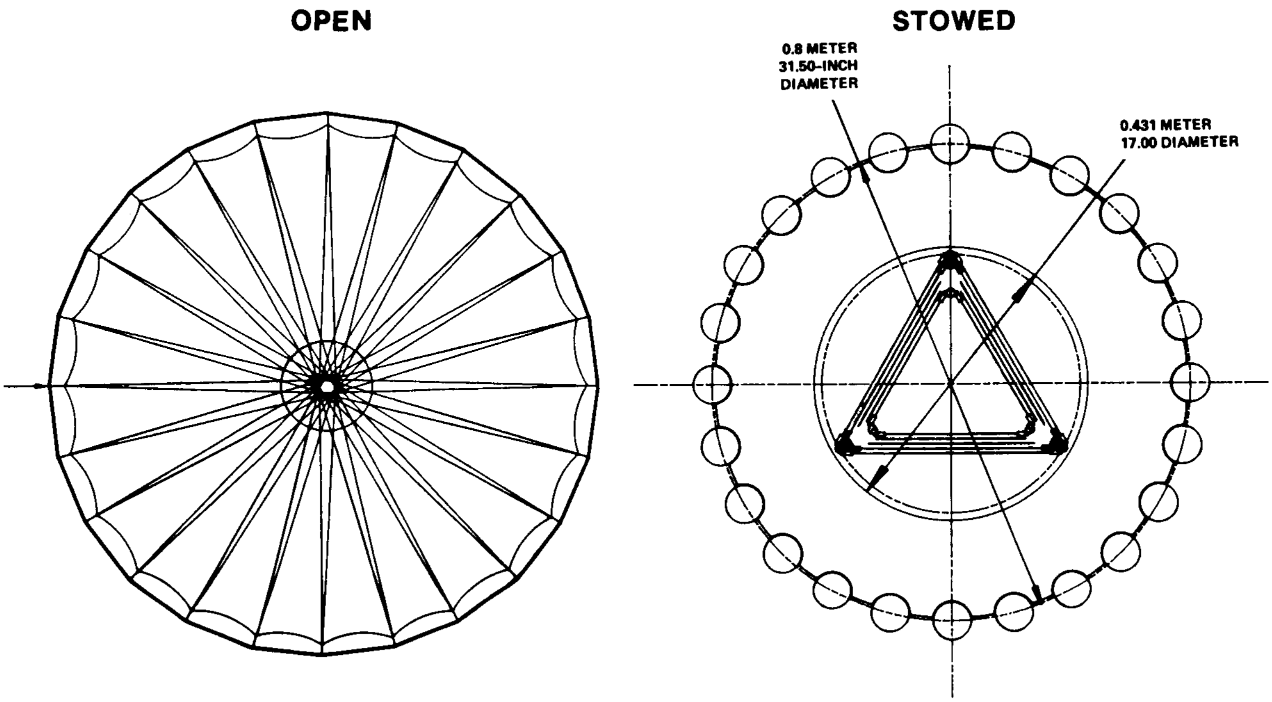


STOWED



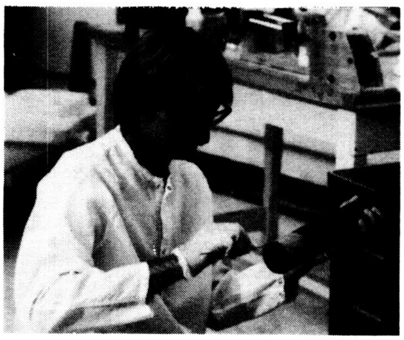
15-METER MODEL - TOP VIEWS

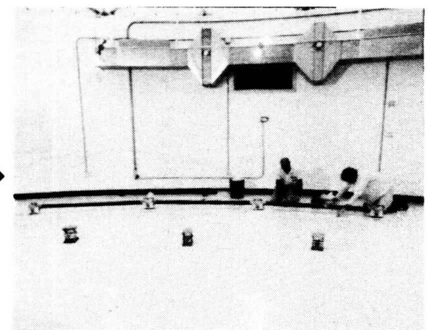
To enhance torsional stiffness the upper hoop support cables are crossed. The surface of the model is quad-aperture. Feeds, which will be retrofitted by NASA prior to RF testing, utilize the total quad-aperture area.

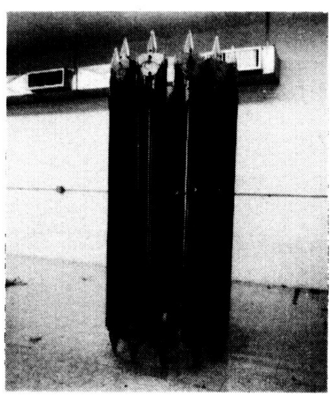


FABRICATION - HOOP

The hoop is assembled and bonded in a fixture three segments at a time. This fixture, which is aligned by means of theodolites, controls the length of each of the segments to within .020 inch. After each of the eight three-segmented assemblies is completed, it is final assembled to the others and the hoop is completed.

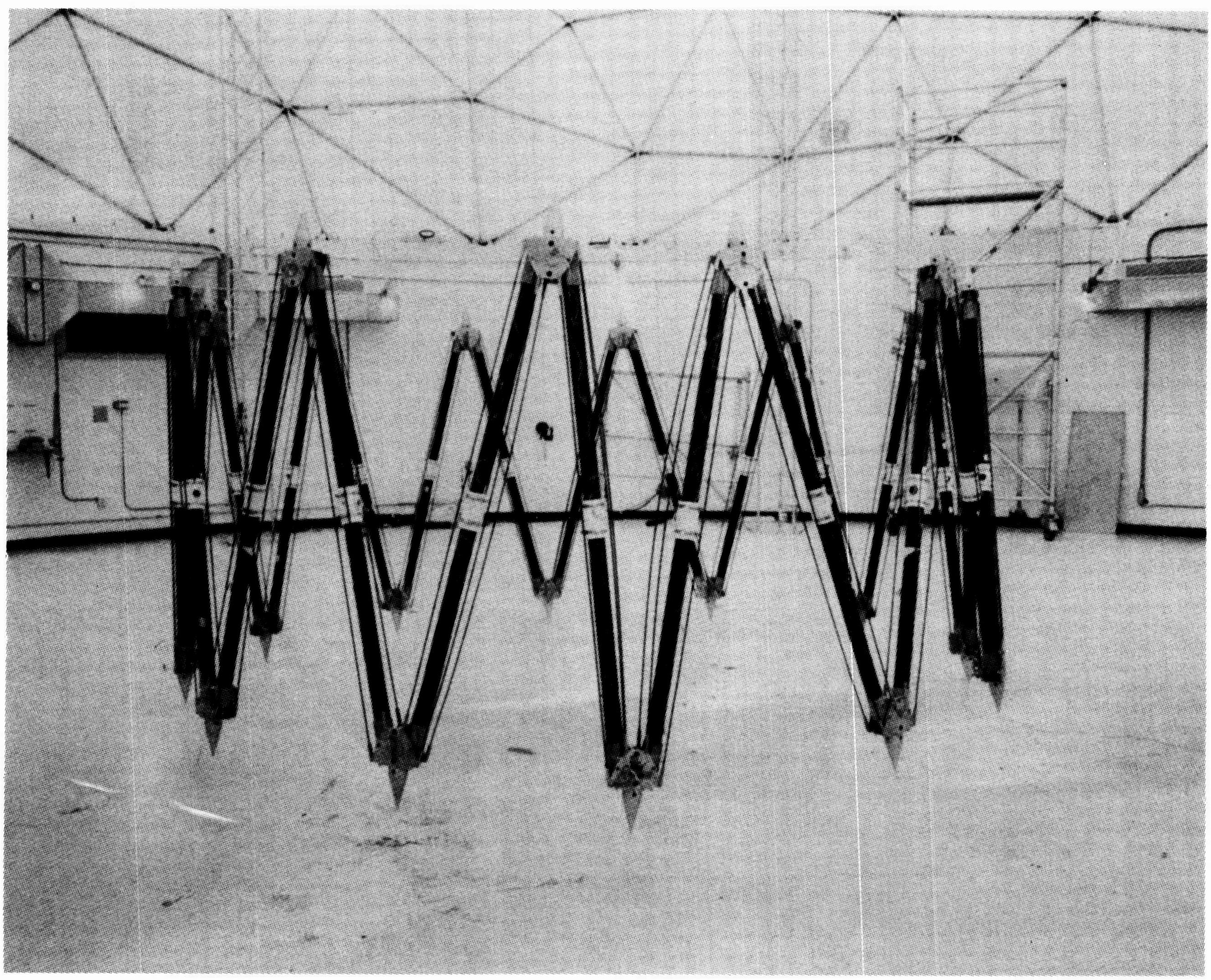






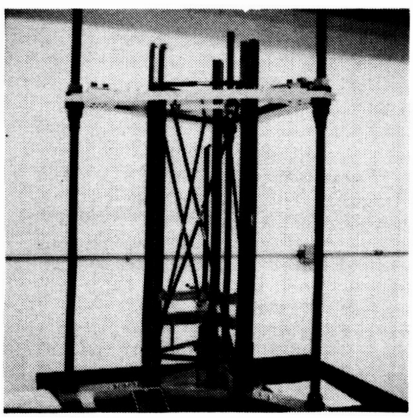
DEPLOYMENT TESTS - HOOP

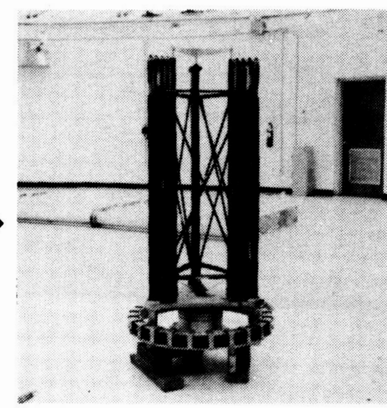
The hoop is attached to its counterbalance system and deployment tested to verify proper alignment of the mechanisms.

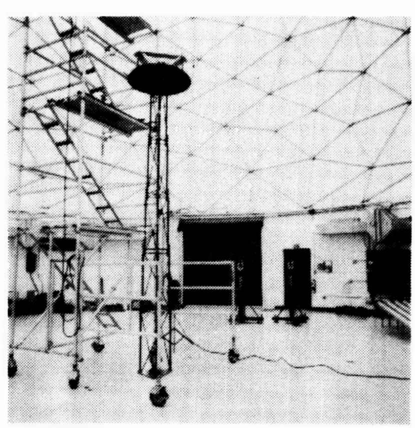


FABRICATION - COLUMN SEGMENT

Each of the column segments is fabricated in the same fixture to ensure geometry requirements are met. The column is proofloaded after it is final assembled and adjusted.

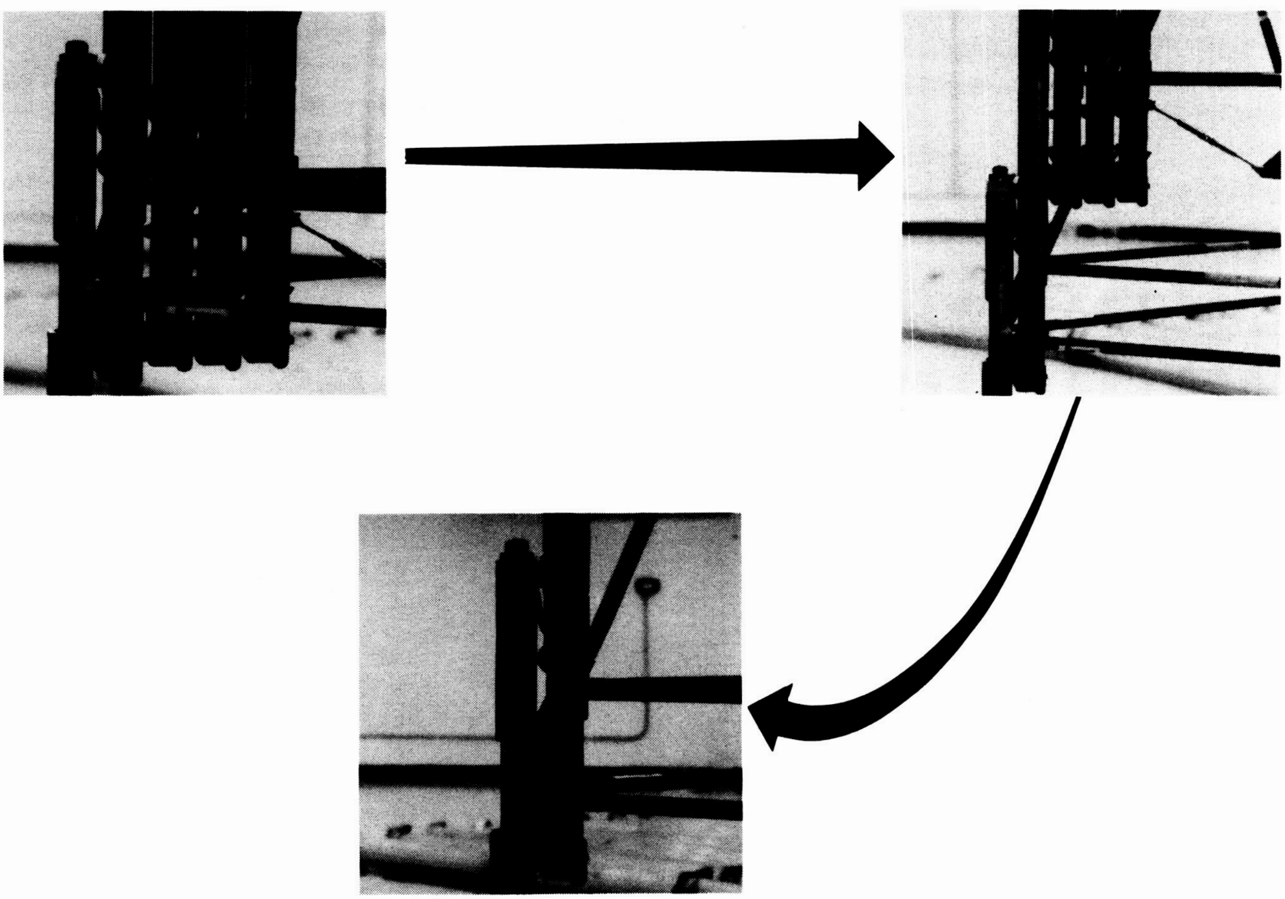






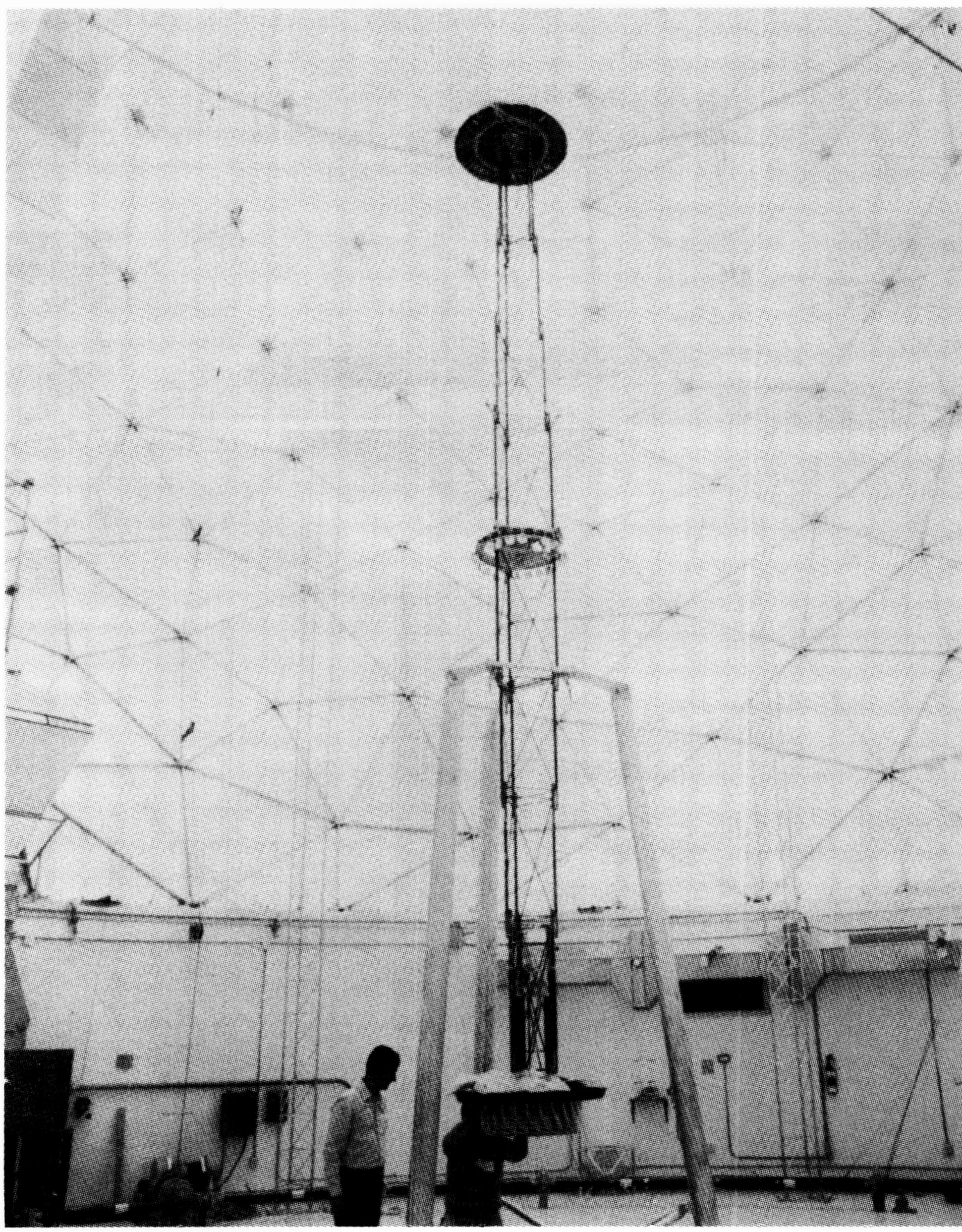
LATCH SEQUENCE

The sequential lockup of the column is necessary to provide it with structural stiffness throughout its deployment. Latches are designed to lock up with their outboard counterparts and at the same time release themselves from their inboard counterparts. This event is shown in stages below. The resulting interface is one which provides compressive and tensile load-carrying capability.



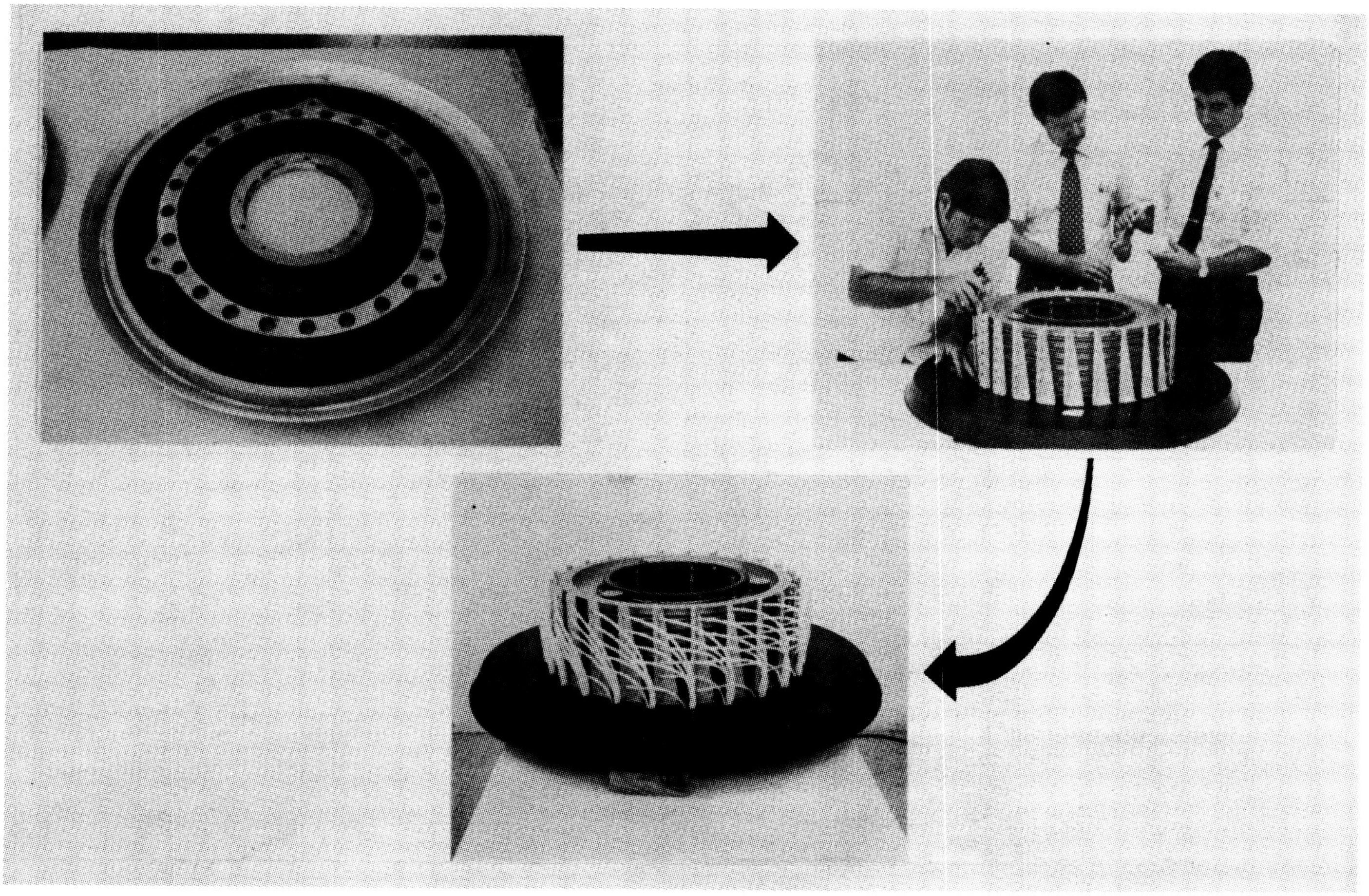
DEPLOYMENT TESTS - COLUMN

The column is attached to the pedestal and run through a series of deployment cycle tests prior to interfacing with the hoop.



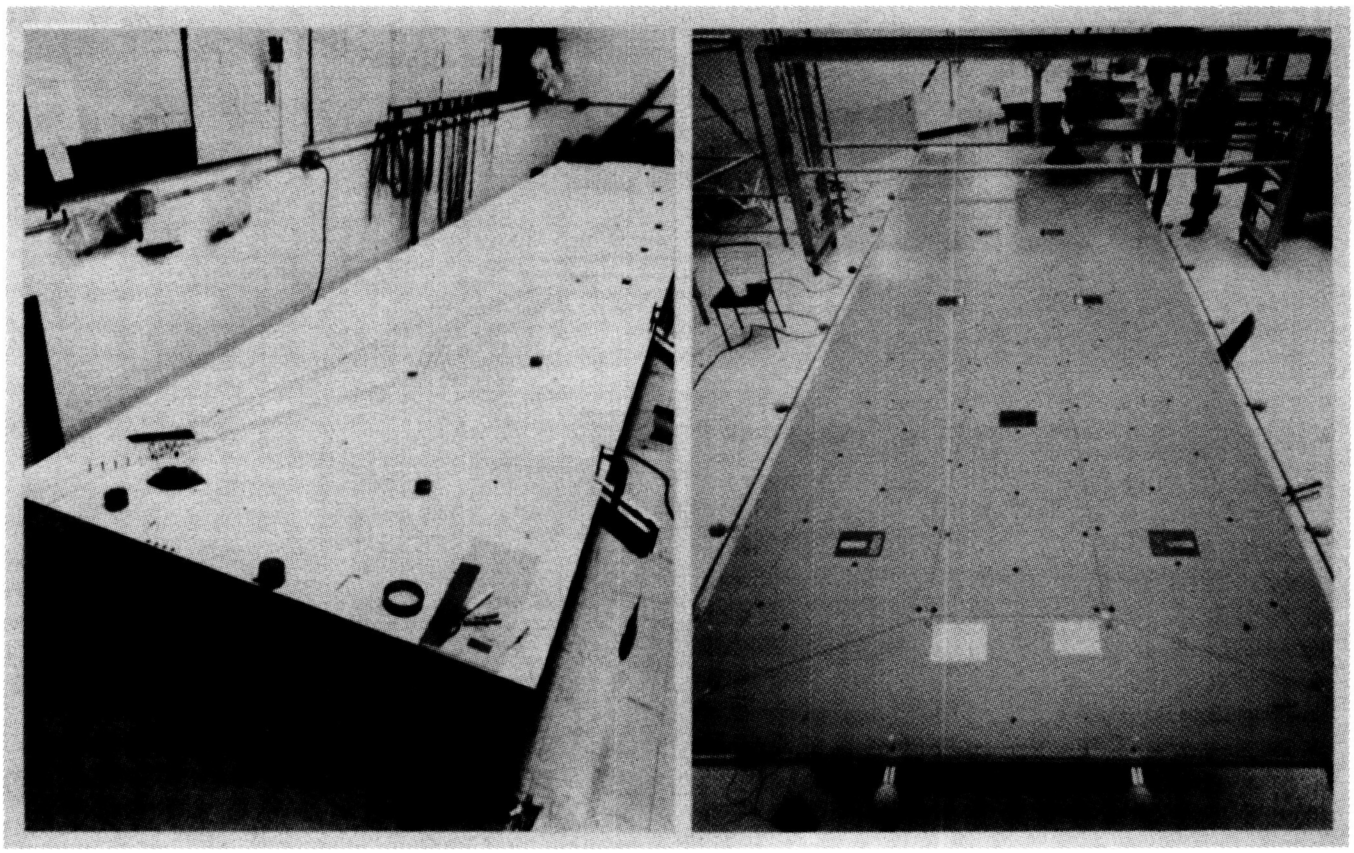
FABRICATION - CABLE STOWAGE

The 15-meter model is manufactured in modular form. For example shown below is a cable stowage assembly under way. This assembly must efficiently pay out, retrieve, and manage 48 cords.



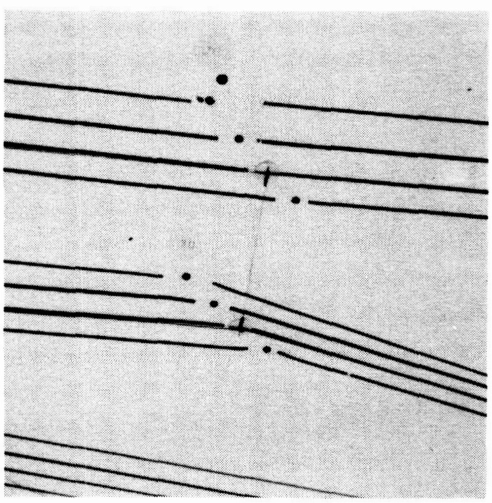
FABRICATION - SURFACE

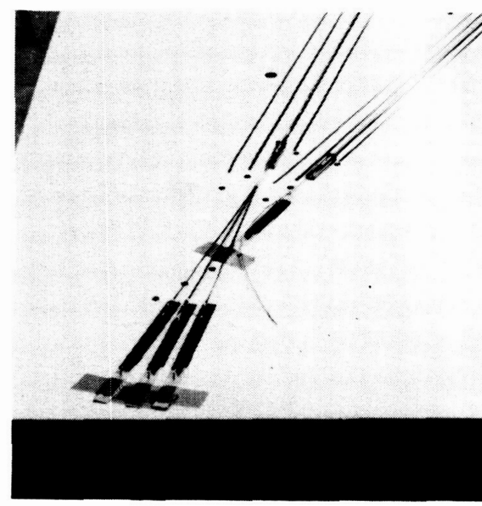
Fabrication of the RF reflective surface is under way. The surface is comprised of two major subassemblies. The rear truss assembly is shown on the left and the front cord assembly is shown on the right. The assemblies are stretched to their operational load and are bonded in place on 25-foot-long templates which maintain an overcome accuracy of .005 inch.

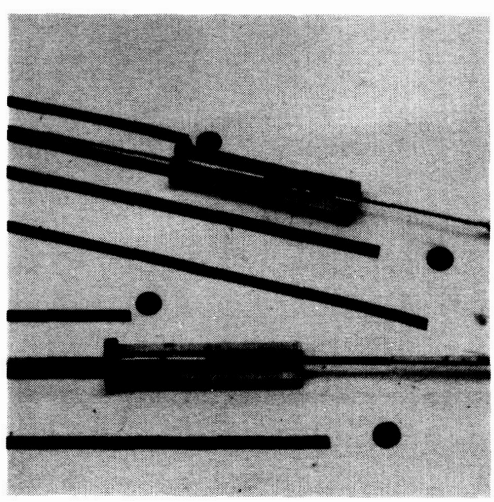


SURFACE FABRICATION

All cords and ties are pretensioned to their operational load prior to bonding by spring tensiometers which are precalibrated. The primary shapers (top left) of the gore edge cords are the vertical ties, the lengths of which are determined by the template interfaces. Ties and cords are manufactured from a unidirection multi-strand graphite yarn which is Teflon impregnated. The edge cords (top right) are bonded into sleeves which are also located by template fixturing. The cords are prepared for bonding by burning the Teflon from the cords. Epoxy is injected into the sleeve by means of a hypodermic needle.

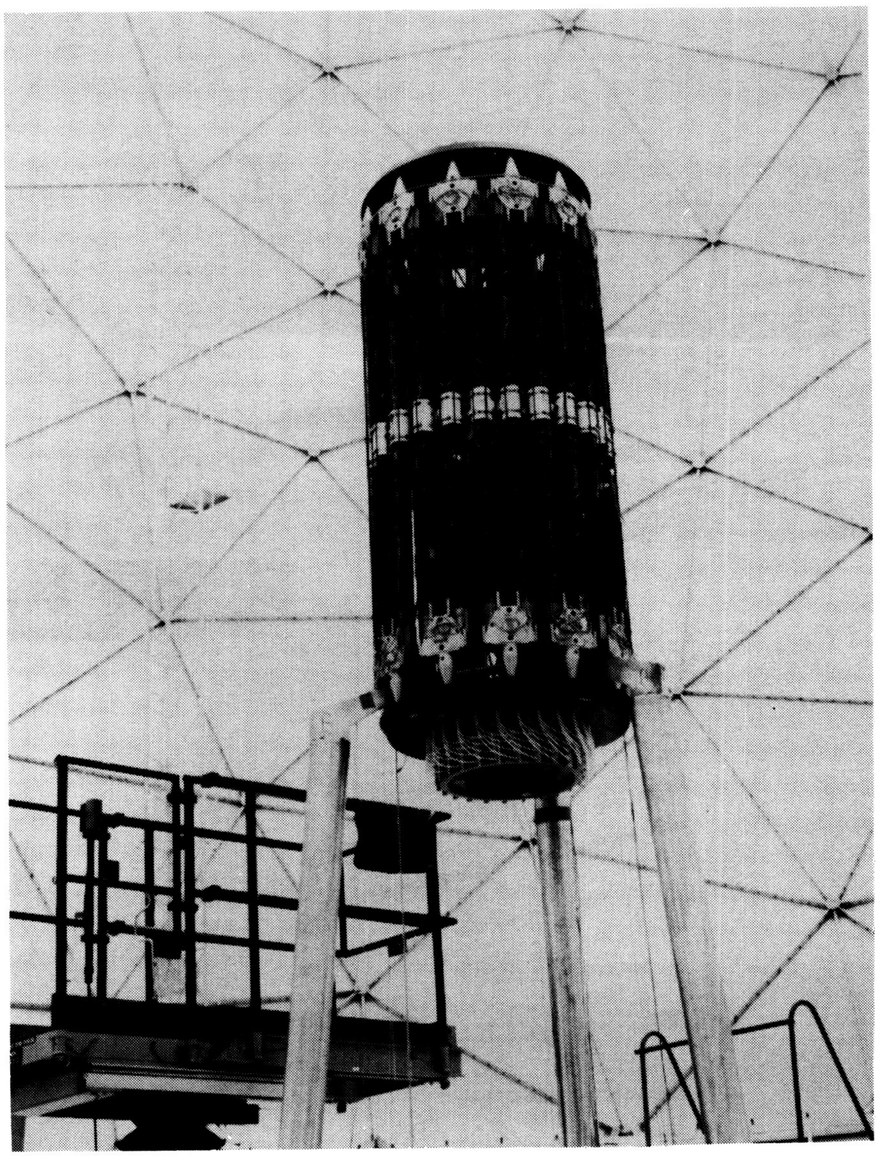






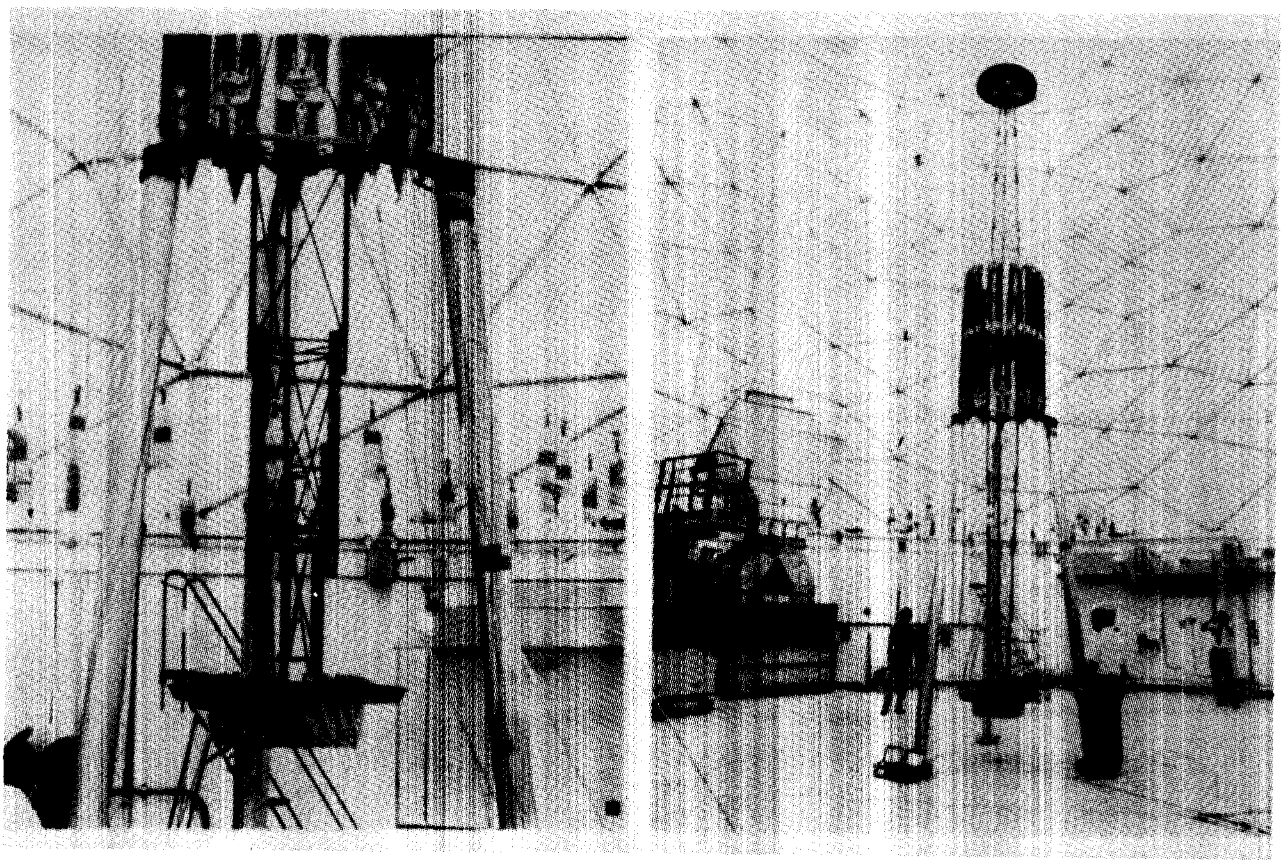
15-METER MODEL - STOWED

Deployment tests of the hoop/column structure have been successfully completed. The photograph was taken during the deployment sequences described previously. The model is shown sitting atop its three-legged pedestal. Both the hoop and the column are comprised of graphite (GFRP) tubular members.



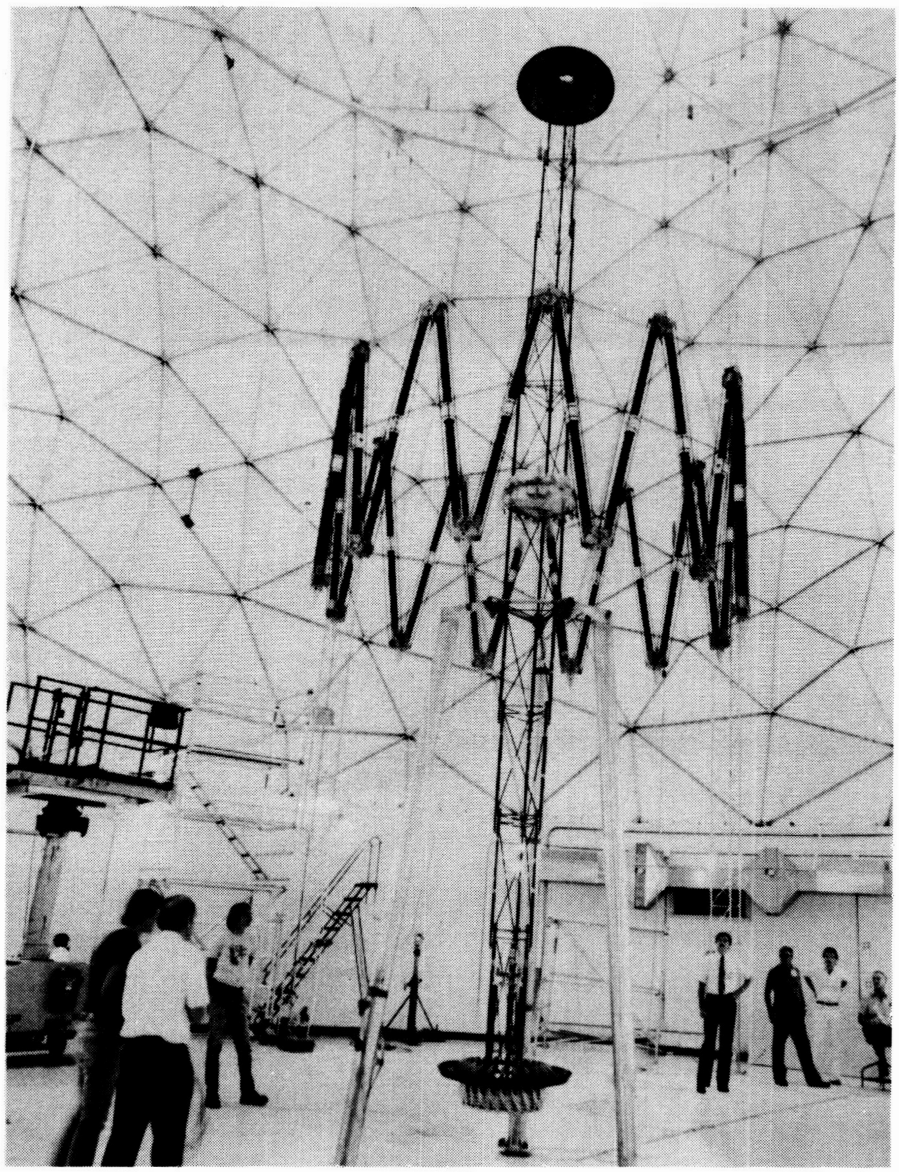
COLUMN DEPLOYMENT

The model begins its deployment by the extension of the telescoping mast. It is driven by means of cables which are retrieved on a spool located in the center of the column.



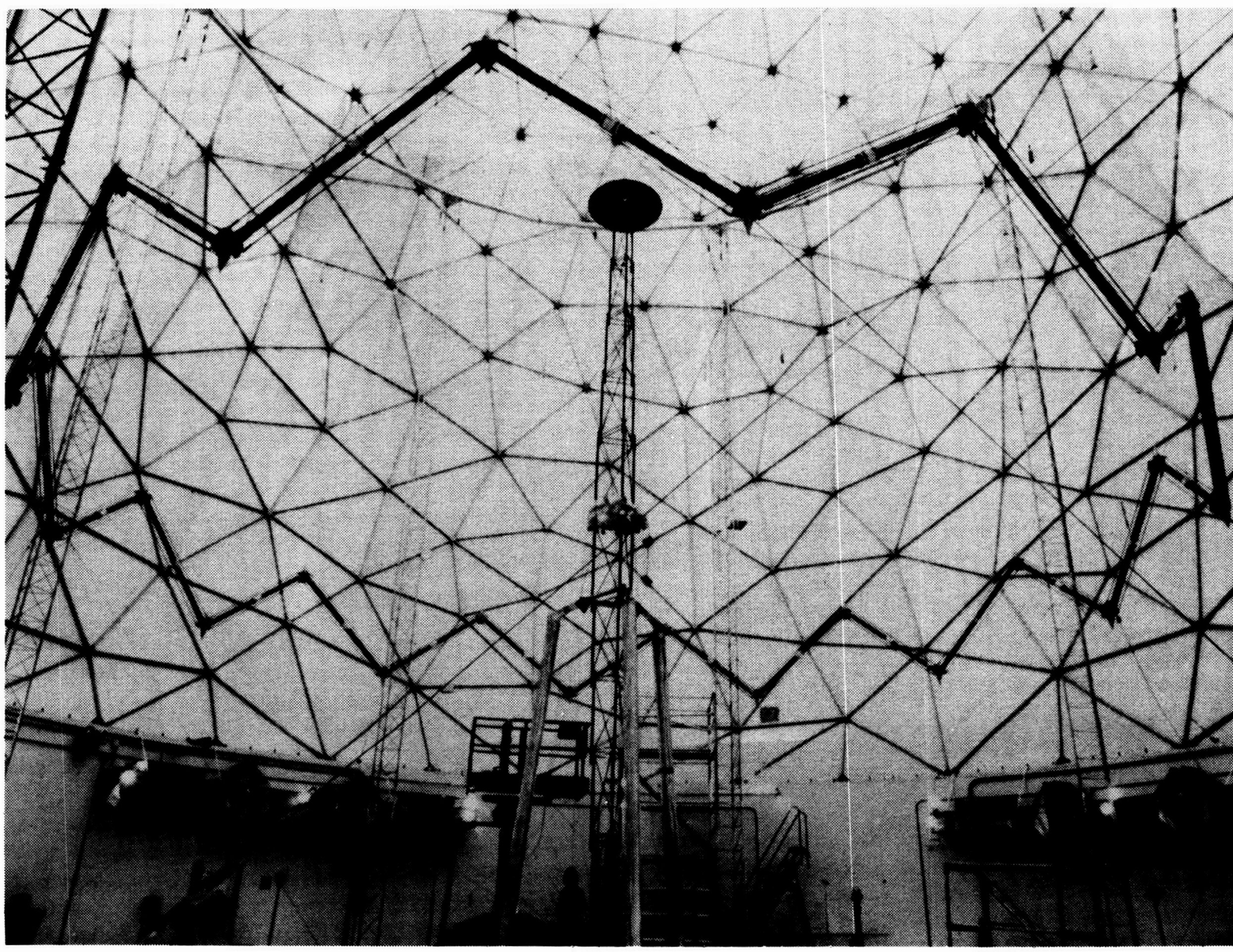
HOOP DEPLOYMENT - INTERMEDIATE STAGE

The hoop is shown in an intermediate stage of deployment. It is positioned during deployment by the upper and lower hoop support cables which emanate from the extremities of the column. The cables, which pay out from common spools, maintain tension throughout the deployment of the hoop.



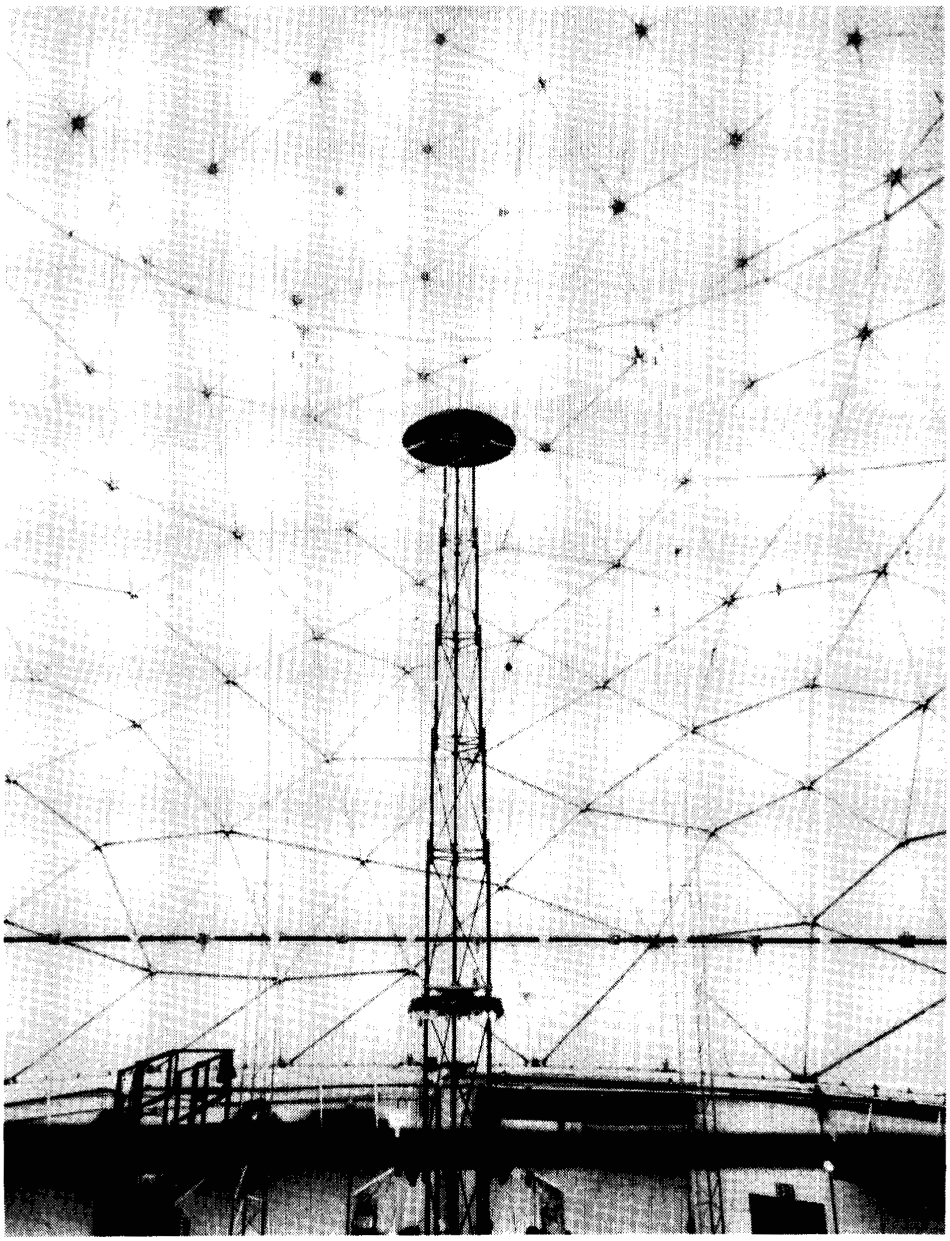
HOOP DEPLOYMENT

The hoop maintains its symmetrical attitude throughout its deployment. Total time of the hoop deployment cycle is approximately 10 minutes. The energy to deploy the hoop is provided by 4 D.C. gear motors.



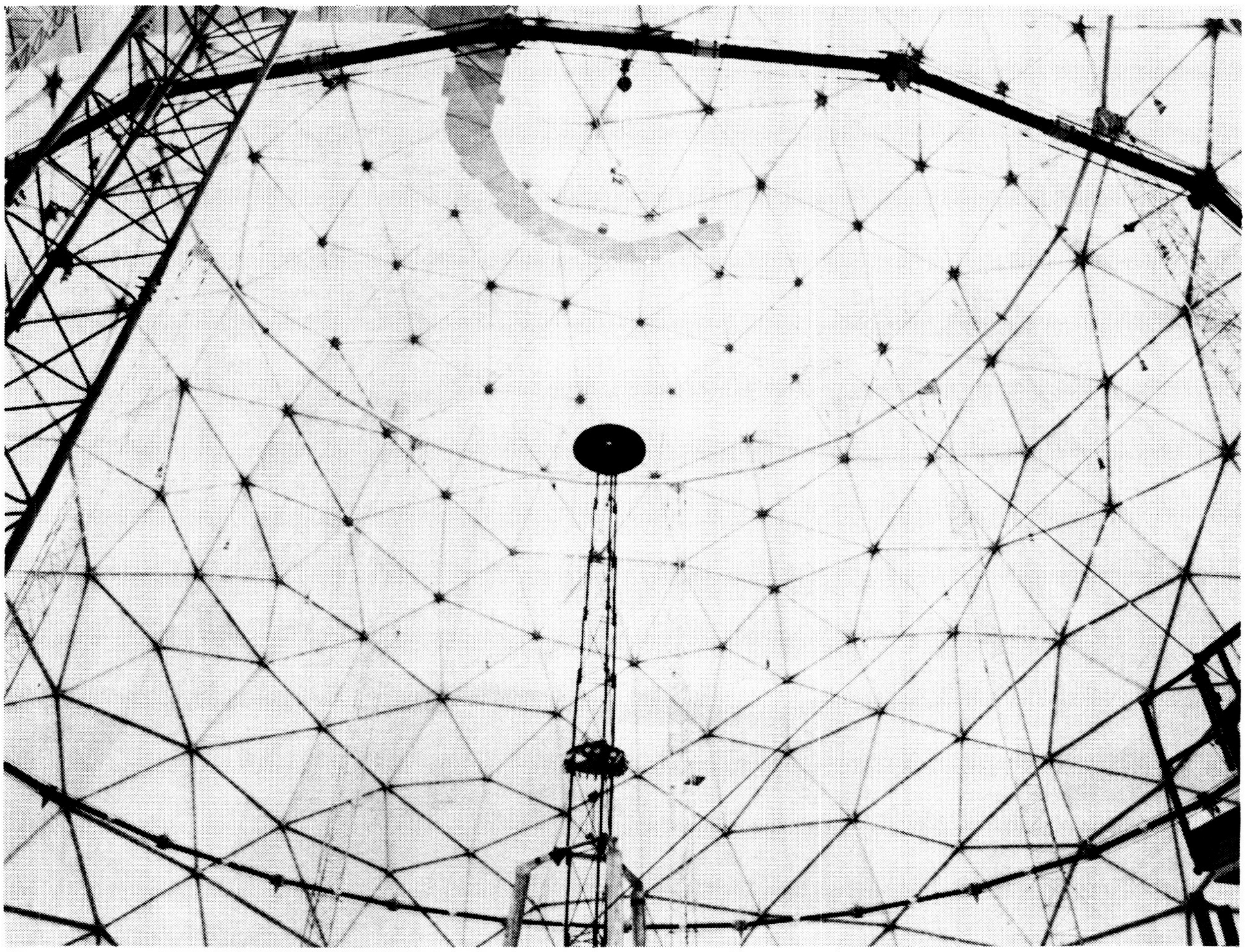
FULLY DEPLOYED - PRELOAD SEGMENT EXTENSION

The model's final stage of deployment is the extension of the preload segment. Subsequent to this all members of the structure are preloaded and the model is self supporting.



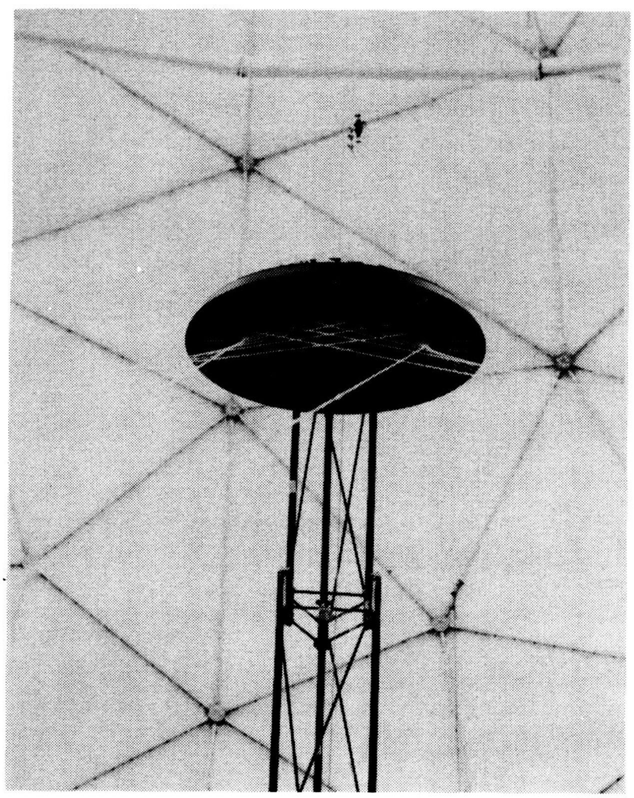
FULLY DEPLOYED

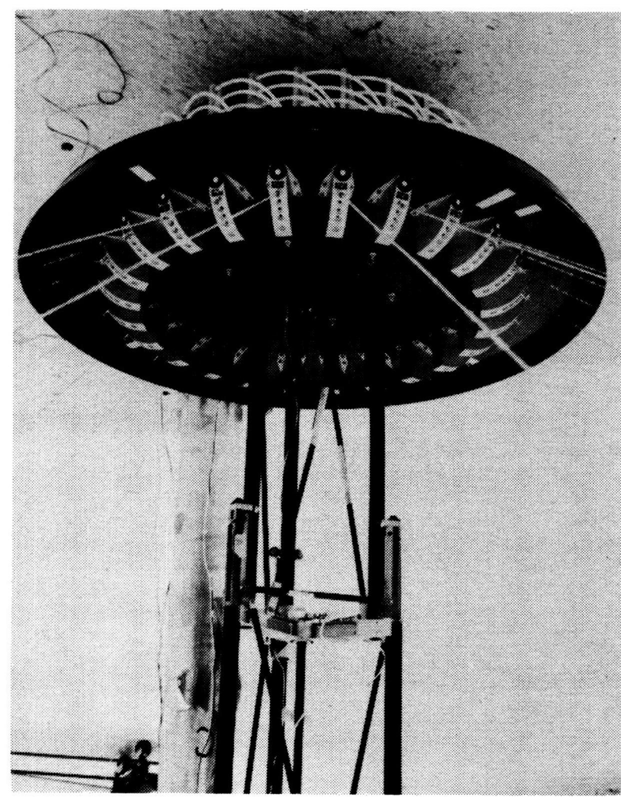
After removal of all counterbalance interfaces the model was measured at the end of each of the three deployments to determine repeatability characteristics. Results show the structure to be within the accuracy required to achieve the eventual surface RMS.



UPPER AND LOWER CABLE CONFIGURATION

The upper hoop support cords (left side) are crossed to enhance torsional stiffness. These cords, which are quartz to minimize RF interference, emanate from the upper cable stowage assembly. The lower hoop support cords (right side) are graphite to provide high stiffness as well as a low coefficient of thermal expansion.





15-M HOOP/COLUMN ANTENNA MODAL SURVEY WITHOUT SURFACE

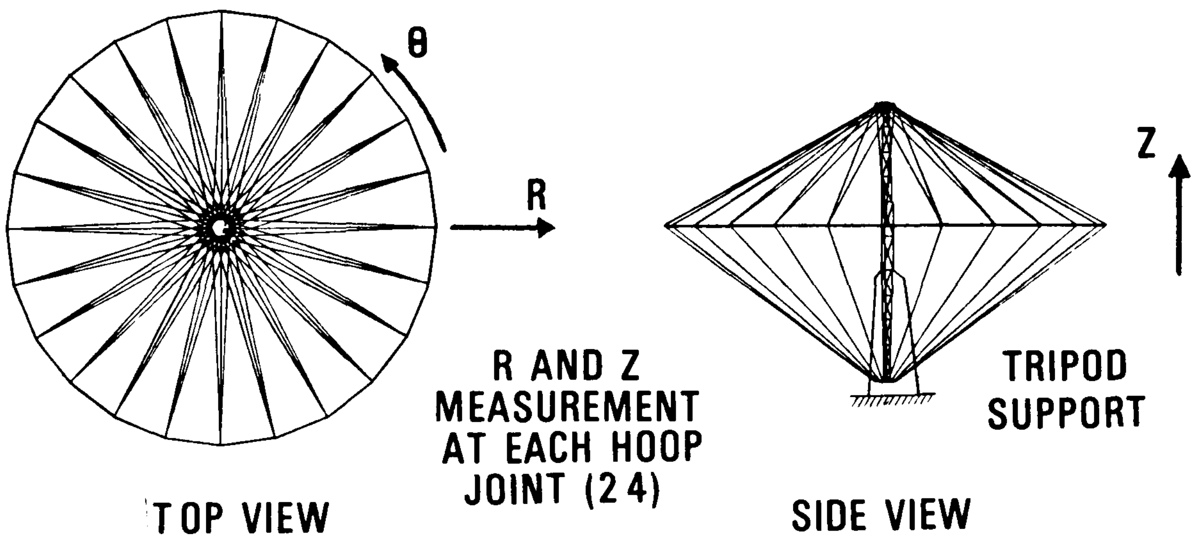
A modal survey of the 15-meter hoop/column antenna was performed to identify the dominant vibration modes below 15 Hz. As described below, a roving impact hammer and one reference accelerometer were used to excite and measure all modes except the fundamental torsion mode. The torsion mode was excited by inducing an initial rotation of the hoop. The impact hammer technique was used because a limited time period was available. This method does not separate closely spaced modes; however, the objectives were achieved with the approach indicated below. Test and analytical results are presented with both the test boundary conditions and free-free boundary conditions. The analysis methods used to model the 15-meter antenna with the surface are described. Complete dynamic characterization tests of the antenna are planned after the surface is installed.

- **OBJECTIVE:**
  - **Experimental identification of modes with dominant hoop and column motion below 15 hertz**
- **APPROACH:**
  - **Survey column with roving impact hammer and reference accelerometer to obtain frequency response functions using a two-channel FFT analyzer**
- **PURPOSE:**
  - **To determine frequency, mode shapes and damping for math model verification before surface installation**

15-M ANTENNA MEASUREMENT LOCATIONS AND TEST CONFIGURATION

The antenna was tested by impacting the hoop at each of the 24 hoop joints. Both radial (R) and vertical (Z) measurements were made. Four additional measurements were made by impacting the column in the radial and circumferential (θ) directions at the upper and lower ends of the column. The low acceleration of the fundamental torsion mode required use of a proximity probe for accurate measurement of frequency and damping. The proximity probe was located on a fixed support with a target located on the hoop. An initial rotation of the hoop was induced by hand such that a free decay of this mode could be measured. An important influence on the test results is the type of boundary conditions imposed by the support structure which consisted of a tripod of six-in. aluminum tubes as shown below. The tripod was attached to the column somewhat below the column center. The tripod flexibility was included in the analysis.

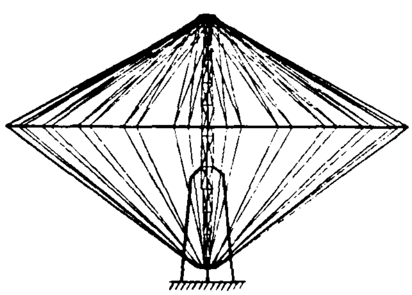
- **FREQUENCY RESPONSE FUNCTIONS MEASURED AT 52 LOCATIONS**
- **FIRST HOOP TORSION MODE EXCITED BY INITIAL DISPLACEMENT**



FIRST FOUR MODES OF THE 15-M ANTENNA

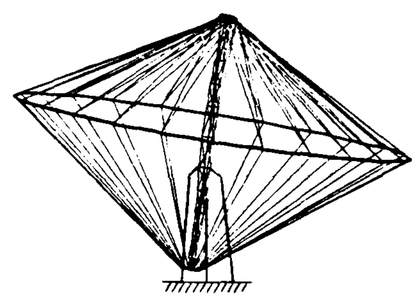
The mode shapes and frequencies of the first four modes are shown below. The fundamental mode involves torsion of the hoop about the vertical axis of the antenna and occurs at a frequency of 0.068 Hz. The second mode occurs at 0.785 Hz and involves rocking of the hoop and bending of the column. Since this mode shape has a harmonic number of N=1, two modes exist at this same frequency if the structure is exactly rotationally symmetric. The mode shapes are identical except for being rotated 90 degrees about the vertical axis. This double mode occurrence is true for harmonics from N=1 to N=10. The third mode involves inplane translation of the hoop and bending of the column. This mode occurs at 1.36 Hz and is also a harmonic of N=1. The final mode shown is torsion of the lower half of the column and occurs at 3.13 Hz. Both the fundamental hoop torsion mode and the lower column torsion mode are referred to as harmonic number N=0.

HOOP TORSION



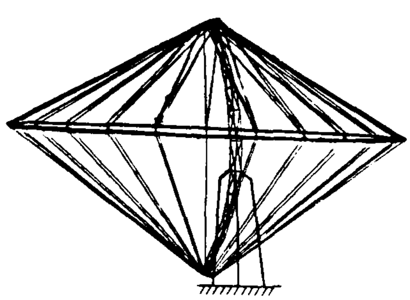
f=0.068

HOOP ROCKING/COLUMN BENDING



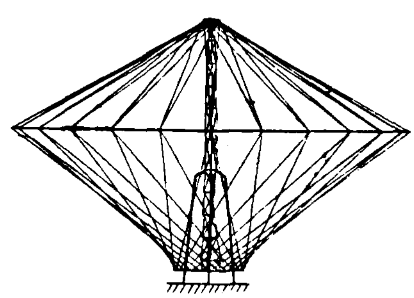
f=0.785

HOOP INPLANE MOTION/COLUMN BENDING



f=1.36

LOWER COLUMN TORSION

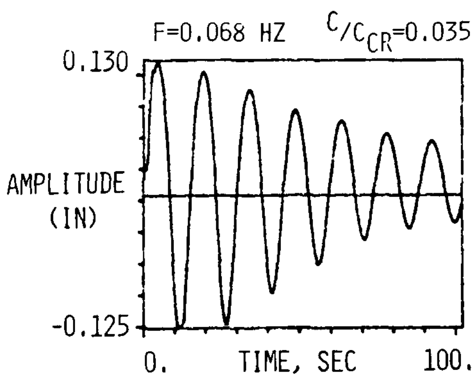


f=3.13

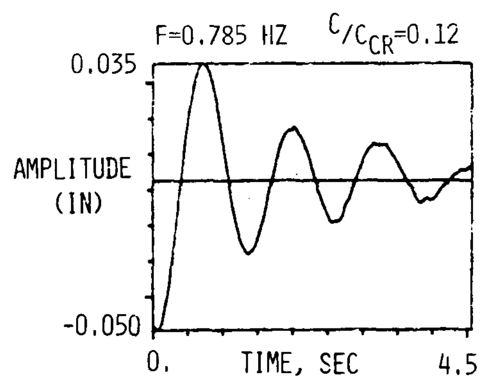
DAMPING IDENTIFICATION FROM FREE DECAY TIME HISTORIES

To obtain data for damping estimation of the first four modes, free decay time histories were recorded for each mode. The time histories shown below are typical of the measurements. None of the curves exhibit pure exponential decay which is representative of viscous damping. Indeed, a structure such as the 15-meter hoop/column antenna probably obtains most of the damping from friction in the joints. Because the friction is nonlinear with the amplitude of vibration, the resulting free decay exhibits an exponential type of decay rather than a classical linear coulomb friction decay. A best fit calculation assuming linear viscous damping results in a critical damping ratio of 0.035, 0.12, 0.041 and 0.026, respectively, for the four modes. These values are considerably higher than estimates of large space antenna damping usually used in analytical simulations. The telescoping column joints are believed to contribute this high damping to the structure.

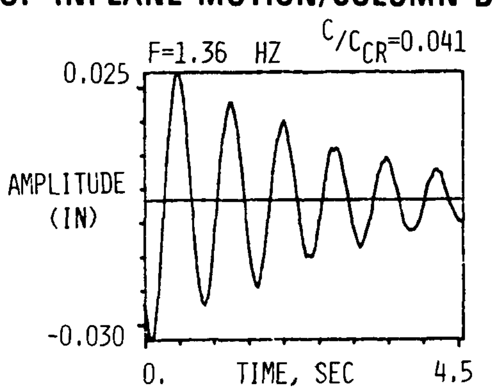
HOOP TORSION



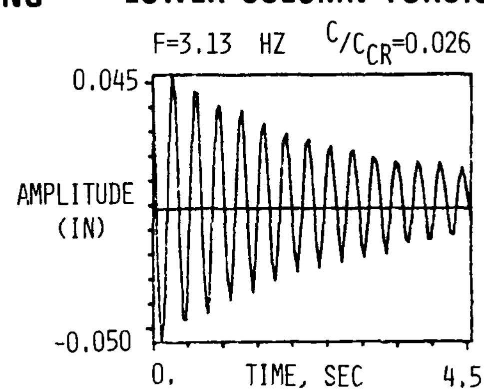
HOOP ROCKING/COLUMN BENDING



HOOP INPLANE MOTION/COLUMN BENDING



LOWER COLUMN TORSION



COMPARISON OF TEST AND ANALYSIS FREQUENCIES

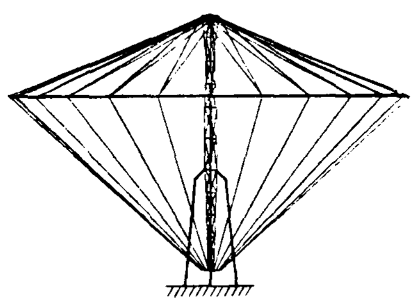
The table below shows a comparison of test natural frequencies to analysis frequencies predicted using the NASTRAN finite-element program. The first four analysis frequencies differ from the test results by 15%, 23%, 18% and -5.4%, respectively. The first three natural frequencies are lower in the test probably due to the flexibility of the column joints. The fourth mode is highly dependent on the rotational inertia of the lower column. It is felt the analysis model overestimates this rotational inertia. Between 7.5 and 10.0 Hz eight test frequencies were identified. These mode shapes involve hoop out-of-plane bending. Analysis predicts 22 modes occur in this frequency range with harmonic numbers from N=0 to N=11. The impact hammer test technique did not provide enough frequency resolution in the test results to identify more than the eight frequencies shown. From 12.05 to 14.55 Hz eight additional modes that involve in-plane hoop bending were obtained from test data. The table also shows cable frequencies that were measured by exciting each of the 72 cables. These frequencies range from 9.25 to 11.45 Hz. The analysis results used a nominal 21-lb load in each of the upper hoop support cables and 15.7 pounds in the lower hoop support cables.

MODE SHAPE DESCRIPTION	FREQUENCIES (Hz)	
	ANALYSIS	TEST
Hoop torsion	0.078	0.068
Hoop rocking/column bending	0.969	0.785
Hoop inplane motion/column bending	1.61	1.36
Lower column torsion	2.96	3.13
Hoop out-of-plane motion	22 Modes from 6.93 to 7.30	7.50 7.95 8.15 8.40 8.60 8.95 9.20 10.00
Hoop inplane bending	10 Modes from 10.16 to 14.22	12.05 12.55 13.00 13.25 13.50 13.75 14.30 14.55
Higher hoop rocking and column bending	11.85 12.72	11.65 13.25
Lower cable modes	10.62	from 9.25 to 11.65
Upper cable modes	9.80	from 9.66 to 11.45

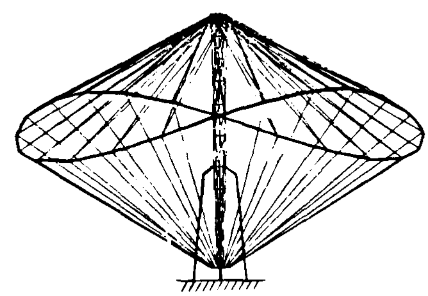
OUT-OF-PLANE HOOP MODES (F=7.5 TO 10.0 HZ)

Shown below are four of the mode shapes typical of the modes in the frequency range from 7.5 to 10.0 Hz. These modes shapes were generated by analysis. The experimental data show these modes to be highly coupled and as such they were not identified completely from the test data. An important consideration in modeling these modes is the existence of a pin in each of the 24 hoop joints. These pins are oriented to allow free rotation of the hoop segments in the out-of-plane direction to facilitate deployment. The analysis results were generated with a perfect pin in each hoop joint. This results in the out-of-plane hoop modes to be spaced very close in frequency (i.e., 22 modes from 6.93 to 7.30). In reality, some degree of rotational stiffness exists in the hoop joints. This stiffness probably accounts for the experimental modes being spaced further apart in frequency (7.50 to 10.0 Hz).

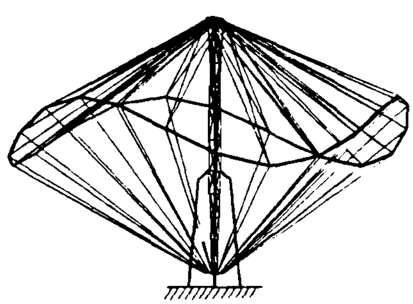
OUT-OF-PLANE HOOP TRANSLATION



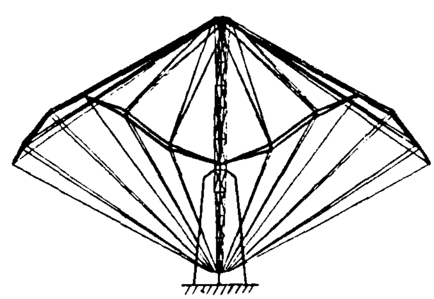
OUT-OF-PLANE HOOP BENDING (N=2)



OUT-OF-PLANE HOOP BENDING (N=3)



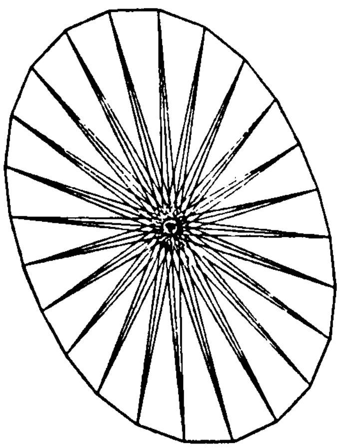
OUT-OF-PLANE HOOP BENDING (N=4)



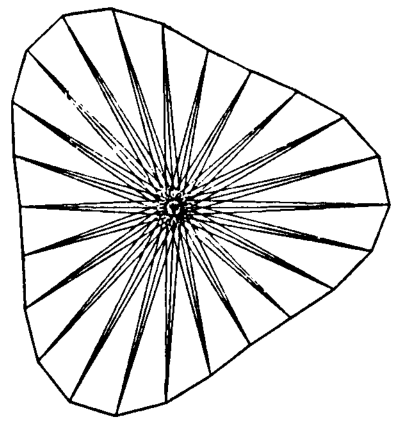
IN-PLANE HOOP BENDING MODES (F=12.0 TO 14.5 HZ)

From 12.0 to 14.5 Hz, a number of modes were measured which exhibit in-plane hoop bending as shown. Again these modes were highly coupled, and the experimental technique did not provide the frequency resolution needed to completely characterize these modes. Nevertheless, the frequencies obtained from the test data correlate to the analysis frequencies reasonably well. The high degree of coupling will require a very extensive test program to uniquely identify these modes.

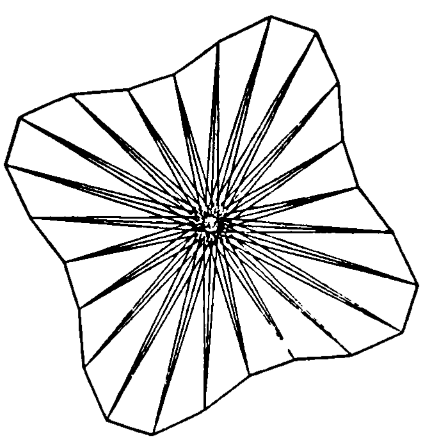
INPLANE HOOP BENDING (N=2)



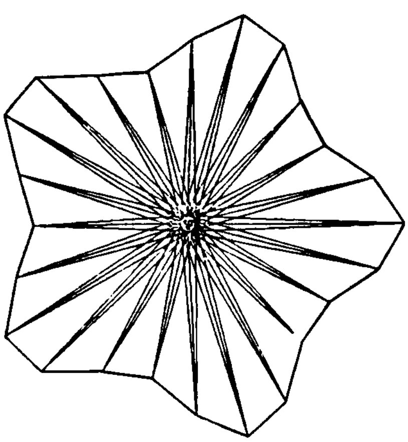
INPLANE HOOP BENDING (N=3)



INPLANE HOOP BENDING (N=4)



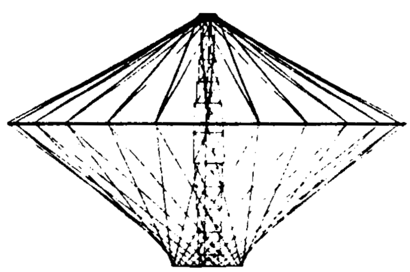
INPLANE HOOP BENDING (N=5)



FIRST FLEXIBLE FREE-FREE MODES OF 15-M ANTENNA

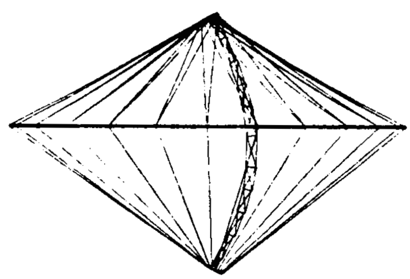
The results presented thus far are highly influenced by the boundary conditions of the test configuration. In space, the antenna would be a free flyer and as such would have free-free boundary conditions. The mode shapes below were generated analytically with free-free conditions. The fundamental flexible mode occurs at 2.47 Hz. This represents an increase by a factor of 36 from the fundamental hoop torsion mode with the test boundary conditions. The next two modes occur at 3.79 and 5.38 Hz. The last figure shows the beginning of a group of hoop out-of-plane bending modes. These modes were not considerably affected by the test boundary conditions.

LOWER COLUMN TORSION



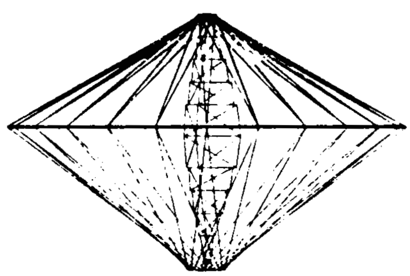
f=2.47

HOOP INPLANE MOTION/COLUMN BENDING



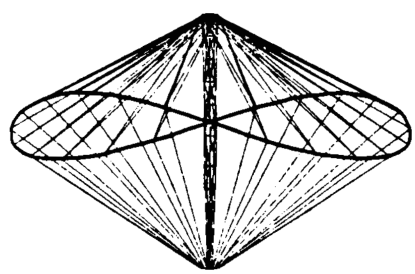
f=3.79

HOOP/COLUMN TORSION



f=5.28

HOOP OUT-OF-PLANE BENDING (N=2)



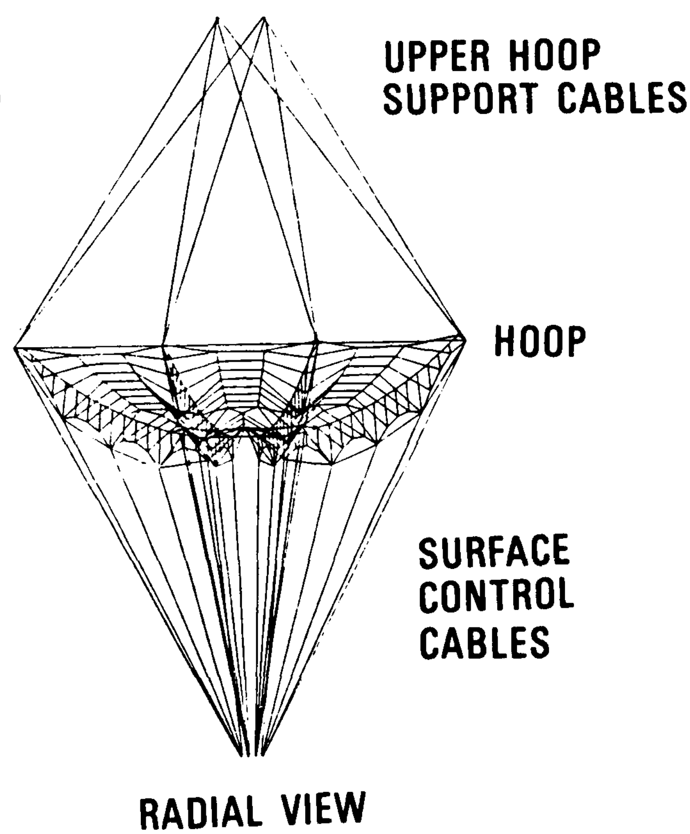
f=6.82

THREE-GORE SURFACE MODEL

In addition to the test and analysis program to determine the 15-meter antenna dynamic properties without mesh, an extensive test and analysis program is under way to completely characterize the 15-meter model after the surface mesh is installed. The figure below shows the model being used to predict the static response of the 15-meter antenna with surface mesh. This three-gore or 45-degree model is the smallest repeating element of a quad-aperture antenna. The model contains appropriate boundary conditions for rotational symmetry. The model size, as indicated below, is large considering no intermediate grid points are used from joint to joint. The model has been extended to 24 gores as described in the next figure.

- **SMALLEST REPETITIVE ELEMENT FOR QUAD-APERTURE ANTENNA**
- **MODEL SIZE**

  317 coordinates
  1097 degrees of freedom
  583 cable elements
  360 membrane elements
  11 beam elements



TWENTY-FOUR GORE DYNAMIC MODEL WITH SURFACE MESH

The three-gore model has been extended to 24 gores to enable accurate modeling of mass and stiffness asymmetries resulting from fabrication tolerances or other sources. As outlined below, the model will be used to predict the vibration modes with surface mesh. Because of the model detail, the 24-gore model can be used as a benchmark with which one can compare various simplified models. For example, modeling of the antenna with repetitive symmetry will be performed.

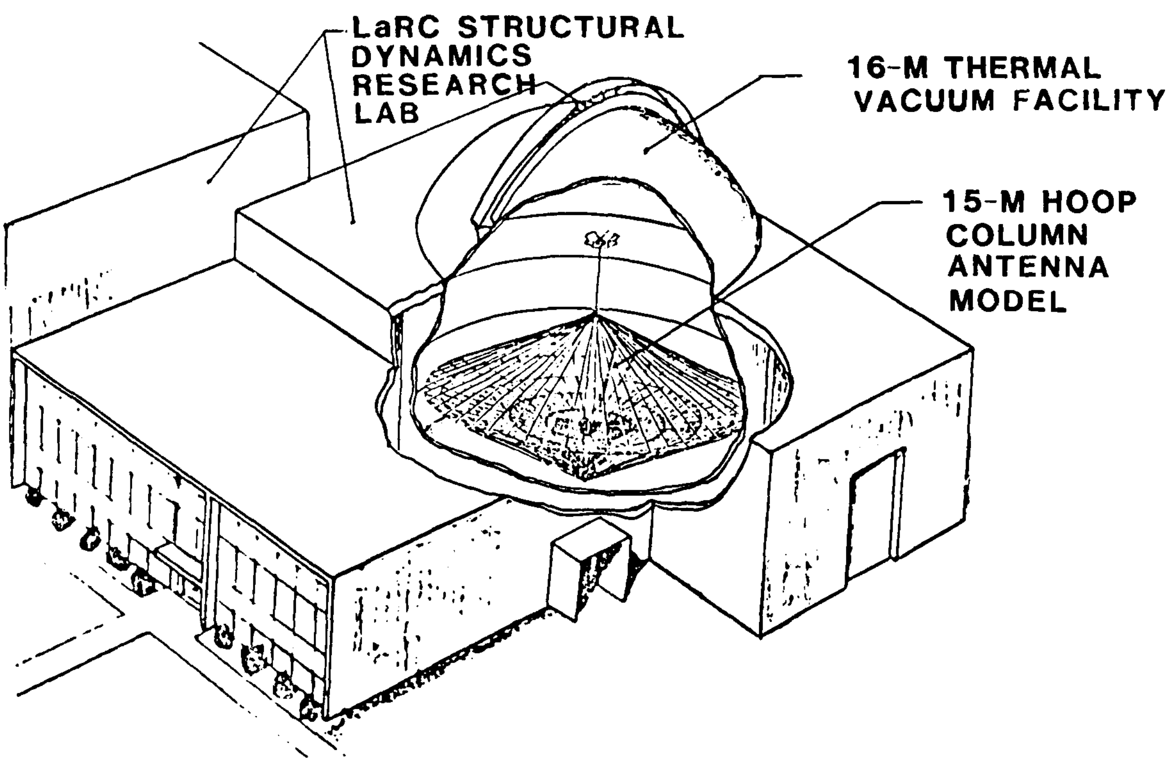
- **ROTATIONAL SYMMETRY NOT ASSUMED TO PERMIT ASYMMETRIC FABRICATION ERROR STUDIES**
- **MODELED WITH FINITE ELEMENTS USING THE EAL ANALYSIS PROGRAM**
  - **2096 Nodes**
  - **8816 Degrees of freedom**
  - **4664 Cable elements**
  - **2880 Two-dimensional membrane elements**
  - **286 Beam elements**
- **MODEL CAPABILITIES INCLUDE:**
  - **Dynamics**
    - **System identification of modes and frequencies**
    - **Transient response analysis**
  - **Statics**
    - **Member length error studies**
    - **Gravity load effects**
    - **Prediction of buckling**
- **PRIMARY PURPOSE OF MODEL IS EXPERIMENT CORRELATION AND TO PROVIDE BENCHMARK FOR COMPARISON WITH SIMPLIFIED MODELS**

PLANNED DYNAMIC CHARACTERIZATION OF 15-M HOOP/COLUMN MODEL WITH MESH SURFACE

Extensive dynamic testing of the 15-meter model is planned to begin in August, 1985, and to last for about 1 year. These tests will be performed in the 16-meter thermal vacuum chamber at Langley as shown below. Various boundary conditions will be used to study the effects of 1-G support systems. Tests will also be performed in both atmospheric and near-vacuum pressures to study ambient air damping and apparent mass effects on the vibration modes. A parallel analysis program will be conducted to ascertain the degree of model sophistication required to accurately predict the model properties. Transient response tests will be used to verify reduced-order simulation models often proposed in control system designs.

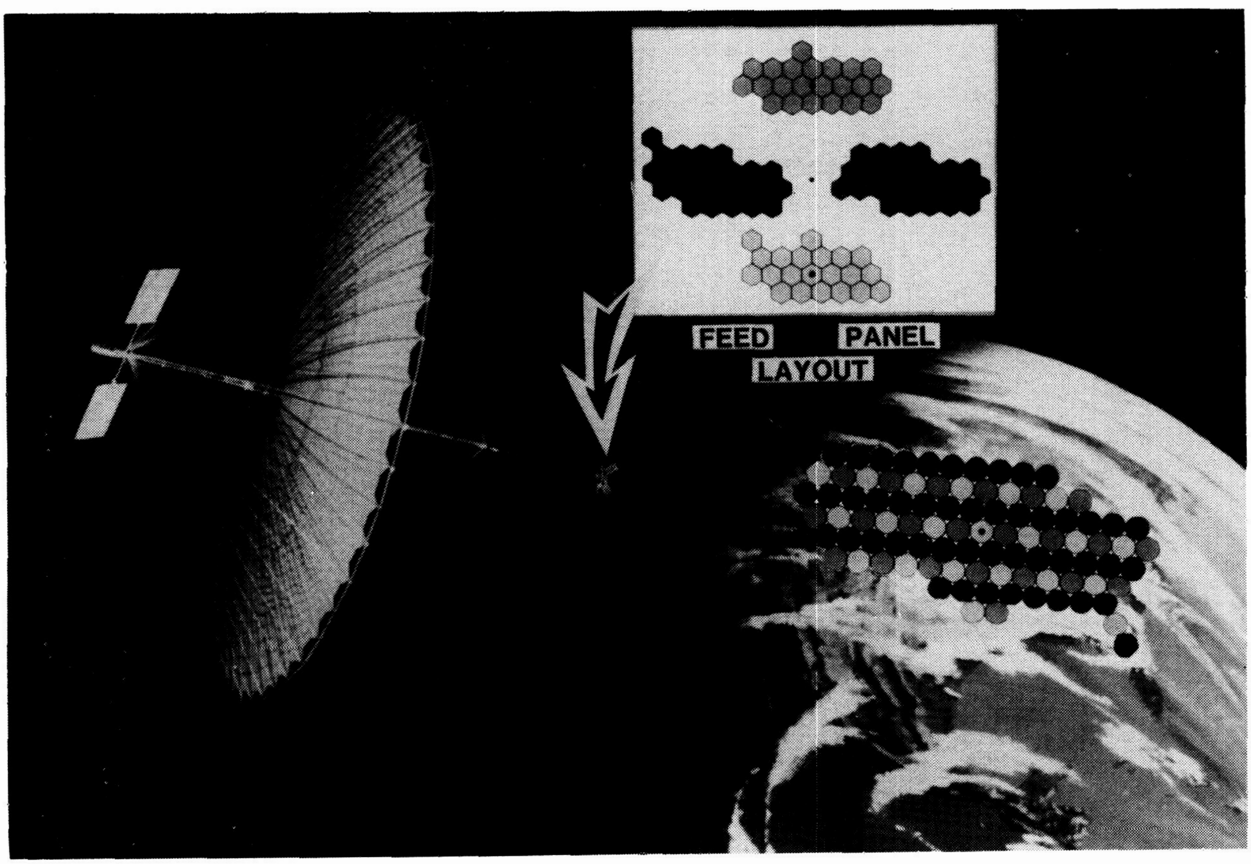
Modal surveys and free response measurements for system identification

- **Transient response tests to verify analytical simulation models**



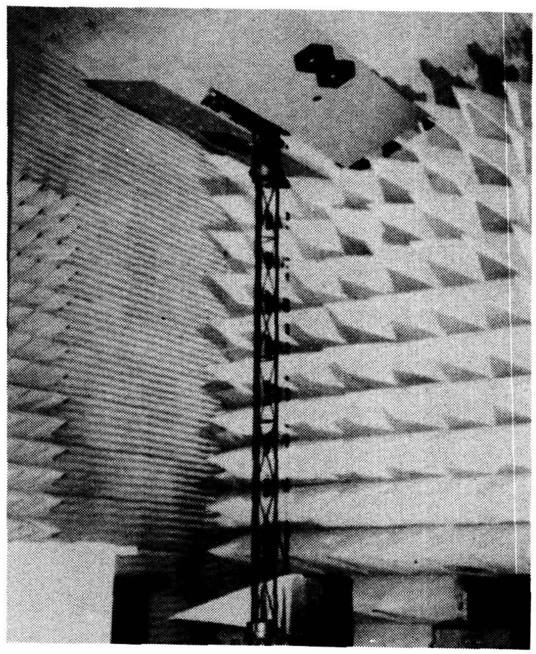
RADIO FREQUENCY SYSTEMS

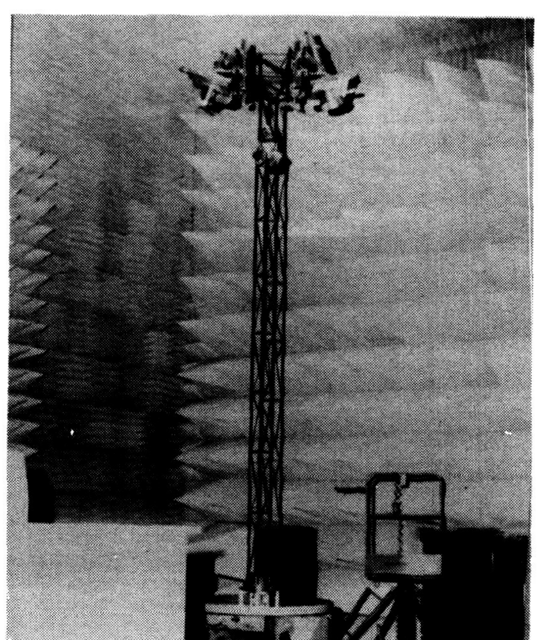
The radio frequency subsystems and plans for near-field testing the 15-meter antenna will now be presented. As indicated earlier, the 15-meter structure will consist of four offset reflectors, and feed systems are being developed by Langley and the Jet Propulsion Laboratory (JPL) to test the performance of multiple apertures (interleaved beams) and single apertures (overlapped beams), respectively, for future multiple-beam missions.



FEED SYSTEM PANELS FOR THE 15-METER ANTENNA

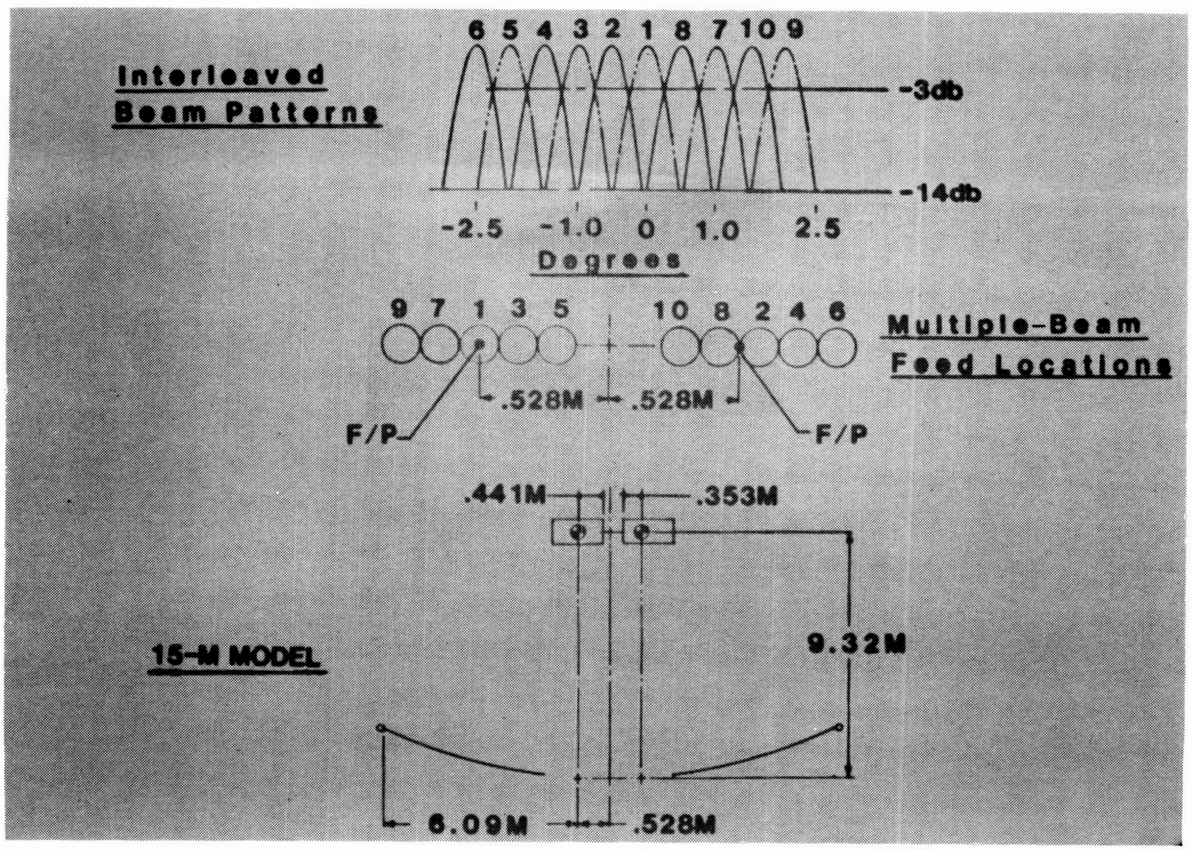
The feed system panels developed by Langley are shown in the photographs below attached to the rigid-feed support mast. This mast will be attached to the end of the telescoping mast of the 15-meter structure for the antenna tests. Two feed panels will be used to demonstrate beam interleaving using two of the four apertures. The feed panels can be positioned in x, y, and z directions using the remote-controlled positioning system located beneath the feed panels.





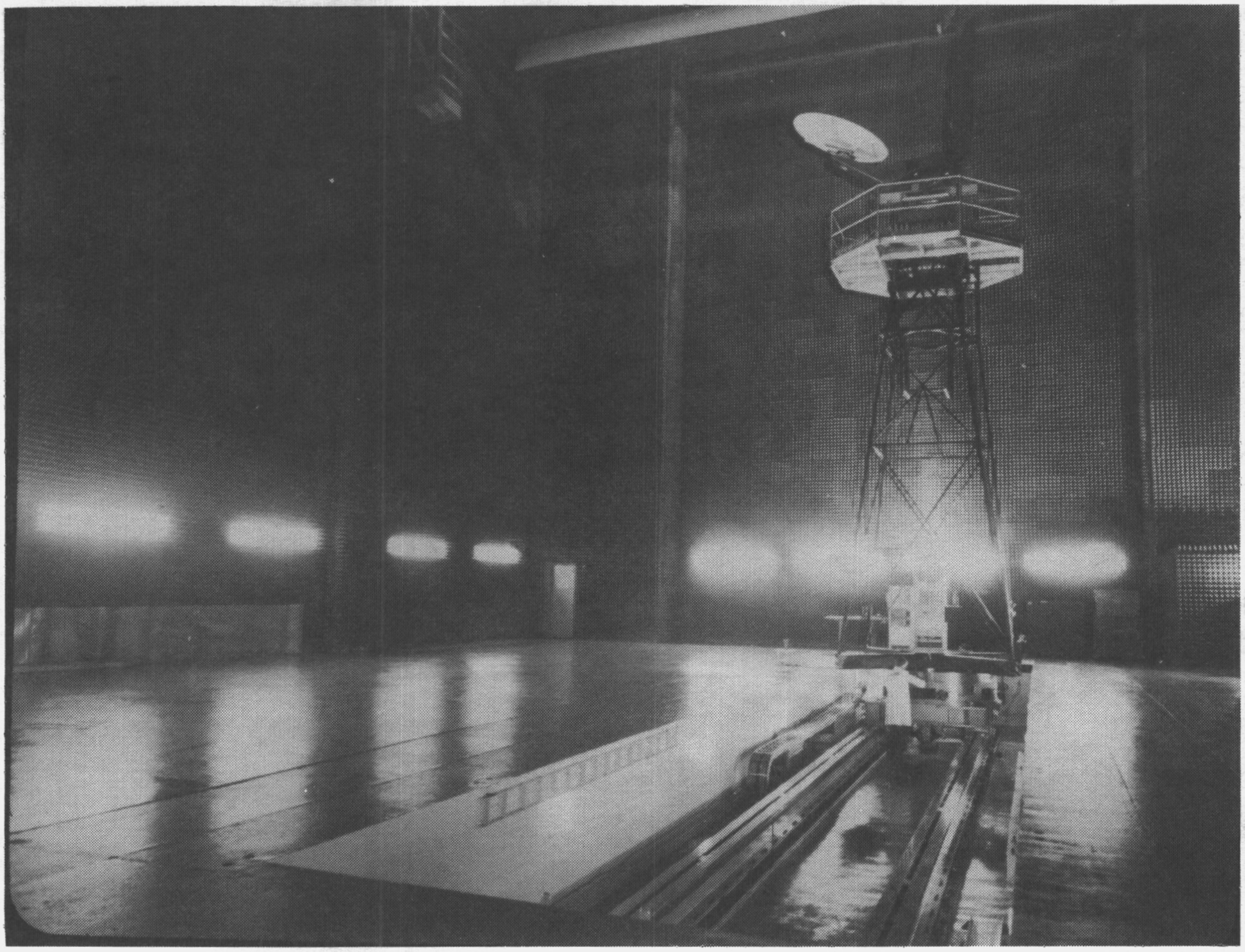
CONCEPT OF INTERLEAVING BEAMS USING THE 15-METER QUAD-APERTURE ANTENNA

The concept of interleaving beams from the individual apertures is shown in the figure below. A method for interleaving ten beams using two diametrically opposed apertures is depicted. This approach will be tested using the 15-meter antenna during the RF test program.



NEAR-FIELD ANTENNA TEST FACILITY

Plans have been formulated for testing the 15-meter antenna in the Martin Marietta Near-Field Facility if schedules permit. A photograph of the facility is shown below during tests of the Langley/TRW offset-fed Ku-band antenna system. This test proved to be very effective in comparing near-field and far-field measured patterns for precision reflector antennas.



SHUTTLE-ATTACHED CONFIGURATION FOR PROPOSED FLIGHT TESTS OF THE 15-METER ANTENNA

In conclusion, a photograph of the multiple-aperture 15-meter antenna is shown attached to Shuttle in a proposed flight experiment configuration. This antenna can be deployed in space and then restowed and brought back to Earth for future flight opportunities.