

D/6

DEVELOPMENT OF THE MAYPOLE (HOOP/COLUMN)  
DEPLOYABLE REFLECTOR CONCEPT FOR LARGE SPACE  
SYSTEMS APPLICATIONS

D. C. Montgomery and L. D. Sikes  
Harris Corporation  
Government Systems Group

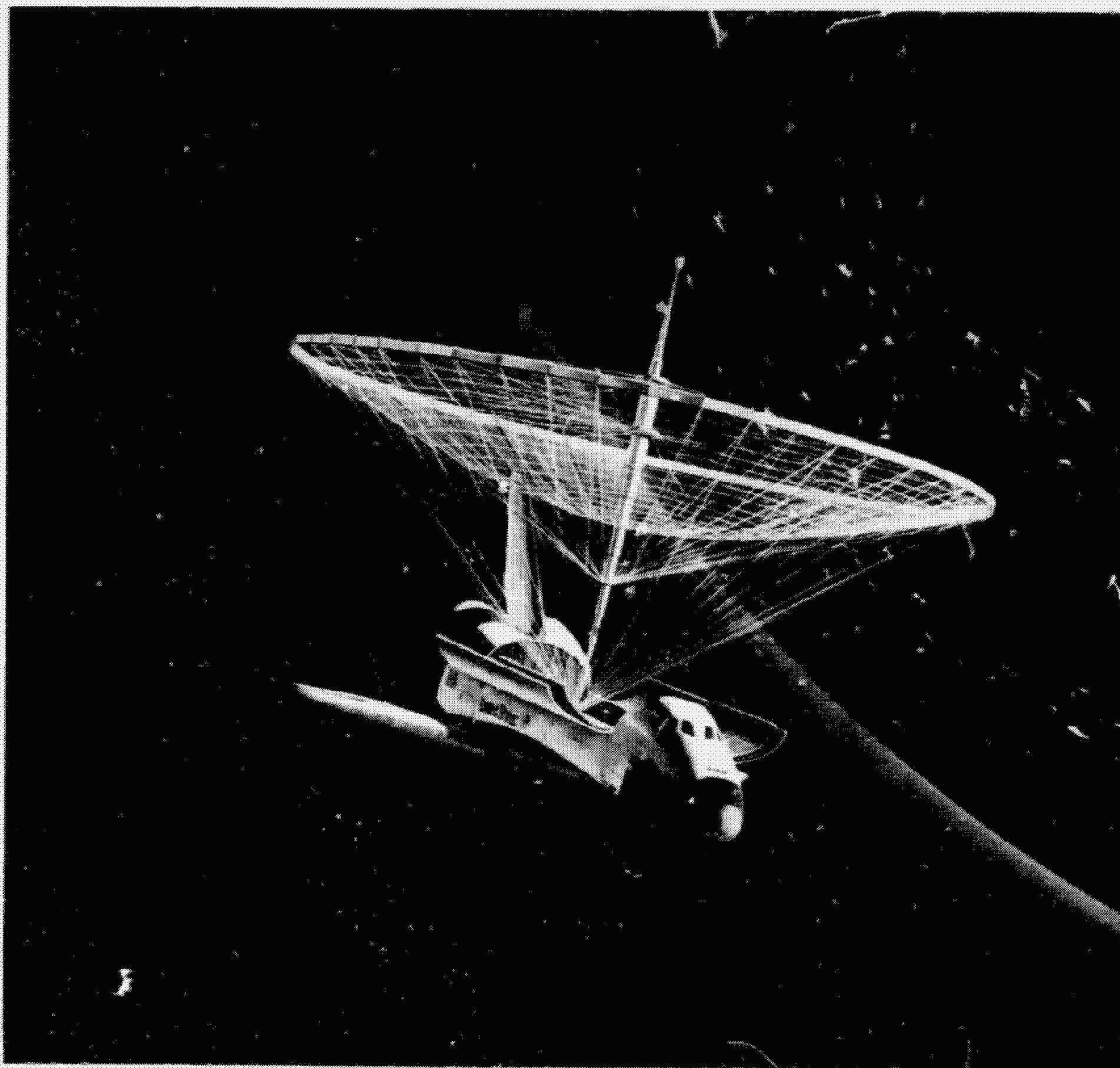
NAS1 - 15763

LSST 1ST ANNUAL TECHNICAL REVIEW

November 7-8, 1979

### HOOP/COLUMN REFLECTOR

The Hoop/Column reflector concept is being developed for mission applications in the mid 1980's and beyond. The accompanying artist's conception shows a 30 meter diameter reflector in the LDASE (Large Deployable Antenna Shuttle Experiment) configuration. This concept was generated during a previous NASA sponsored AAFE program.



ORIGINAL PAGE IS  
OF POOR QUALITY.

N80-19151

**PROGRAM OBJECTIVE**

The program is a technology development study. The specific technologies to be developed are stated below.

**PROGRAM OBJECTIVE**

**TO DEVELOP THE TECHNOLOGY NEEDED TO EVALUATE,  
DESIGN, FABRICATE, PACKAGE, TRANSPORT AND  
DEPLOY THE MAYPOLE HOOP/COLUMN REFLECTOR**

## PROGRAM DESCRIPTION

The program is organized by specific tasks. Each task has specific objectives which, when combined, are directed at meeting the overall program objective. Two tasks have been initiated to date. They will be highlighted later in this report. The remaining tasks are summarized below.

Task 3 is an Advanced Concepts task which permits the study of spinoff technologies or other TBD areas of study. Task 4 is the hardware phase of the contract. This task will be used to build demonstration models of the Hoop/Column antenna which show how it satisfies various focus mission requirements. Additionally, an active surface adjustment breadboard model will be built to demonstrate this capability. Other elements of the design will be fabricated for evaluation. Task 5 will utilize the PRICE routine to provide parametric cost data or a family of antennas based on size, configuration, etc. Task 6 is a task intended to design a 5 meter dia. verification model which will be built and tested subsequent to this contract.

## PROGRAM DESCRIPTION

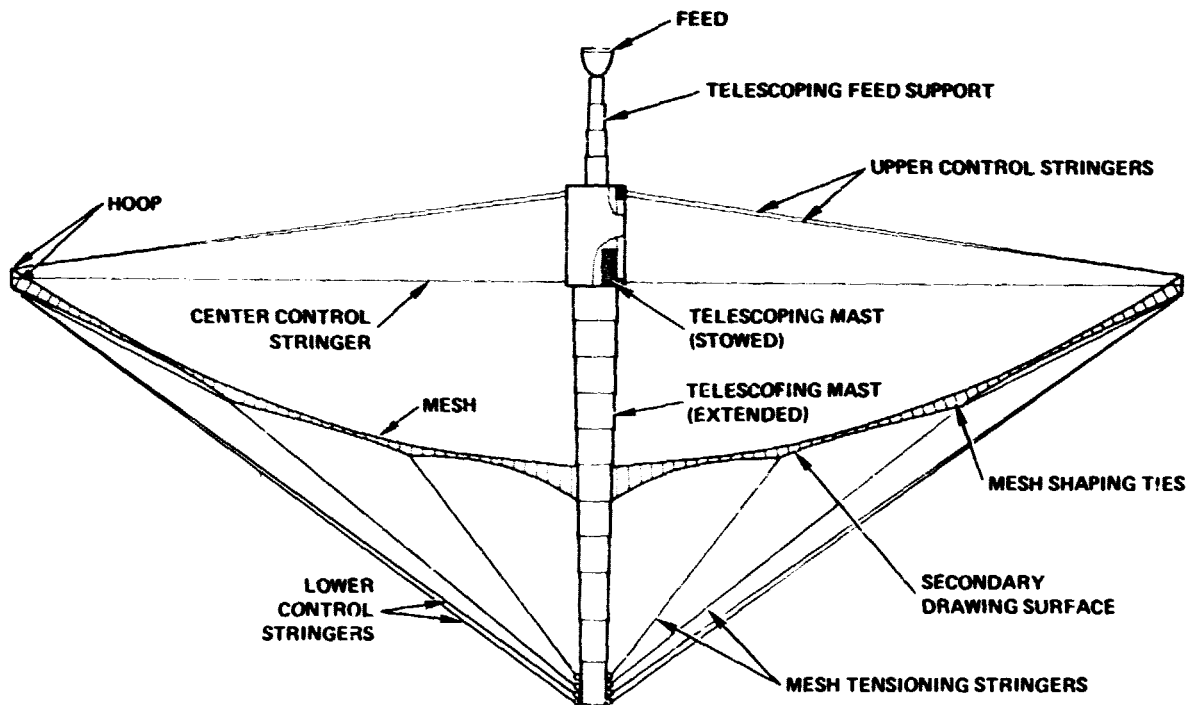
- TASK 1 – CONCEPTUAL DESIGN AND PERFORMANCE PROJECTIONS FOR THE MAYPOLE (HOOP/COLUMN) REFLECTOR CONCEPT FOR LARGE SPACE SYSTEMS APPLICATIONS
- TASK 2 – MATERIALS DEVELOPMENT
- TASK 3 – ADVANCED CONCEPTS
- TASK 4 – DEMONSTRATION MODELS AND FULL SCALE ELEMENTS
- TASK 5 – ECONOMIC ASSESSMENT
- TASK 6 – 5-M DIAMETER VERIFICATION MODEL



## HOOP/COLUMN CONCEPT

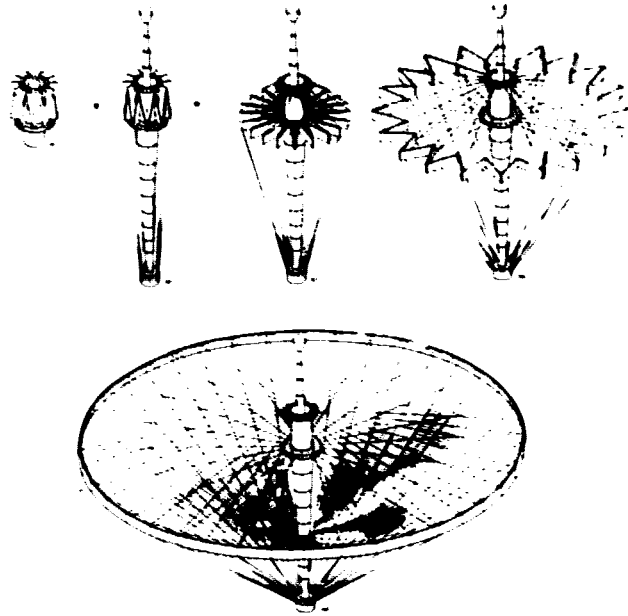
The following three figures illustrate the basic concept approach. The conceptual design shown was the direct result of the previously mentioned AAFE program and formed the basis of the present LSST Hoop/Column development study effort. The basic elements described are the telescoping mast, the rigid articulating hoop and a series of cords used to shape the surface and position the hoop.

## HOOP/COLUMN CONCEPT

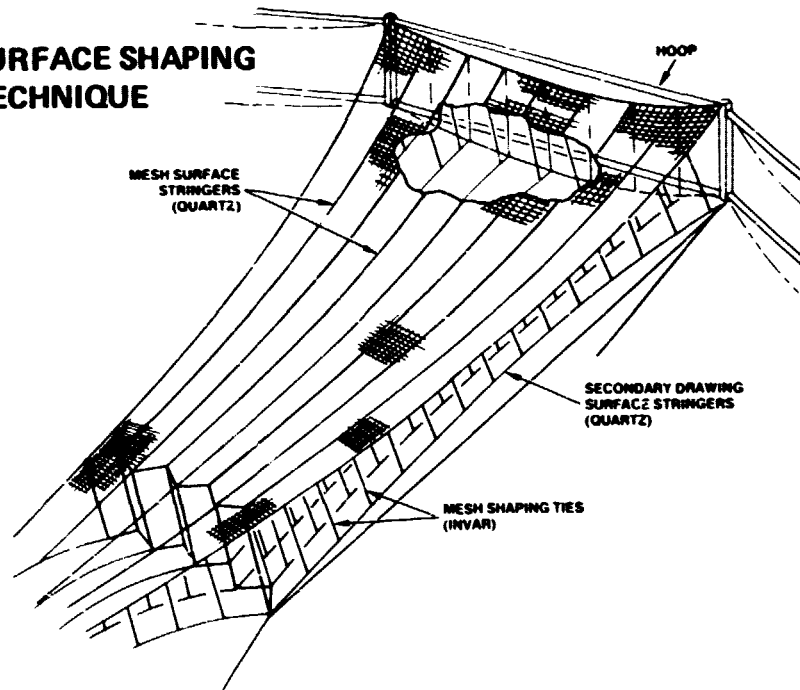


68992-3A

### Hoop/Column Deployment Sequence



### SURFACE SHAPING TECHNIQUE



# **TASK 1**

**CONCEPTUAL DESIGN AND PERFORMANCE PROJECTIONS  
FOR THE MAYPOLE (HOOP/COLUMN) REFLECTOR  
CONCEPT FOR LARGE SPACE SYSTEMS  
APPLICATIONS**

## TASK 1 OBJECTIVES

This task is the primary design and analysis portion of the program. The first objective is key to performing all subsequent activities in this task. By reviewing the focus mission scenarios provided by NASA, specific configuration requirements have been determined. Upon completion of this review, technology drivers are identified and organized into a document (Reflector Requirement Document) which will serve as the design specification for the balance of the program. These requirements will define the configuration or "point design" which may or may not be one specific mission.

A detailed conceptual design must then be established around the requirements of the RRD. Full analyses will be accomplished in order to provide performance projections for the design. Related to this analysis will be the development of a scaling technique which will permit performance estimates for a given configuration over the range of sizes from 15 to 100 meters in diameter.

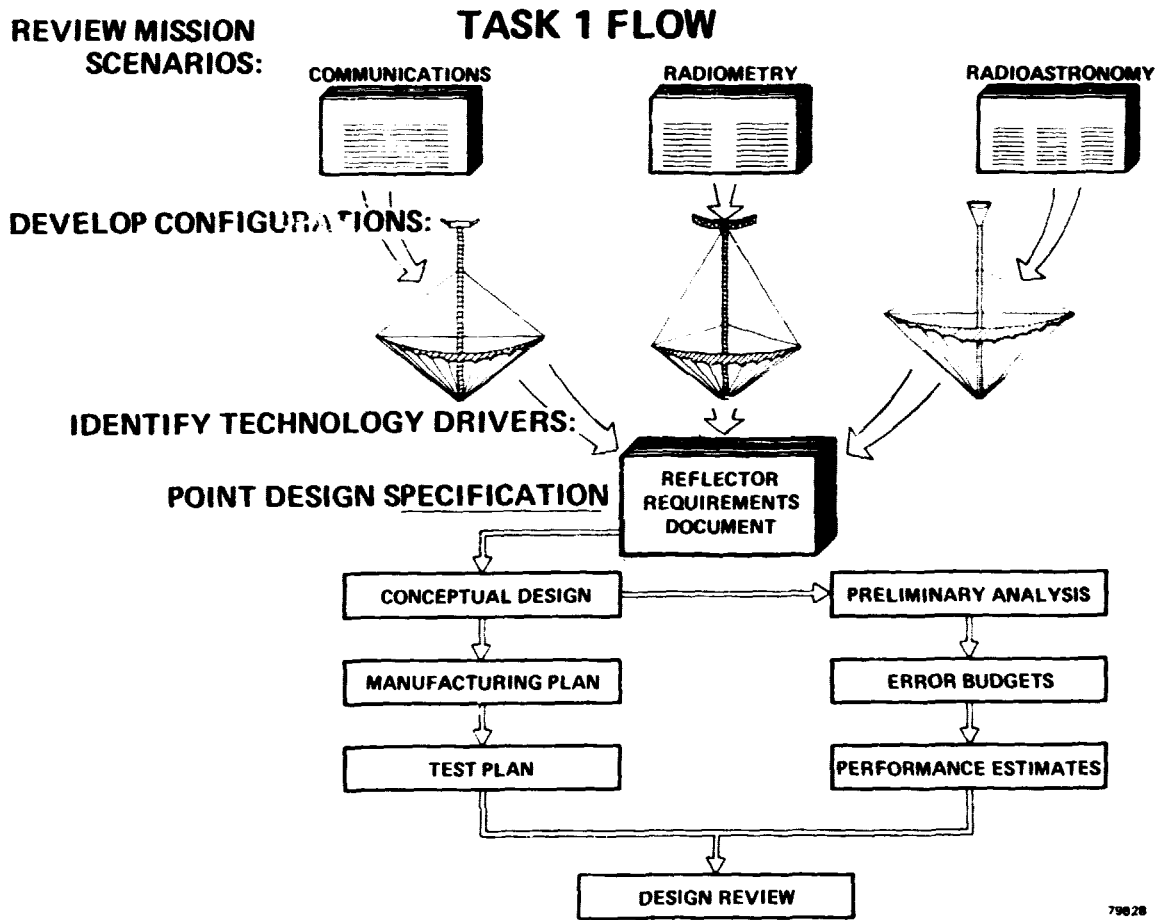
Additional objectives include the development of both manufacturing and testing methods consistent with structures of this size.

## OBJECTIVES

- DEFINE "POINT DESIGN" CONFIGURATION RESULTING FROM TECHNOLOGY DRIVERS IDENTIFIED DURING MISSION SCENARIO STUDIES
- DEVELOP A REFLECTOR REQUIREMENTS DOCUMENT (RRD)
- ESTABLISH A DETAILED CONCEPTUAL DESIGN AROUND REQUIREMENTS OF THE RRD
- PERFORM ANALYSIS TO PREDICT ANTENNA PERFORMANCE
- ESTABLISH A "SCALING" PHILOSOPHY AND TECHNIQUES TO PREDICT PERFORMANCE OF ANTENNAS OVER THE RANGE OF 15-M TO 100-M DIAMETER
- ESTABLISH A MANUFACTURING PLAN CONSISTENT WITH THE REQUIREMENTS OF THE DESIGN
- DEVELOP A TEST PHILOSOPHY AND APPROACHES REQUIRED TO VERIFY PERFORMANCE

TASK 1 FLOW

The plan for meeting the objectives of this task is shown in the figure below. Present activities are centered around identification of the technology drivers necessary to define the point design.



## LSST MISSION SCENARIO SUMMARY

Mission scenario data was provided by the NASA Langley Research Center in the form of a report given by ref. 1. Therein was described mission data for advanced communications and public service satellite, soil moisture radiometry, and radio astronomy. An exercise of evaluating various system configuration alternates based on the individual missions was implemented with the intent of choosing the most optimum design approaches. The only scenario which was not clearly defined was the public service satellite mission. It seemed most reasonable during preliminary evaluations to postulate maximum mission requirements to conform to that of advanced communications. If this is done, and as this mission becomes more clearly defined with indications that the requirements are not as complex as previously assumed, the proposed system can be reduced in complexity.

## LSST MISSION SCENARIO SUMMARY

MISSION PARAMETER	COMMUNICATIONS				MICROWAVE RADIOMETER SYSTEM	RADIO ASTRONOMY (VLBI)
	ADVANCED		PSS			
FREQUENCY (GHz)	4-6	11-14	0.87	2.0	1.4	1.4-22
POINTING ACCURACY (DEGREES)	0.035	0.035	0.035	0.035	0.1	0.01
BEAM NUMBER	219	219	TBD	219	200-300	1
BEAM ANGLE (DEGREES)	0.256	0.256	TBD	0.256	0.06	FREQUENCY DEPENDENT
BEAM ISOLATION (dB)	-30	-30	-30	-30	N/A	N/A
ORBIT ALTITUDE	GEO	GEO	GEO	GEO	LEO	LEO
RESOLUTION (km)	N/A	N/A	N/A	N/A	1	10 <sup>-5</sup> /SEC* 10 <sup>-3</sup> /SEC**
REVISIT COVERAGE (DAYS)	N/A	N/A	N/A	N/A	3	N/A
SWATH ANGLE (DEGREES)	N/A	N/A	N/A	N/A	±30	N/A
LIFE TIME (YEARS)	>20	>20	>20	>20	>20	>20

\*TARGET  
\*\*GOAL

## FACTORS INFLUENCING CONFIGURATION CHOICE

### (ADVANCED COMMUNICATIONS)

The Advanced Communication mission scenario calls for a multiple beam antenna capable of producing 219-100 mile highly isolated spot beams covering the Continental United States. Selection of appropriate designs fulfilling this coverage requirement places great stress on configuration dependent parameters. These parameters greatly influence the ability of the proposed system to meet the coverage requirement while at the same time meeting the isolation and efficiencies required. Trade studies must be performed to define acceptable bounds on reflector size, F/D, feed array configuration geometries and array sizes, each of which influence multibeam performance, blockage and intrabeam isolation. Depending on whether a large symmetrical reflector or an offset reflector system is used, the feed system may either be extremely complex or simple. This will influence internal system losses and overall system efficiency.

## FACTORS INFLUENCING CONFIGURATION CHOICES

### (ADVANCED COMMUNICATIONS)

- MULTIPLE BEAM PERFORMANCE
  - REFLECTOR F/D
  - REFLECTOR SIZE/MULTIPLE REFLECTORS
  - AVAILABLE FEED ARRAY REAL ESTATE
  - FEED ARRAY ELEMENTS
- BEAM-TO-BEAM ISOLATION
  - REFLECTOR F/D
  - BLOCKAGE
  - FEED ARRAY ELEMENTS
  - BEAM USAGE SCHEMES
- INTERNAL SYSTEMS LOSSES
  - FEED ARRAY CONFIGURATION CHOICES
  - BEAM ISOLATION SCHEMES

## RESOLUTION OF RF DESIGN CONCERNS

### (ADVANCED COMMUNICATION)

Use of the total aperture of the symmetrical reflector system is desirable since this appears to be the most efficient use of the total system. Trade studies have been conducted which indicate that to use the entire reflector implies that an extremely large feed array must be employed where each feed element is small. The reflector system is over illuminated with a large percentage of blockage, resulting in high sidelobes. Additionally, the secondary beams are too narrow for this application. This requires that the beams be combined in such a way that the overall combining process produces a flat topped beam with high sidelobes. The isolation will be achieved by utilizing frequency and polarization diversity to provide guard bands which will contain the sidelobes.

Alternatively, an offset system may be designed which produces the appropriate secondary pattern size. The blockage will not be present but the feed array real-estate availability will dictate that several offset reflectors will be required. Use of this type of system buys the added advantage of low coma distortion and low scan loss as indicated by ref. 2.

## RESOLUTION OF RF DESIGN CONCERNS (ADVANCED COMMUNICATIONS)

- THE OBVIOUS INHERENT RF DESIGN CONCERN FOR A LARGE SYMMETRICAL REFLECTOR CAN BE RESOLVED BY DEVISING A BEAM PLAN WHICH ISOLATES SIDE LOBES BY UTILIZING GUARD BANDS GENERATED BY PROPER USE OF POLARIZATION AND FREQUENCY DIVERSITY
- RF BLOCKAGE AND LOW F/D PROBLEMS CAN ALSO BE OVERCOME BY USING MULTIPLE OFFSET REFLECTORS
  - AS F/D INCREASES THE ASSOCIATED COMA DISTORTIONS DECREASE, BUT SO DOES THE AVAILABLE FEED ARRAY REAL ESTATE; HENCE A MULTIPLE REFLECTOR SYSTEM MUST BE EMPLOYED USING BEAM INTERLEAVING
  - BEAM ISOLATION IN THESE DESIGNS OBTAINED BY USING FREQUENCY DIVERSITY AND ORTHOGONAL POLARIZATIONS



## ANTENNA CONFIGURATION CANDIDATES

### (ADVANCED COMMUNICATIONS)

The Maypole Hoop/Column concept lends itself quite well to two configurations—a symmetrical reflector system and a quad offset design. The basic configuration in either case is what appears to be a symmetrical reflector system with F/D of approximately one. Referring to the discussion on the previous page, the symmetrical system is very complex where each individual  $0.25^\circ$  beam is comprised of nine narrower beams. Total array size is 1317 feeds. The offset design is achieved by generating a surface in each quadrant of the symmetrical Hoop/Column which represents an offset reflector system having a boresight axis parallel to the Column axis. Since the available area for feed elements has been increased by four, the number of feeds per reflector is 55 full sized scalar feeds. The total structural size is the same for the offset geometry as it is for the symmetrical system; hence, the offset F/D is effectively doubled to two.

## ANTENNA CONFIGURATION CANDIDATES

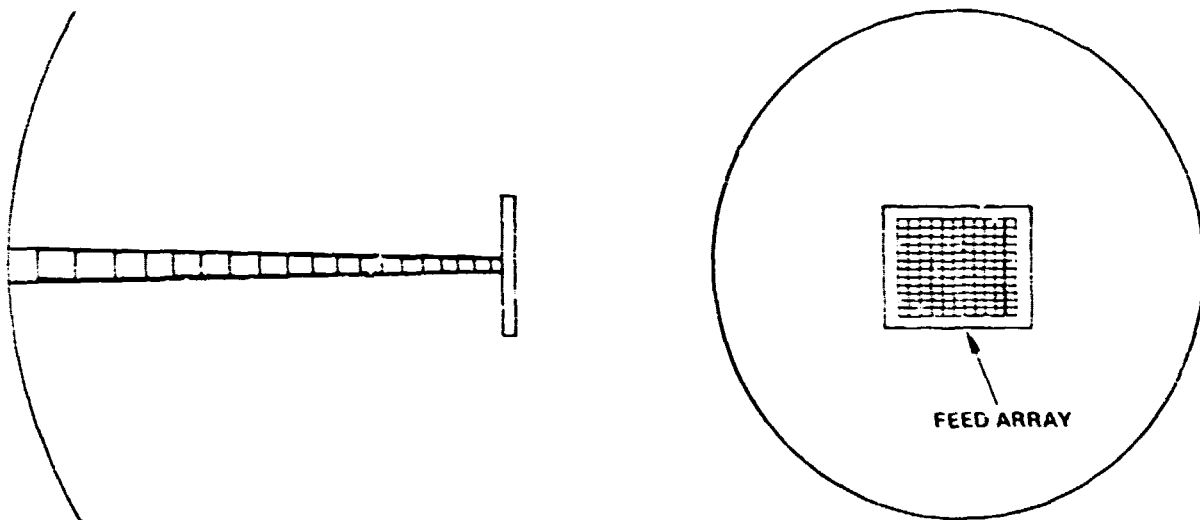
### (ADVANCED COMMUNICATIONS)

- **SINGLE SYMMETRICAL FOCAL POINT FED PARABOLOID**
  - F/D  $\approx$  1
  - 219 BEAMS (BEAM WIDTH =  $0.25^\circ$ )
    - EACH SPOT BEAM COMPOSITE OF NINE SUMMED BEAMS
    - BEAM ISOLATION ACHIEVED BY USING POLARIZATION AND FREQUENCY DIVERSITY
    - SINGLE FEED ARRAY – 1317 FEEDS
- **CUSPED QUAD APERTURE DESIGN**
  - SINGLE REFLECTOR WITH QUADRANT SUBDIVISIONS
    - EACH QUADRANT CONTAINS SINGLE OFFSET SYSTEM
    - 55 BEAMS (FEEDS)/OFFSET REFLECTOR SPACIALLY INTERLEAVED TO PRODUCE 219 EQUALLY SPACED SPOT BEAMS
  - F/D  $\approx$  2 FOR OFFSET SYSTEM

### SINGLE SYMMETRICAL REFLECTOR

As has been discussed, the array feed geometry for the symmetrical reflector is very imposing and causes the symmetrical system to have several serious R.F. problems. The aperture blockage problem causes the overall gain loss to be appreciable. This can be partially compensated for by adjusting the aperture size slightly. A total buy back cannot be achieved in this way, however. The system sidelobe level is also increased, but this may be compensated for by generating guard bands by properly utilizing the band channelization. The system network loss will be higher than normal due to the requirement of using multiple diplexers, many power dividers and yards of waveguide.

### SINGLE SYMMETRICAL REFLECTOR (ADVANCED COMMUNICATIONS)



1922

## QUAD APERTURE/FEED CHARACTERISTICS

The Quad Aperture system employing the Maypole Hoop/Column concept requires four individual surfaces whose boresights are parallel to the Column axis. The focal point of each offset is totally offset so that the aperture is unblocked. The feed arrays for each reflector are attached to the central columns via a five axis gimbaling system. This gimbal is required on each feed array to do an orbit adjustment of reflector illumination in the situation where small amounts of compensation are required due to deployment misalignment. This function is performed by two axes of the five axis system by rotating the array in two planes. The beam interleaving is adjusted by translating the feed array in two dimensions. This effectively scans the beam bundle in space and fixes the beam crossover levels. Beam focusing adjustments are performed by a single dimensional translation along the offset boresight.

## QUAD APERTURE/FEED CHARACTERISTICS (ADVANCED COMMUNICATIONS)

- INDIVIDUAL CUSPED APERTURE CONFIGURED IN OFFSET GEOMETRY
- OFFSET REFLECTOR SURFACE COMPRISED EITHER OF MULTIPLE MESHES OR SCALLOPED OFFSET OUTLINE
  - MULTIPLE MESHES
    - OFFSET REFLECTOR MESH HIGHLY REFLECTIVE AT 4-6 GHz BAND
    - SURROUNDING MESH LOW DENSITY OR COMPRISED OF FREQUENCY SENSITIVE SURFACE (FSS) ELEMENT
  - SCALLOPING TO OUTLINE OFFSET REFLECTOR SURFACE
- FEED SYSTEM FOR EACH QUAD SECTION ADJUSTED BY FIVE AXIS GIMBAL
  - REFLECTOR EDGE ILLUMINATION ADJUSTMENT
  - BEAM INTERLEAVING POSITION ADJUSTMENT
- FEED GEOMETRY IS AREA COVERAGE DEPENDENT

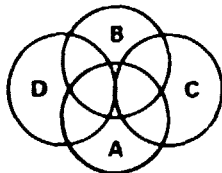
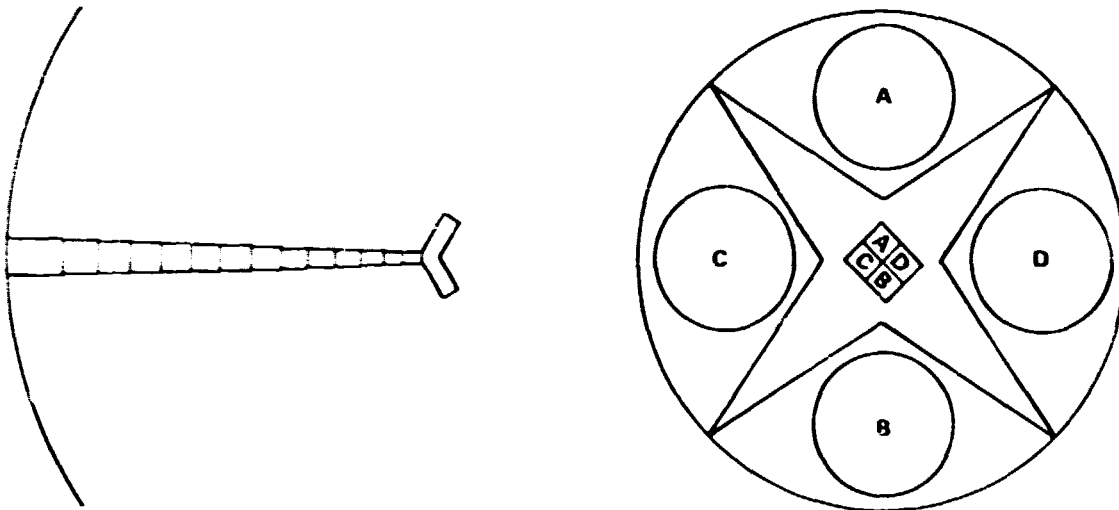
## QUAD APERTURE APPROACH

(ADVANCED COMMUNICATION)

The mesh region shown in each quadrant must be comprised of multiple meshes, or the offset reflector outline must be defined by a scalloped exterior. If the wedged shaped region in each quadrant was developed from a single mesh, the feed energy would not be efficiently used. The circular regions shown in the figure represent the -15 dB feed pattern main beam levels. Past this circular area several high level sidelobes exist. The first sidelobe is -17 dB compared to the main beam, and the second and third sidelobes are relatively high as well. If these sidelobes fall on the reflector surface, they will cause substantial gain loss. The region per quadrant beyond the circular area must be either open mesh or frequency sensitive surface elements tuned to a sufficiently displaced out-of-band frequency so that sidelobe energy is leaked through that region of the reflector.

## QUAD APERTURE APPROACH

(ADVANCED COMMUNICATIONS)



SPACIALLY INTERLEAVED BEAMS

70021

## SYMMETRICAL/QUAD APERTURE TRADES

(ADVANCED COMMUNICATIONS)

Comparisons of the symmetrical reflector to the offset system have been made on a qualitative basis without applying exacting scrutiny to system related performance parameters. However, enough investigative rigor has been applied to feel that selection of one of these approaches can be clearly made. The symmetrical reflector system appears to fail on several important counts. Network losses make this system less efficient than is desirable for a communications mission. Other inefficiencies relating to gain loss due to blockage and loss in beam efficiency due to high sidelobe level make this approach unattractive. Conversely, the quad aperture design wins on all counts and is clearly the most appropriate use of the Maypole Hoop/Column geometry for advanced communications.

## SYMMETRICAL/QUAD APERTURE TRADES (ADVANCED COMMUNICATIONS)

PERFORMANCE PARAMETER	EVALUATION SUMMARY	
	SYMMETRICAL	QUAD APERTURE
LOSSES		
● SCANNING	MEDIUM	LOW
● COMBINING	-9 dB	LOW
● NETWORK	LOSSY	NEGLIGIBLE
COMA DISTORTION	MODERATE	NEGLIGIBLE
CROSS POLARIZATION	NONE	NEGLIGIBLE
ISOLATION	GOOD	EXCELLENT
BLOCKAGE	LARGE	NONE
FEED SYSTEM COMPLEXITY	EXTREME	MODERATE
GAIN VARIATION (BEAM-TO-BEAM)	NEGLIGIBLE	-3 dB
OVERALL GAIN (COMPARATIVE)	-9.5 dB + NETWORK LOSSES	-9 dB + NETWORK LOSSES

## ALTERNATIVE METHOD FOR USING CUSPED QUAD APERTURE

### DESIGN FOR 4-6 GHz AND 11-14 GHz

#### (ADVANCED COMMUNICATIONS)

As defined by the mission scenario information, the advanced communication system should employ both C-band and Ku-band capability. However, such a dual band system would require individual antennas per band unless a scheme for using a single Maypole antenna could be devised. This is, in fact, the intent. Before this method is discussed, some of the physics of aperture antennas should be addressed. Recalling that the system requirement is for 219-100 mile spot beams, the angular half-power beam width is approximately 0.25 degrees. The reflector size required for this beamwidth can be determined by a commonly known formula relating reflector size in wavelengths to half power beamwidth. The relationship is linear so that since the C-band wavelength is 2.5 times longer than the Ku-band wavelength the apertures must be 2.5 times different in size to produce the same beamwidth.

## ALTERNATE METHOD FOR USING CUSPED QUAD APERTURE DESIGN FOR 4-6 GHz AND 11-14 GHz (ADVANCED COMMUNICATIONS)

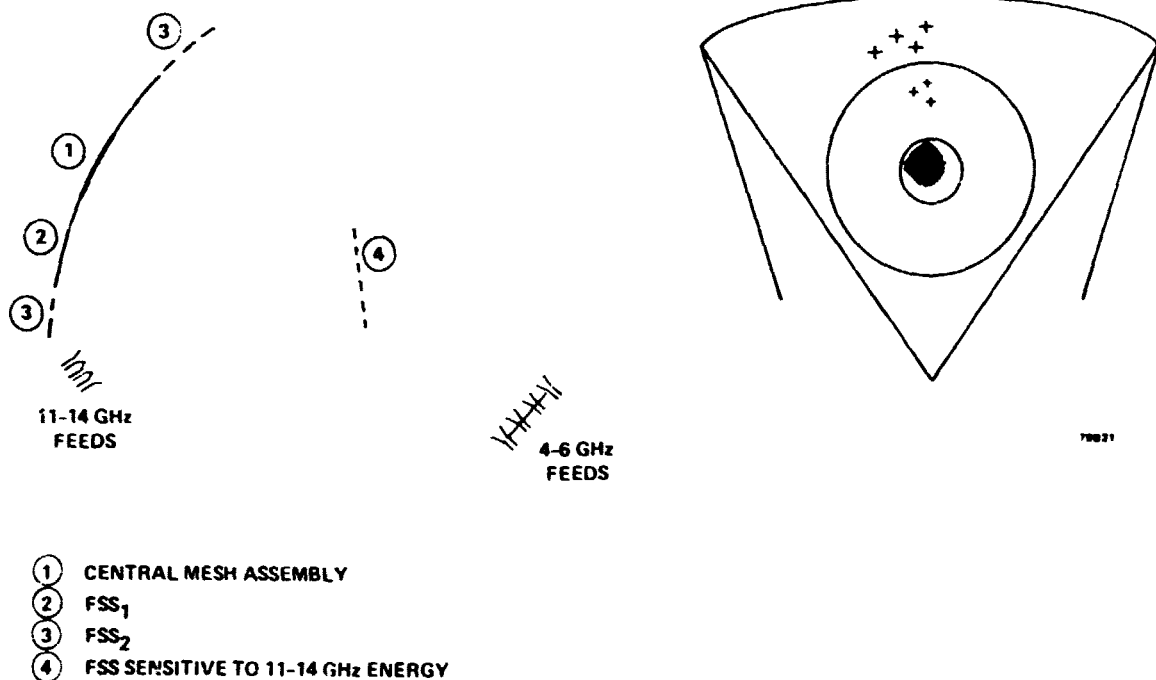
- **INDIVIDUAL OFFSET REFLECTOR EMPLOYS TWO MESH ARRANGEMENTS**
  - **CENTRAL MESH ASSEMBLY HAS GOOD REFLECTION CHARACTERISTICS IN BOTH BANDS; HOWEVER, PROJECTED CIRCULAR APERTURE DIAMETER DESIGNED TO GIVE 0.25° HPBW AT 12.5 GHz**
  - **FSS<sub>1</sub> DESIGNED TO PASS 11-14 GHz ENERGY WHILE REFLECTING 4-6 GHz ENERGY; DIAMETER OF FSS<sub>1</sub> PROJECTED APERTURE DESIGNED TO GIVE 0.25° HPBW AT 5 GHz**
  - **FSS<sub>2</sub> TRANSPARENT TO BOTH 4-6 GHz AND 11-14 GHz ENERGY**
- **11-14 GHz FEEDS LOCATED IN VERTEX REGION OF HOOP/COLUMN SYSTEM; SPLASH PLATE FSS SUBREFLECTOR USED TO ILLUMINATE OFFSET REFLECTOR**
- **4-6 GHz FEEDS LOCATED AT FOCAL POINT OF OFFSET SYSTEM**

4-6 GHz/11-14 GHz SYSTEM

(ADVANCED COMMUNICATIONS)

The mesh system that is used for the two bands of operation can be designed to be frequency sensitive so that portions of the mesh are reflective only at the appropriate design frequencies. As shown in the figure the central region of the C/Ku reflector is highly reflective to both bands while being the correct diameter to produce a 0.25 degree pencil beam at Ku-band. The mesh immediately attached to the central area is composed of frequency sensitive surface (FSS<sub>1</sub>) elements which are resonant (reflective) at C-band only and transparent to Ku-band energy. The immediate surface (supporting surface) surrounding FSS<sub>1</sub> (FSS<sub>2</sub>) is transparent to both C/Ku band energy. The FSS<sub>1</sub> surface and central region correspond to a circular aperture size required to produce a 0.25 degree spot beam in C-band. Since the C/Ku-band feeds cannot occupy the same area, the Ku-band feeds must be placed along the central column out of the focal region of the offset, hence, the requirement for the FSS splash plate.

4-6 GHz/11-14 GHz SYSTEM  
(ADVANCED COMMUNICATIONS)



## PUBLIC SERVICE SATELLITE MISSION

As discussed previously, public service satellite mission scenario data was not as definitive as was advanced communications data. Since advanced communications appeared to be a most difficult mission to accomplish systems wise, it was felt that the same systems description should be applied to the bands of application. Hence, a simple scaling operation was performed on the offset reflectors. The feed array geometry does not change since the required real estate is determined by the area coverage requirement. Therefore, the dimensions shown were chosen on that basis. The 870 MHz system is a very formidable structure; however, it is felt to be an achievable size.

## PUBLIC SERVICE SATELLITE MISSION

- EMPLOY SAME CONFIGURATION AS ADVANCED COMMUNICATION DESIGN
- FREQUENCIES OF INTEREST: 0.87 AND 2.0 GHz
- DIRECTLY SCALE ADVANCED COMMUNICATIONS DESIGN
  - 0.87 GHz : 200 METERS
  - 2.0 GHz : 97 METERS



## LSST MICROWAVE RADIOMETER MISSION

The soil moisture radiometer/advanced crop forecasting study data has shown an extremely large structure (upwards to a 660 meter reflector). Since it is felt that this requires a far term technology commitment, a reduced size radiometer addressing the same mission must be investigated to define a more practical approach for a near term LSST focus mission. Several reduced size concepts were investigated including a low earth orbit configuration requiring reboost. The reboost geometry is interesting, but the propellant required to occasionally reboost is excessive. The non reboost geometry still involves large structural components, which places this LSST mission in the far term application category.

# LSST MICROWAVE RADIOMETER MISSION

- FURTHER SYSTEM DEFINITION REQUIRED BY ADDITIONAL TRADE STUDIES
- POTENTIAL MISSION REDUCTION TRADE-OFF ANALYSES ONGOING
- CURRENT CONCEPTUAL CONFIGURATIONS TEND TO PLACE THIS MISSION IN THE LSST FAR TERM APPLICATIONS CATEGORY
  - REDUCED SIZE RADIOMETER EXTREMELY DIFFICULT
    - CENTRAL COLUMN LENGTH      400 METERS
    - FEED ARRAY LENGTH            100 METERS
  - REBOOST CONFIGURATION INVOLVES EXCESSIVE PROPELLANT

## PROPOSED RADIO ASTRONOMY (VLBI)

The orbiting very long baseline interferometer reflector system requirements were investigated and a Cassegrain antenna system was suggested. The specifics of the reflector and subreflector shaping were not addressed, but gross parameters of the system were defined. It is felt that very specific aspects of the systems' design can be defined at a later point since major antenna performance dependence is defined by the separation distances of the antennas on the baseline. Other antenna characteristics which should be considered early in the program are receiver front ends, feeds and the associated cryogenics. An important systems aspect which should not be overlooked is the beam squint compensation problem which can be solved by employing a pointable subreflector. Actual implementation of this compensating means has not been defined; however, illustrations of proposed mechanisms shall be shown later.

## PROPOSED RADIO ASTRONOMY (VLBI)

- INITIAL STUDIES INDICATE THAT A 30-METER CASSEGRAIN SYSTEM WILL SERVE VLBI NEEDS
  - $F/D = 0.7$
  - ~3-METER SUBREFLECTOR
- FREQUENCY BANDS OF INTEREST: 1.4, 2.3, 5.0, 7.9, 11, 15, 22 GHz
- SINGLE BEAM PER FREQUENCY
- FEED ARRAY CONSISTING OF CIRCULAR ARRAY OF SCALAR HORNS
- FEED ARRAY/SUBREFLECTOR SYSTEM COMMONLY SUPPORTED BY CENTRAL MAST IN HOOP/COLUMN CONFIGURATION
- POINTABLE SUBREFLECTOR COMPENSATION FOR SQUINTED BEAMS

## LSST ANTENNA REQUIREMENTS BASED ON MISSIONS

To this point in the LSST program the following data has been compiled, outlining clearly defined antenna configurations. Parameters for each antenna including surface accuracy and gain have been included. Work is still being done in the radiometry area and as acceptable mission scenario reductions are done to allow for a more realistic near term design, this will be presented. However, to the date of this publication those mission reductions have not been forthcoming. It is clear that for such large structures, for cost amortization, the system must remain operational for at least a 20 year period. This is felt to be a realistic and achievable goal from a structural lifetime standpoint.

## LSST ANTENNA REQUIREMENTS BASED ON MISSIONS

MISSION PARAMETER	COMMUNICATIONS				RADIO ASTRONOMY (VLBI)
	ADVANCED		PSS		
FREQUENCY (GHz)	4-6	11-14	0.87	2.0	1.4-22
REFLECTOR DIAMETER (METERS)	55	55	200	97	30
F/D	2	2	2	2	0.7
SURFACE ACCURACY	$\lambda/50$	$\lambda/50$	$\lambda/50$	$\lambda/50$	$\lambda/30$
GAIN (dB)	60.3	60.3	60.3	60.3	52.6-76.0
BEAM NUMBER	219	219	219	219	1/FREQ
BEAM ISOLATION (dB)	-30	-30	-30	-30	N/A
LIFE TIME (YEARS)	>20	>20	>20	>20	>20

## **MAJOR ELEMENTS - AREAS OF CONCENTRATION**

During the period involving the study of the mission scenarios and configuration definition, design activities continued in parallel on non-mission dependent elements. The major elements are listed below.

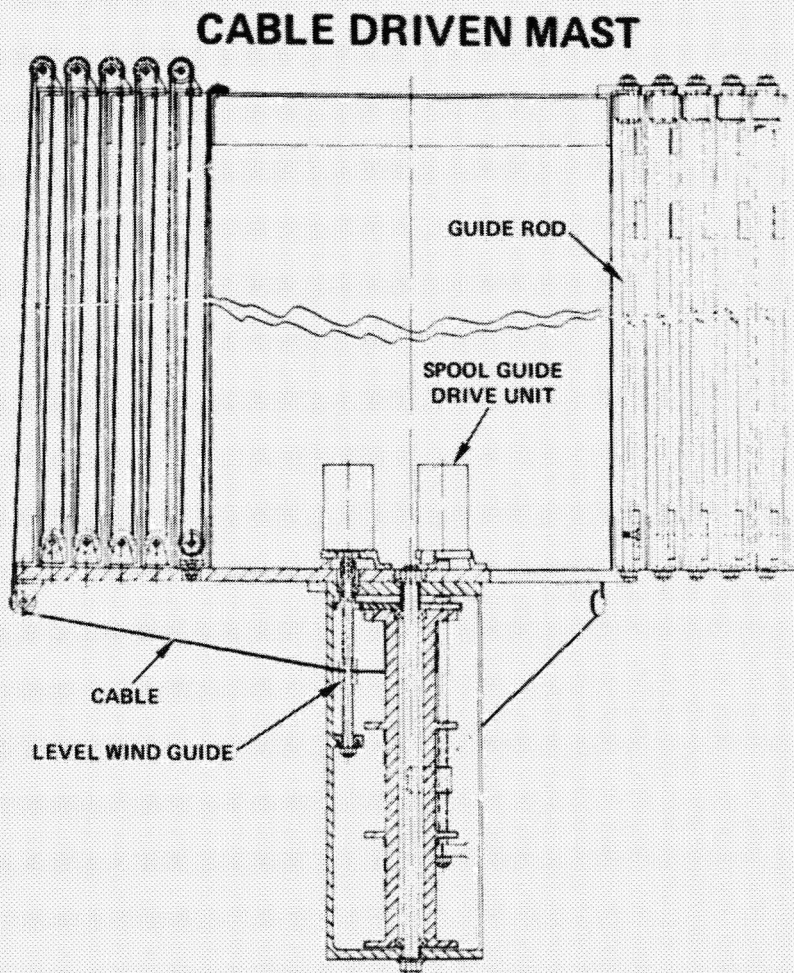
# **MAJOR ELEMENTS AREAS OF CONCENTRATION**

- TELESCOPING MAST
- HOOP
- CONTROL SYSTEM

## CABLE DRIVEN MAST

One mast design which was pursued is the cable driven mast. This concept is a variation on several state-of-the-art designs presently being utilized as high-lift personnel platforms. The figure below depicts a mast cross section which is typical 3 places around the central axis. The basic design consists of multiple shells nested inside each other. Attached to the flange of each section is a pulley. A cable is fastened to the inner-most section and routed over pulleys on the upper and lower flanges of adjacent sections. The opposite end is routed through a level wind device and terminated on a spool.

Three drive motors are provided for redundancy. Each motor is connected to a level wind drive screw and the main take-up spool by means of gears. As the cable is wound on to the spool, the mast sections are driven outward until latching of each section is accomplished. The reverse cycle (retracting) is accomplished by means of a single cable (not shown) attached to the inner-most section. By pulling this cable, unlatching of the 1st section takes place and it is retracted. Each section is unlatched by the motion of adjacent inner sections.

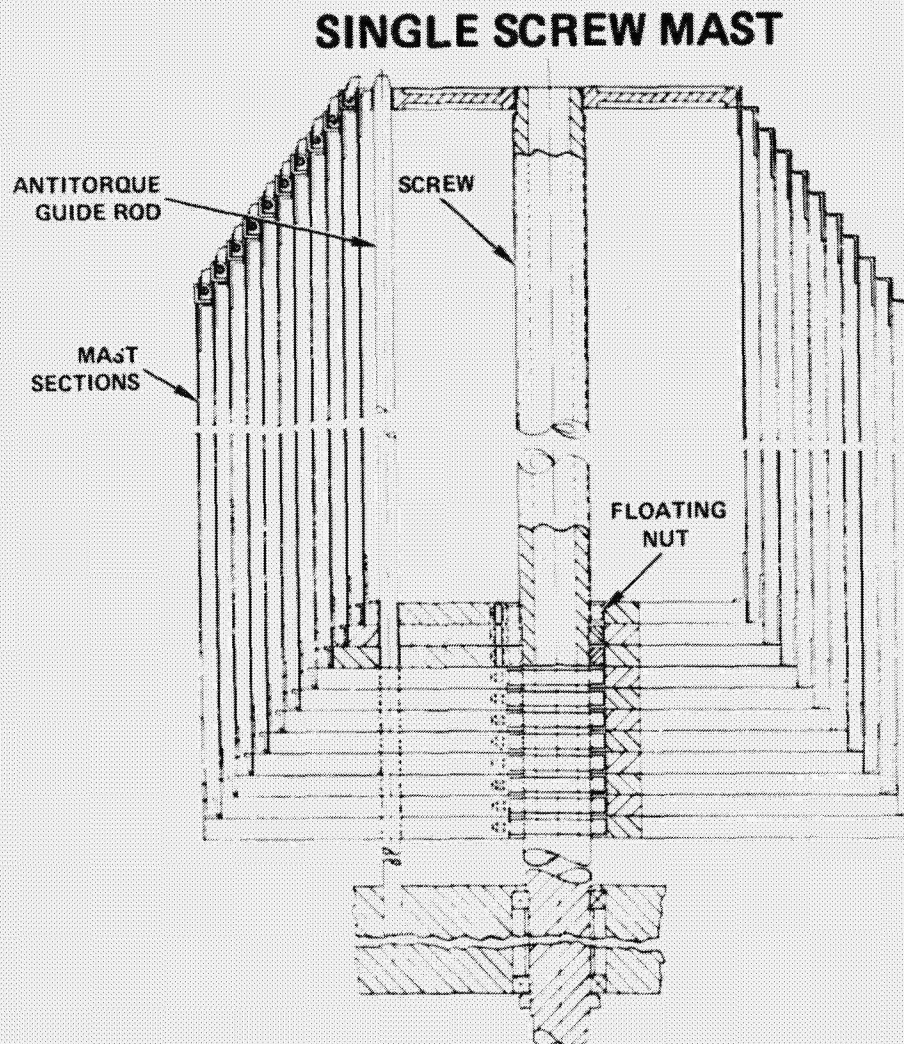




## SINGLE SCREW MAST

A second mast configuration under study is the single screw mast concept. Deployment is accomplished by a jack-screw type mechanism. The telescoping shell members are nested inside each other when stowed. The inner-most section has a nut element which is engaged on the threaded portion of the single screw along the central axis. All these sections have floating nuts which are not engaged on the threaded portion of the screw. As the screw is rotated, the inner section translates outward. Three guide rods provide alignment and rotational restraint for each section. When the inner section contacts the upper flange of the adjacent section, it forces that section to translate upward also. This motion causes the floating nut of the second section to engage on the threaded portion of the screw.

The floating nut is required to ensure the thread lead of the screw mates properly and causes no binding or jam nut type action. The cycle continues in the same manner for all subsequent sections.

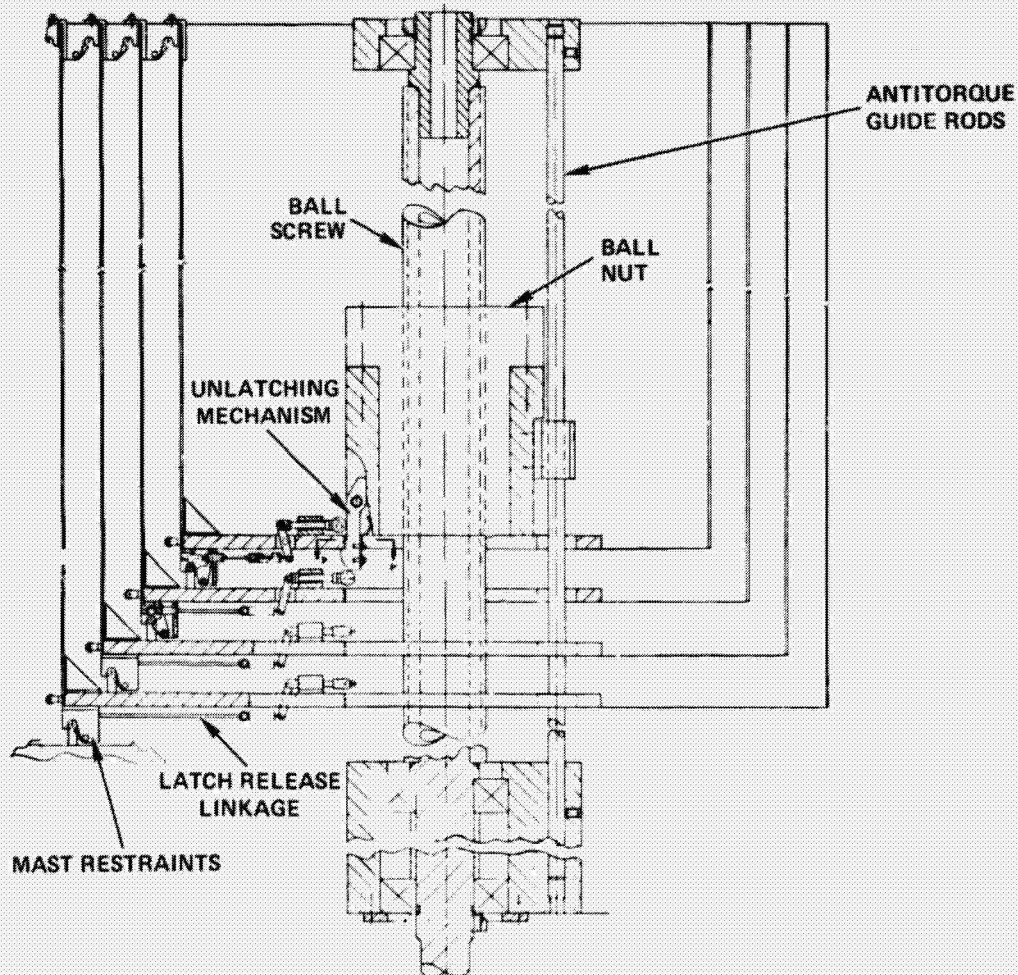


### SINGLE REVERSIBLE BALLSCREW MAST

The third mast concept described here is similar to the single screw mast. It differs in the fact that a single nut element is used to drive all sections. As in all the concepts, the mast sections are nested inside each other when stowed. Deployment takes place by rotating the screw which in turn causes the nut to translate. The nut contains a mechanism which unlatches all sections, plus a hook element that captures the base of each section and provides a means to drive the sections outward.

When the first section nears the end of its travel, it latches with the upper flange of the adjacent section. When latching is complete, the drive unit reverses direction causing the nut element to return down the screw until it unlatches the second section and engages its base. The drive unit again reverses direction and drives the second section outward in the same manner as the first section. The sequence is repeated until all sections are deployed.

### SINGLE REVERSIBLE BALL SCREW MAST



## CABLE PULLEY SYNCHRO

The initial work done on hoop development consisted of improving the deployment reliability of the AAFE designed hoop. The approach was taken that if a synchronization method could be incorporated into the design, the overall reliability would be enhanced greatly. The method developed is described below.

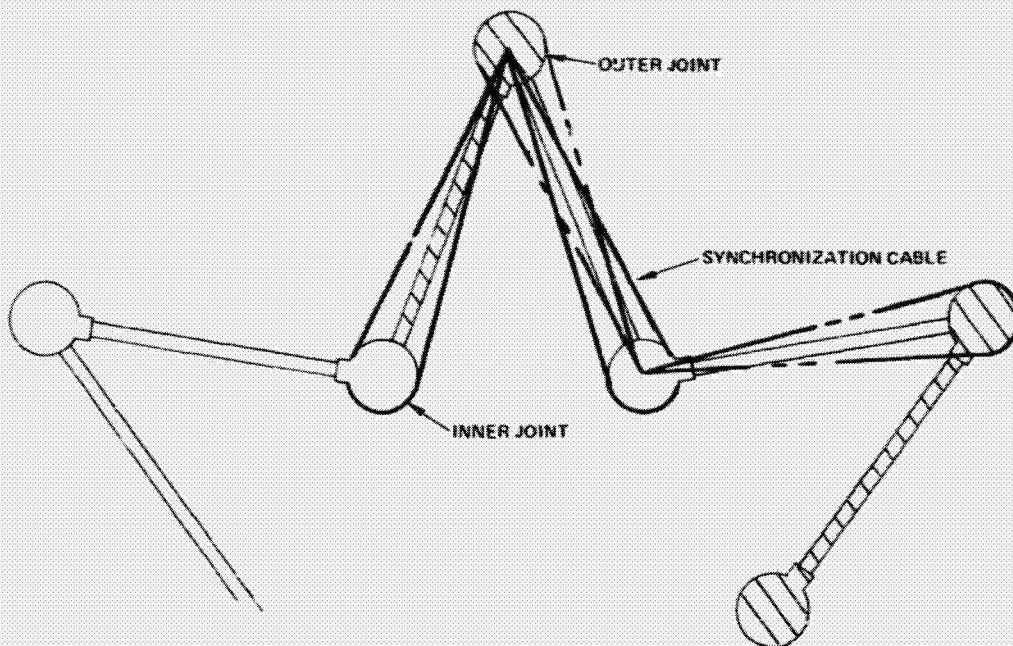
The figure below shows a schematic representation of a portion of the hoop at some intermediate deployment position. Consider the hoop members which are shown cross-hatched.

A pulley is attached to the end of each of these members at the outer joints. A cable is routed over each pulley in a figure "8" pattern with the cross-over point on the center of rotation of the inner joint between the two outer joints shown. The cable is also fixed to each pulley so that sliding is not possible. If the hoop member attached to the left most outer joint under consideration is rotated clockwise about the outer joint, it can be seen that the right most hoop member will be driven counterclockwise by the same amount. In other words the angle formed by one outer joint will always equal the angle formed by the next outer joint. The same method is used to synchronize the inner joints.

The basic premise of this method of synchronization is that if all outer joints form equal angles and all inner joints form equal angles, then a regular polygonal shape must be described at any point in the deployment. The regular shape implies synchronization.

## CABLE/PULLEY SYNCHRO

ALL INNER JOINTS FORM EQUAL ANGLES AND  
ALL OUTER JOINTS FORM EQUAL ANGLES  
THEREFORE: THE PLANAR FIGURE MUST FORM A  
REGULAR POLYGON

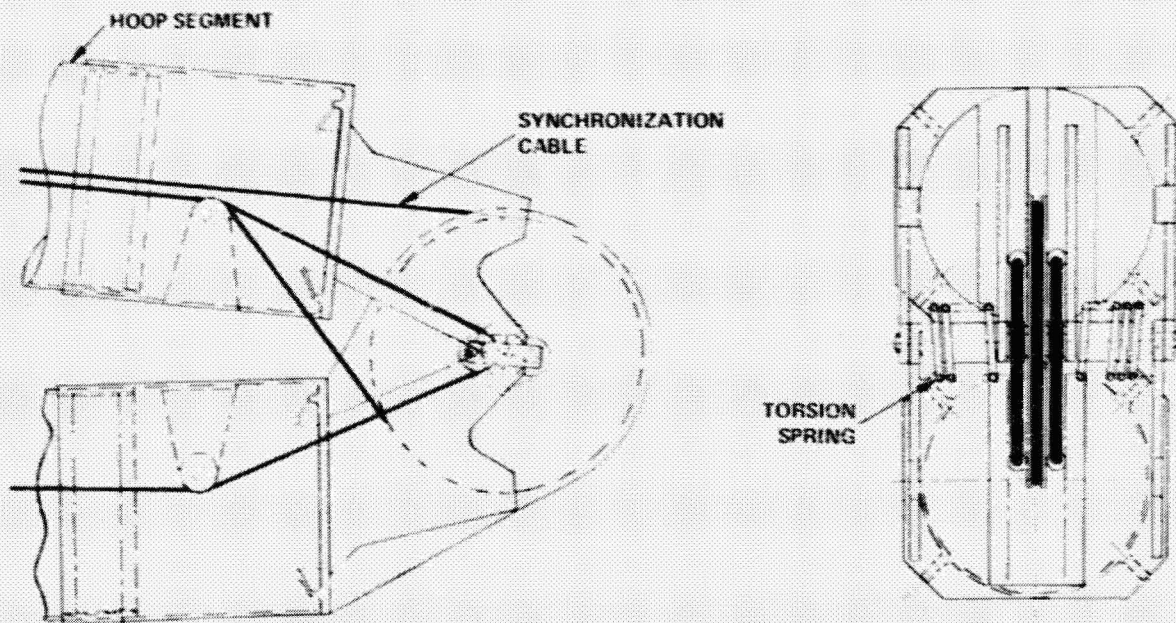




## MODIFIED AAFE HOOP

This figure shows a detailed layout of a single hoop joint with the synchronization method just described included.

### MODIFIED AAFE HOOP HINGE JOINT

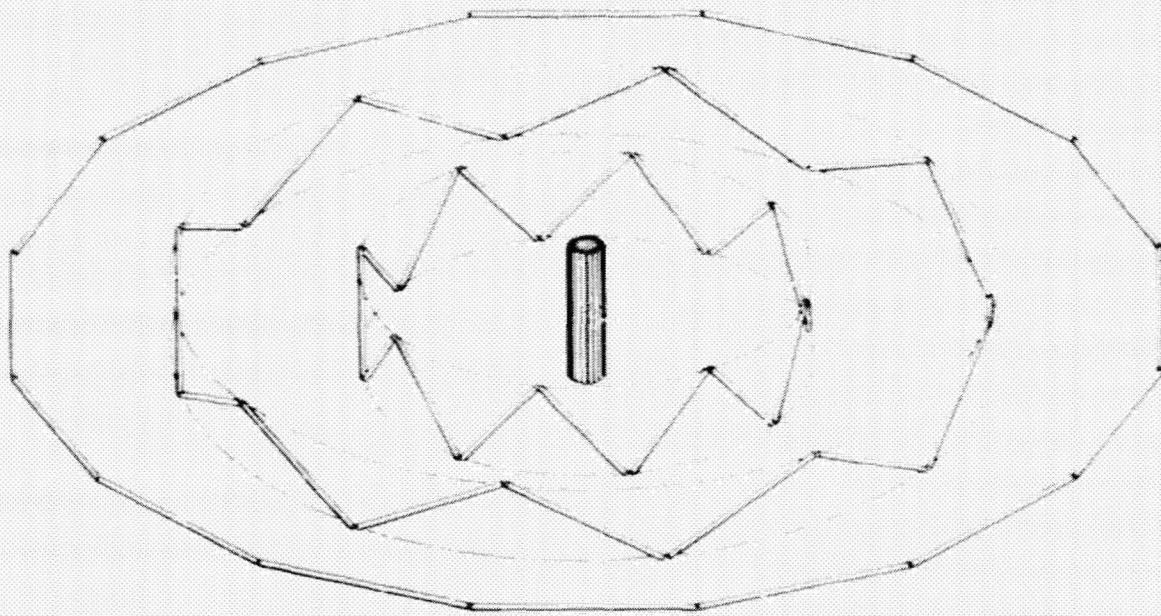


### SINGLE STAGE HOOP DEPLOYMENT SEQUENCE

Another hoop concept was developed on this program in an attempt to simplify the deployment and hence control system requirements of the hoop. The deployment sequence of this concept is shown in the figure below. The approach developed utilizes a double hinge at each joint which permits rotation without any torsional wrap-up in the hoop members. The single stage deployment refers to the motion of the hoop throughout its deployment. The joints of the hoop describe a right circular cylinder at all stages of deployment. The individual hoop segments simply rotate from vertical to horizontal about an axis through the center of each member. These axes are radial lines forming a plane normal to the axis of the mast.

Advantages of this hoop deployment method include control system simplification, good mesh handling characteristics, and no toggling action as the hoop completes its deployment.

### SINGLE STAGE HOOP DEPLOYMENT SEQUENCE

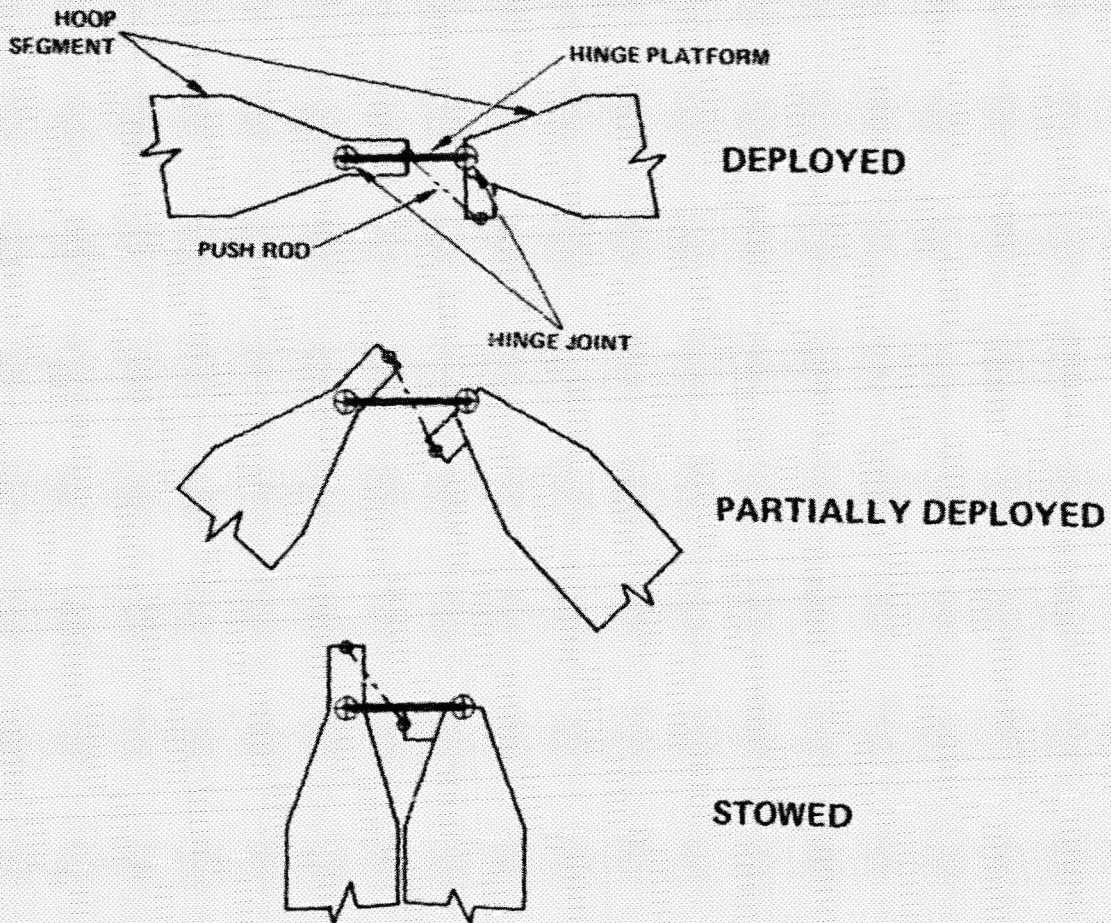




### SINGLE STAGE HOOP

This figure shows a schematic of the joint required for the single stage hoop and how one member is coupled to another in different stages of deployment. The hinge platform supports the two hinge points required of this concept. Each hinge axis is along a radial line through the center of the mast and in a plane normal to the mast central axis. Uniform motion is achieved by means of a pushrod connected to offset attach points. Synchronization of this hoop is realized by keeping all hinge platforms parallel during deployment. This occurs by means of strips or cables (not shown) connecting one platform to the next. The system works similarly to a pantograph.

### SINGLE STAGE HOOP

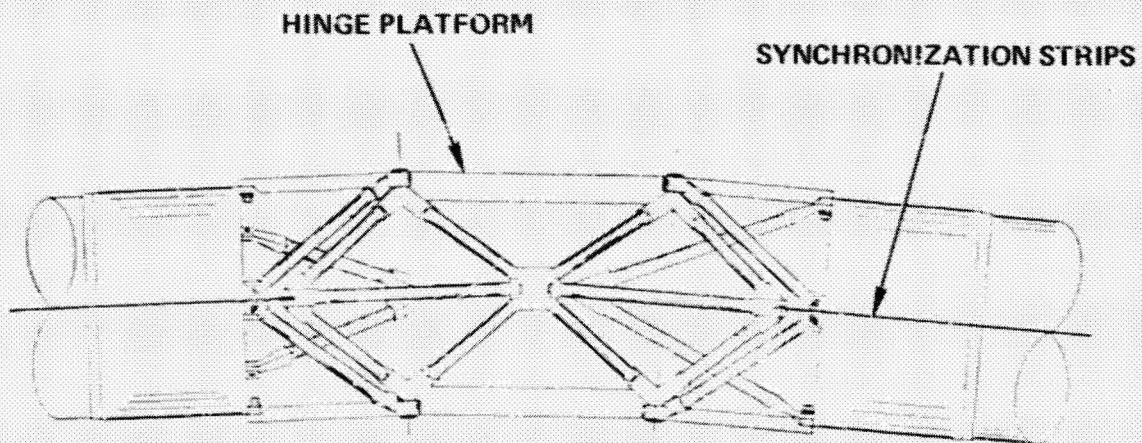


## SINGLE STAGE HOOP

### PLAN VIEW

This figure and the next figure show detailed layouts of the actual hinge joint. The hinge platform is a truss structure which exhibits high efficiency from a strength and stiffness to weight standpoint. The tubular hoop segments are terminated with bonded fittings which transition from a tubular section to a truss section which mates with the hinge platform.

## SINGLE STAGE HOOP – PLAN VIEW



MOTOR NOT SHOWN FOR CLARITY



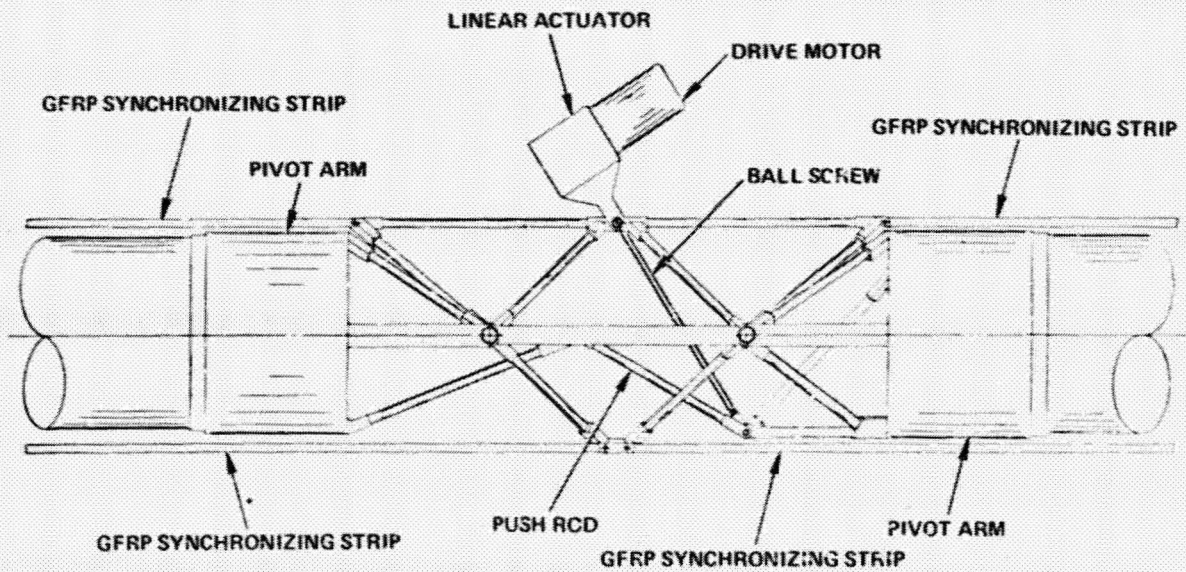
## SINGLE STAGE HOOP

### SIDE VIEW

This figure shows the joint previously described from a side view. The pushrod is visible in this view and can be seen connecting the adjacent hoop segments. The synchronization strips can also be seen attaching to the hinge platform. Also described in this figure is a method for driving the hoop. A linear actuator is used to drive one section which in turn drives the adjacent section.

## SINGLE STAGE HOOP – SIDE VIEW

### DEPLOYED POSITION

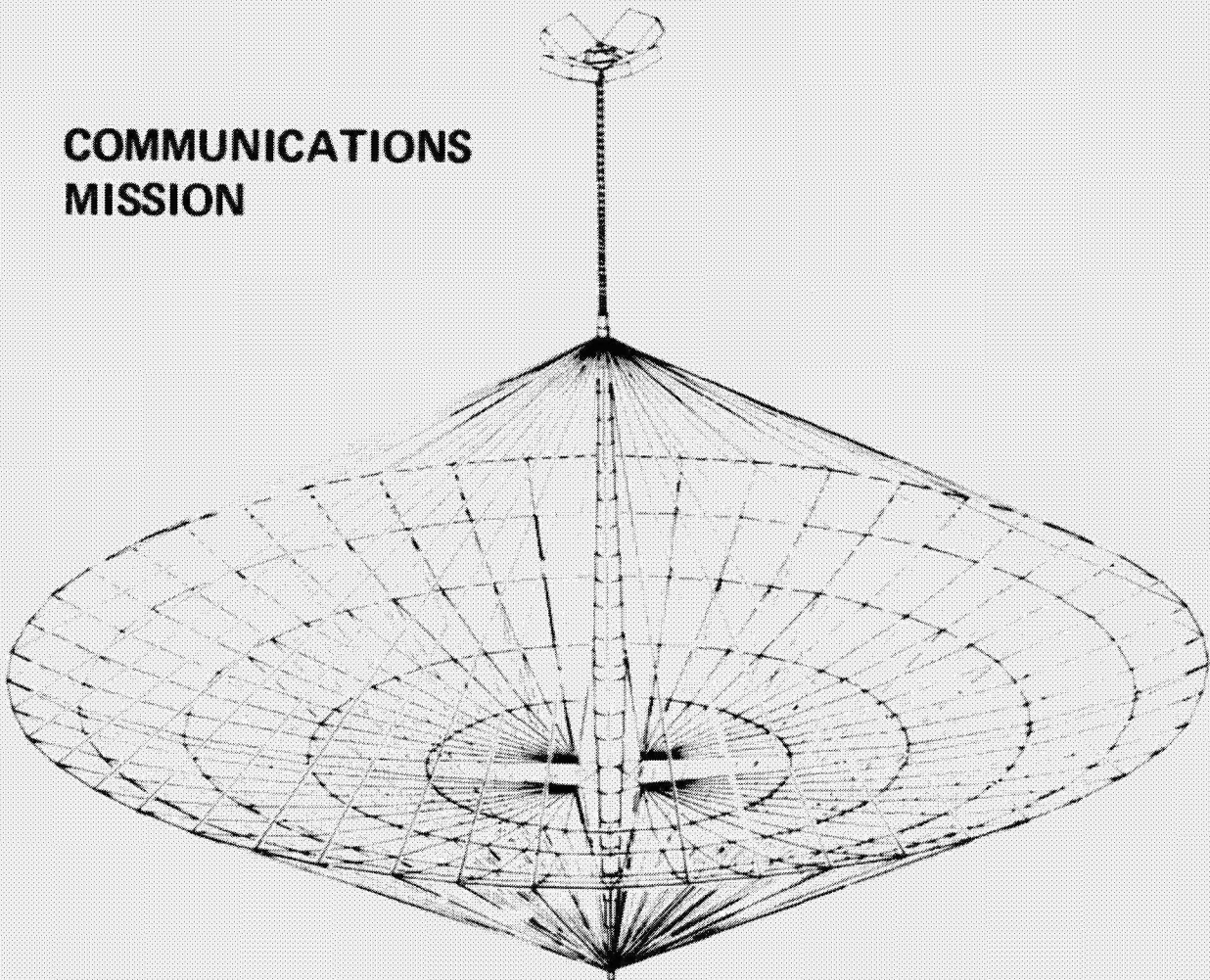


## COMMUNICATIONS MISSION

Configuration studies previously described have established the requirements for various Hoop/Column configurations which meet the focus mission applications. The first configuration described is for the communications mission.

The figure shows an isometric representation of the Quad Aperture approach. Four individual regions of the reflector are formed in an offset configuration. A separate offset feed array illuminates each cusp or quadrant of the reflector. The mast shown utilizes a telescoping concept for the primary structural member and an Astromast, manufactured by ASTRO Research Corporation, for the feed support.

## COMMUNICATIONS MISSION

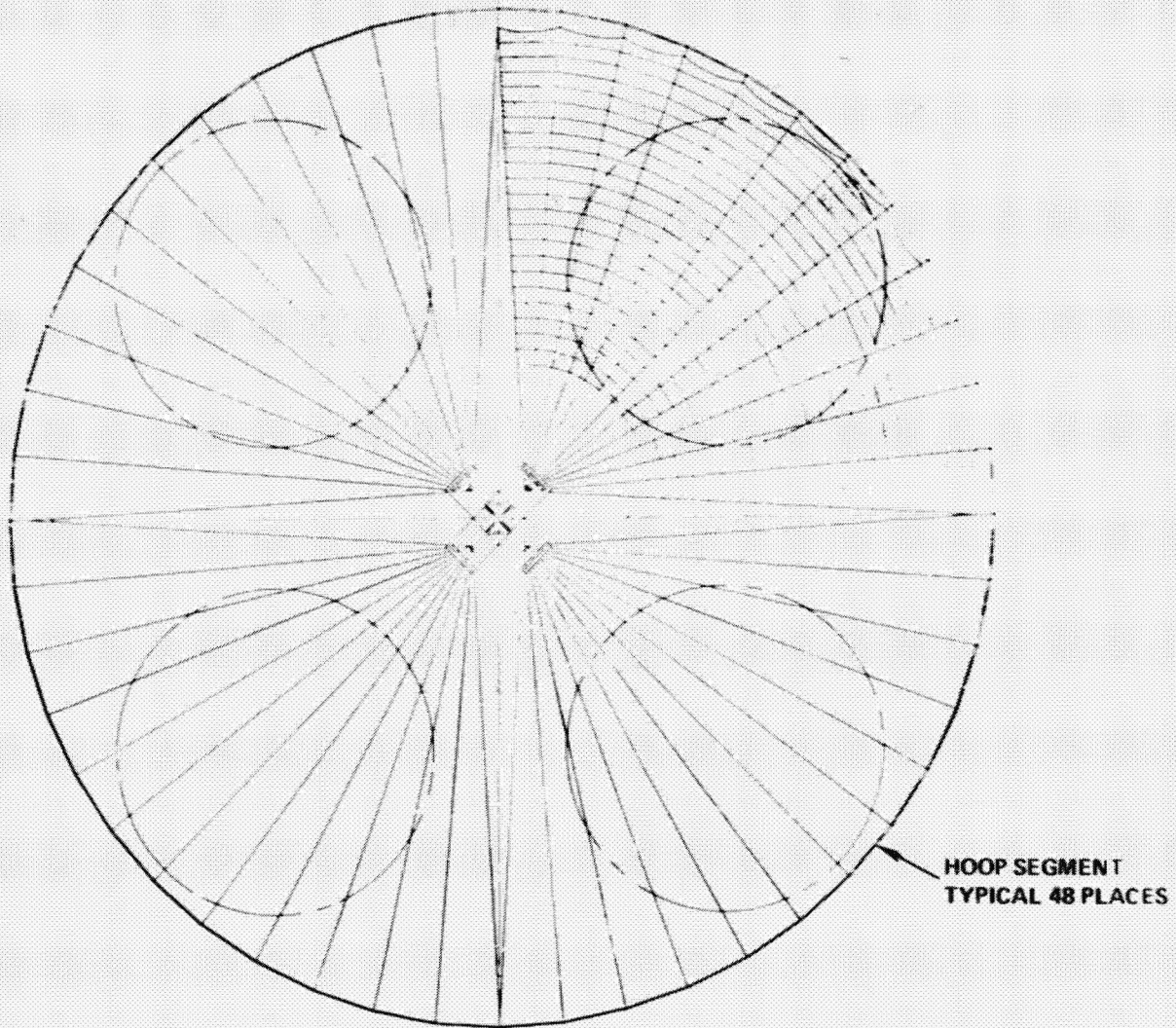




COMMUNICATIONS MISSION DEPLOYED

This figure shows a top view of the deployed antenna. The circular areas represent the individual feed array illumination areas on each quadrant.

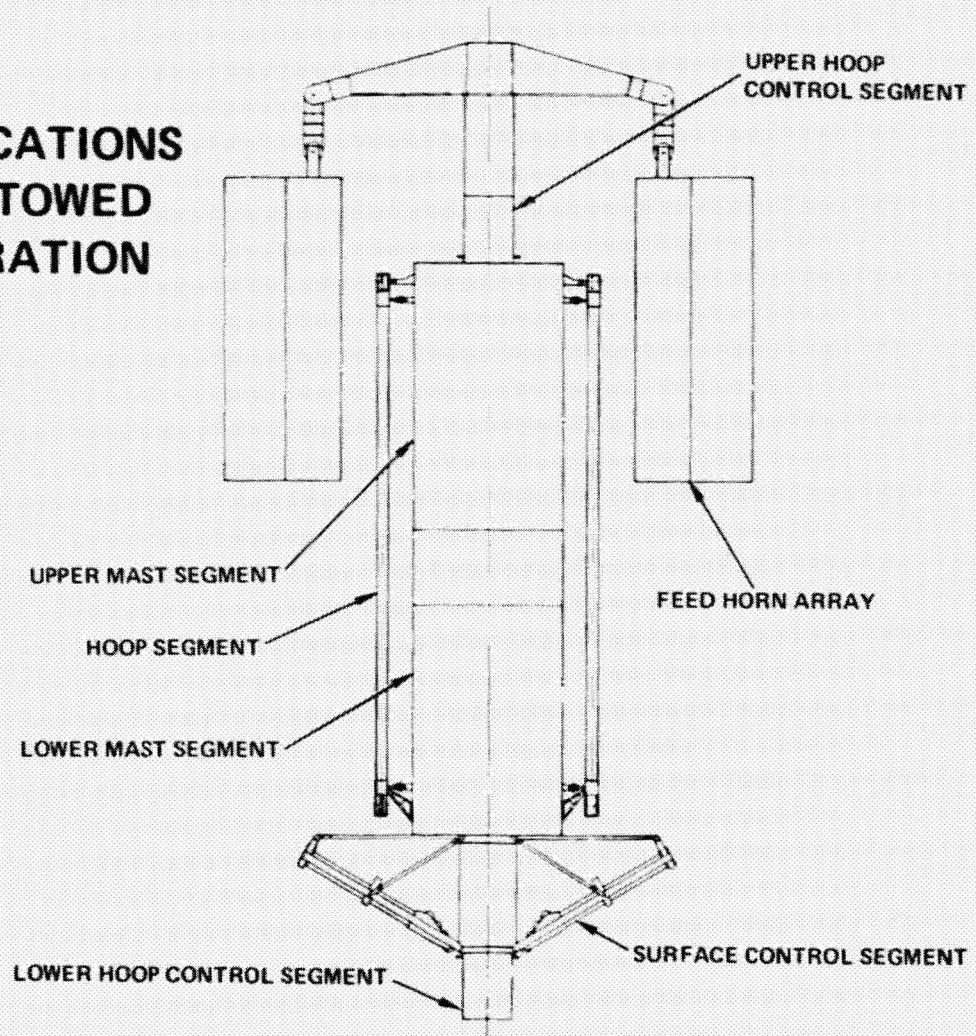
**COMMUNICATIONS MISSION DEPLOYED**



### COMMUNICATIONS MISSION STOWED

This figure shows a representation of the basic stowed configuration. The feed arrays are attached to a supporting beam by 5-axis gimbals. These gimbals provide all adjustment capabilities necessary to align all R.F. beams after deployment. The lower end of the configuration shows a mechanism which permits the required offset attach point for the surface control stringers.

### COMMUNICATIONS MISSION STOWED CONFIGURATION

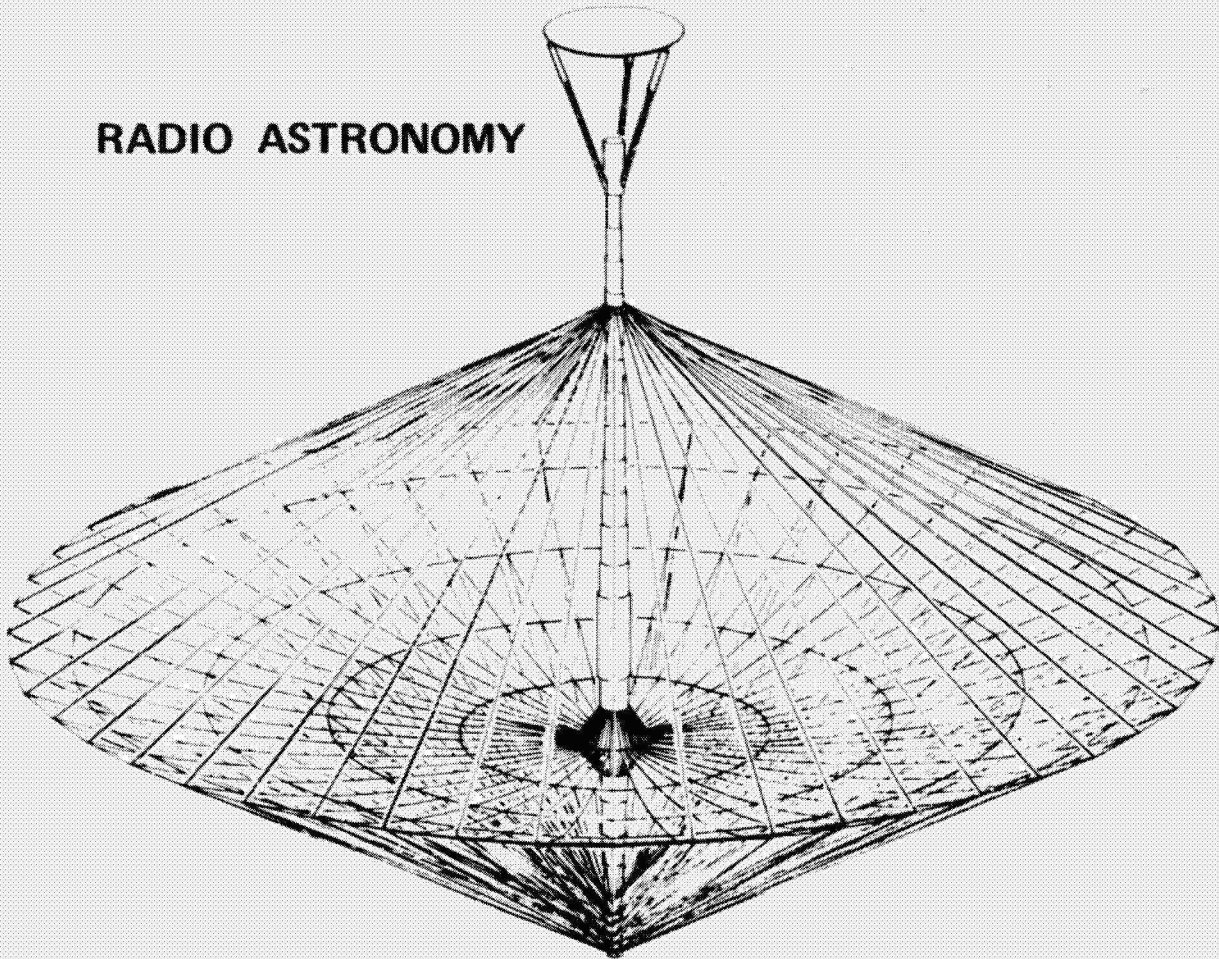




## RADIO ASTRONOMY

A second mission for which the Hoop/Column concept was configured is Radio Astronomy. This approach utilizes a symmetrical reflector and a multi-horn Cassegrain system. The subreflector is supported by extendable Astromasts, manufactured by ASTRO Research Corporation, in a tripod arrangement. This permits pointing of the subreflector as well as axial defocusing adjustments. The antenna is sized at 30 meters in diameter.

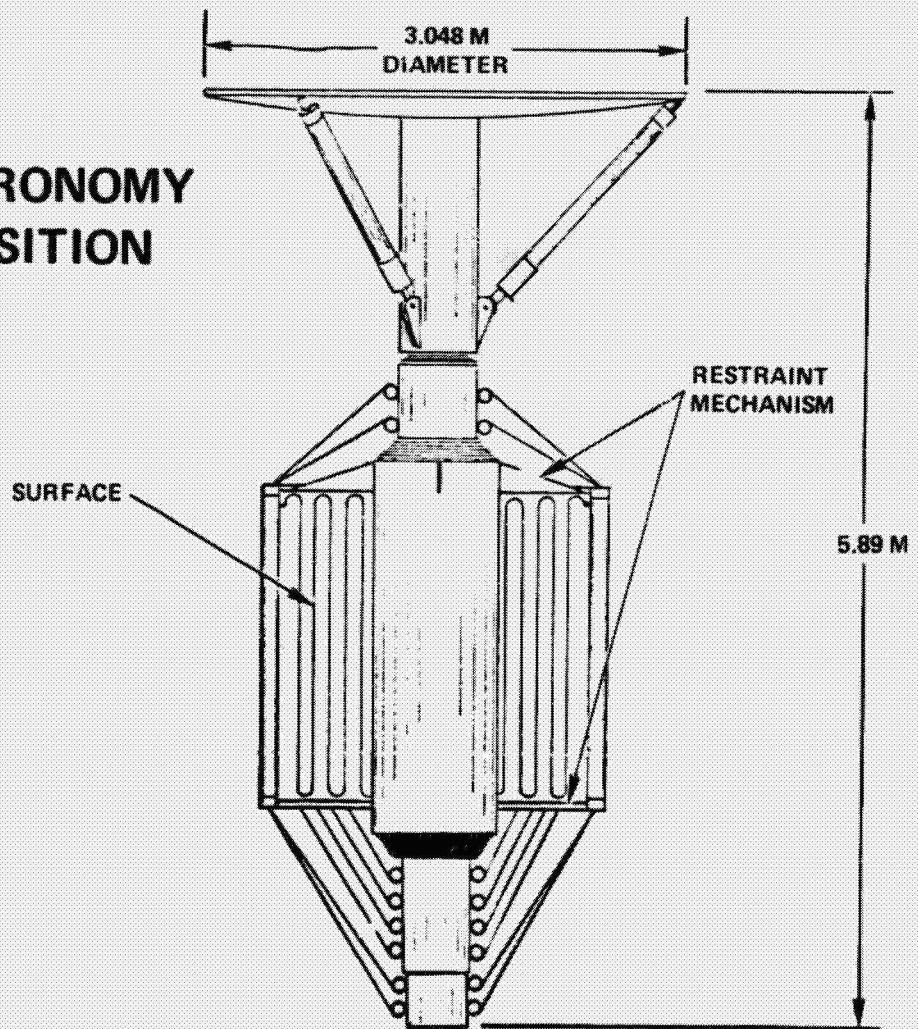
## RADIO ASTRONOMY



### RADIO ASTRONOMY STOWED

The figure below depicts the antenna configuration in the stowed position. The solid subreflector is the driving constraint on stowed diameter. The stowed package is readily accommodated by the shuttle cargo bay.

### RADIO ASTRONOMY STOWED POSITION



## TASK 2 MATERIALS DEVELOPMENT

This task is the only other task initiated to date. The entire task funding is directed toward development of cable technology. The applications of this technology reach well beyond the Hoop/Column antenna to many of the proposed large space structures using cable tensioned structural elements.

## TASK 2

## MATERIALS DEVELOPMENT – CABLE TECHNOLOGY

## TASK 2 OBJECTIVES

This development activity is tailored toward the specific environmental requirements of earth orbits. Detailed requirements must be defined in order to limit the scope of the task toward particular applications. A review of available data is required to provide background information and clues to what approaches appear feasible or worth pursuing.

Basic material candidates will be generated and samples fabricated in various configurations. Material properties data will be developed through a number of tests. Finally, a cable configuration will be selected and its properties used in the analytical models of task 1 which are used for performance projections.

# OBJECTIVES

- DEFINE CABLE REQUIREMENTS, STRUCTURAL, THERMAL, ENVIRONMENTAL
- PERFORM DATA RESEARCH
- EVALUATE CANDIDATE MATERIALS AND CONFIGURATIONS
- FABRICATE SAMPLES OF SELECTED CABLE MATERIAL/CONFIGURATION COMBINATIONS
- DETERMINE MATERIAL PROPERTIES OF SELECT CONFIGURATIONS VIA APPROPRIATE TESTS
- PROVIDE DESIGN DATA AS INPUT TO TASK 1 ANALYSIS

## FIRST YEAR OBJECTIVES AND STATUS

The joint NASA/HARRIS objectives and milestones for the first year of the program are shown below. The status of the activities underway to meet these objectives are also listed.

### FIRST YEAR OBJECTIVES

### STATUS

- DEVELOP REFLECTOR REQUIREMENTS DOCUMENT
- PRELIMINARY POINT DESIGN TO MEET LSST REFLECTOR REQUIREMENTS DOCUMENT
- DESIGN AND PERFORMANCE ANALYSES FOR MAYPOLE HOOP/COLUMN
- DESIGN AND FABRICATE SCALED FEASIBILITY MODELS FOR FOCUS MISSION APPLICATIONS
- DESIGN SURFACE CONTROL BREADBOARD
- MISSION SCENARIOS RECEIVED AND EVALUATED
- TECHNOLOGY DRIVERS IDENTIFIED
- PRELIMINARY DOCUMENT DEVELOPED
- FINAL DOCUMENT COMPLETE, 1980
- ELEMENT CONCEPT DESIGN TRADE STUDY IN PROGRESS
- CONCEPT DESIGNS DEVELOPED FOR FOCUS MISSIONS
- POINT DESIGN SELECTION SCHEDULED THIS MONTH
- POINT DESIGN CONCEPT REVIEW IN FEB, 1980
- TRADE ANALYSES SUPPORTING ELEMENT CONCEPT SELECTION UNDERWAY
- PRELIMINARY PERFORMANCE ANALYSES FOR POINT DESIGN SCHEDULED FOR FEB 1980 COMPLETION
- EXTRAPOLATED PERFORMANCE FOR VARIOUS SIZE REFLECTORS AND FOCUS MISSIONS SCHEDULED FOR MAY, 1980
- TO BE INITIATED UPON ACTIVATION OF THE DEMONSTRATION MODELS TASK
- COMPLETION SCHEDULED FOR FEBRUARY, 1980
- TO BE INITIATED AFTER POINT DESIGN SELECTION
- COMPLETION SCHEDULED FOR MAY, 1980

#### REFERENCES

1. Campbell, T.G.; and DiBattista, J.: Focus Mission Scenarios for Communications, Radiometer and Radio Astronomy—LSST Technology Requirements Definition, NASA Langley Research Center, May 1979.
2. Ruze, J.: Lateral-Feed Displacement in a Paraboloid, IEEE Transactions on Antennas and Propagation, September 1965.