

FREE-FLYING SOLAR REFLECTOR SPACECRAFT

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Large Space Systems Technology - 1980
Second Annual Technical Review
November 18-20, 1980

BASELINE CONFIGURATION OF A SOLAR REFLECTING SATELLITE

Since 1978, Astro has been working for NASA LaRC on "Design Requirements for Large Space Structures." Some results have been reported in refs. 1 and 2. Other results are being published. Some will be presented at the forthcoming AIAA Second Conference on Large Space Platforms in February 1981. The present paper gives results of investigations of requirements and design concepts for large solar-reflecting spacecraft. The emphasis is on the 1-kilometer-diameter self-contained spacecraft that can be packaged and launched in the Space Shuttle shown in Figure 1.

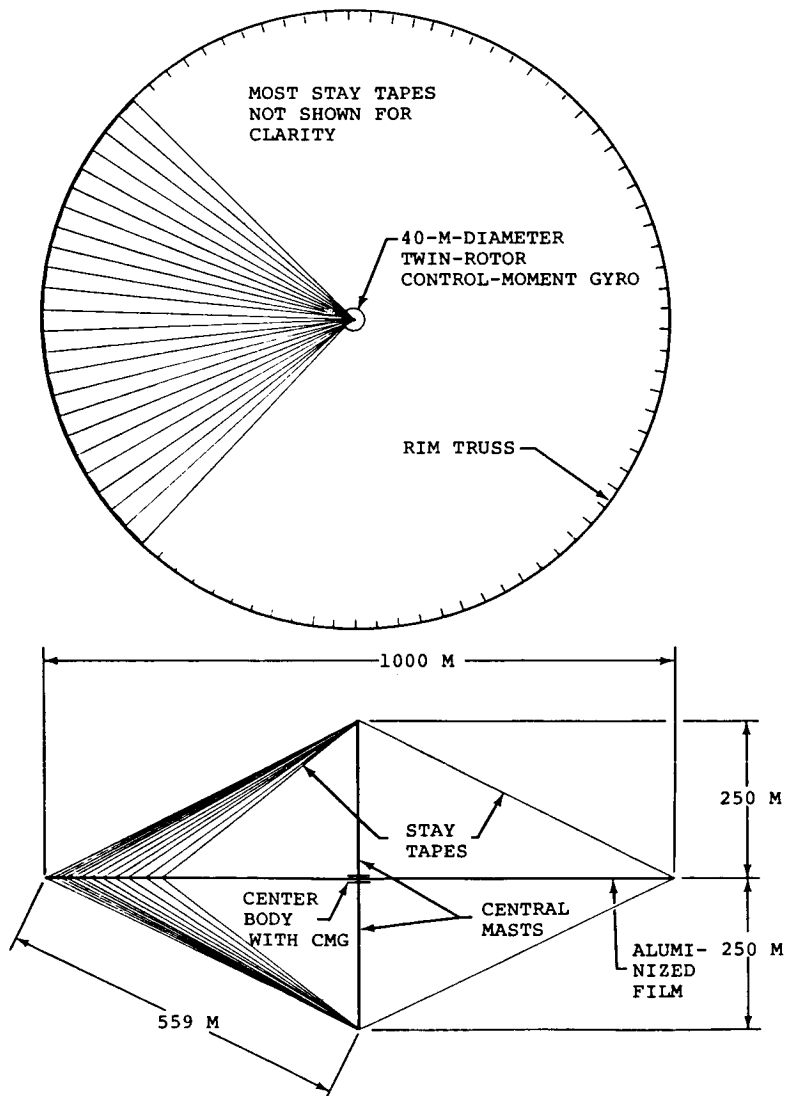


Figure 1.

CIRCULAR SOLAR-REFLECTING SATELLITE

The structure of the spacecraft is similar to that previously reported in ref. 3. Some details are shown on figure 2. The configuration consists of a compression rim stabilized by stays coming from each end of the central compression hub. The stays are stowed on reels on the ends of the hub. The hub consists of two Astromasts which are deployed after launch. The reflector membrane is a 2-micron-thick Kapton film with a vapor-deposited aluminum coating. With seams and joints, the average weight of the film is 4 g/m^2 . The feasibility of this type of film was demonstrated in 1977 during work on solar sailers. Note that expansion compensators will be needed at the attachment between the film (which is assumed to have a dimensional stability of ± 0.5 percent) and the relatively stable graphite/epoxy rim structure.

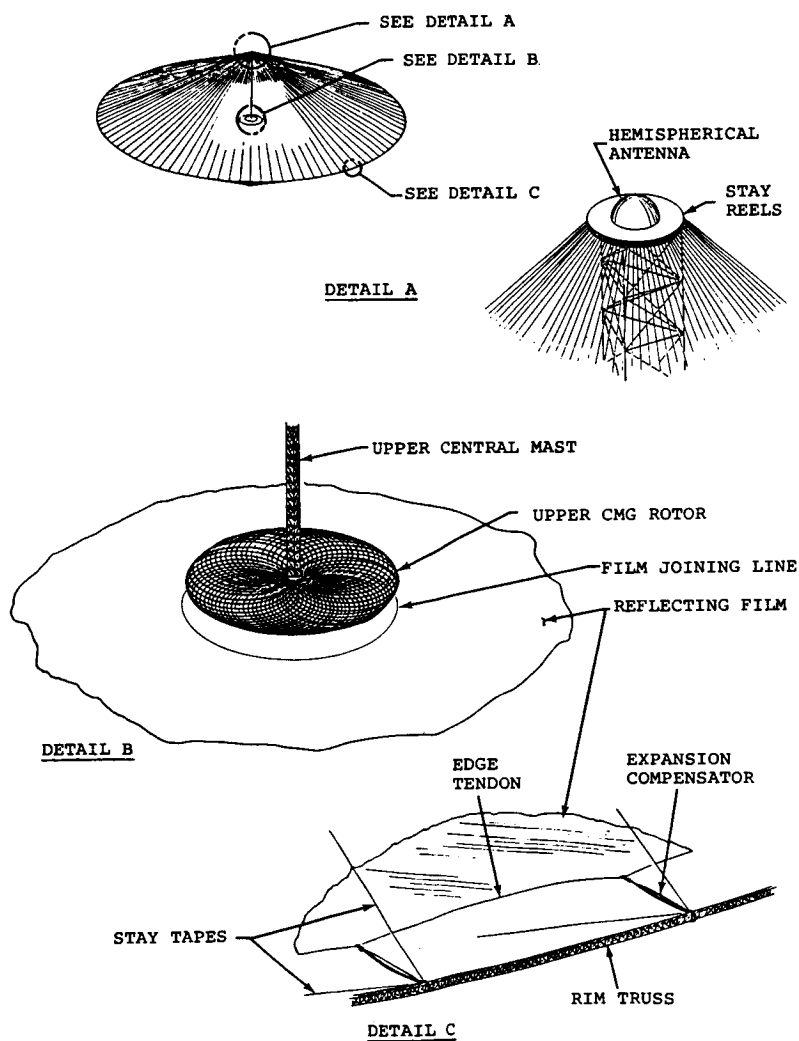


Figure 2.

CLOSEUP OF CENTER BODY SHOWING TWIN-ROTOR CONTROL-MOMENT GYRO

The "muscle" for the attitude control system is a pair of counter-rotating control-moment gyros with deployable flywheels. The requirements for control capability are obtained for the SOLARES mission in which the satellite is rotated so as to reflect the sunlight to a fixed point on the Earth as it passes near it. The torques and angular impulses required are large enough that exorbitant masses would be needed if the flywheels were small enough to be contained within the Shuttle. Hence, deployable flywheels are necessary. Even with the large diameter available with deployable flywheels, the electrical power required to accelerate the flywheels used as momentum wheels is unacceptably large. Hence, the control-moment-gyro approach was selected and is schematically shown in figure 3.

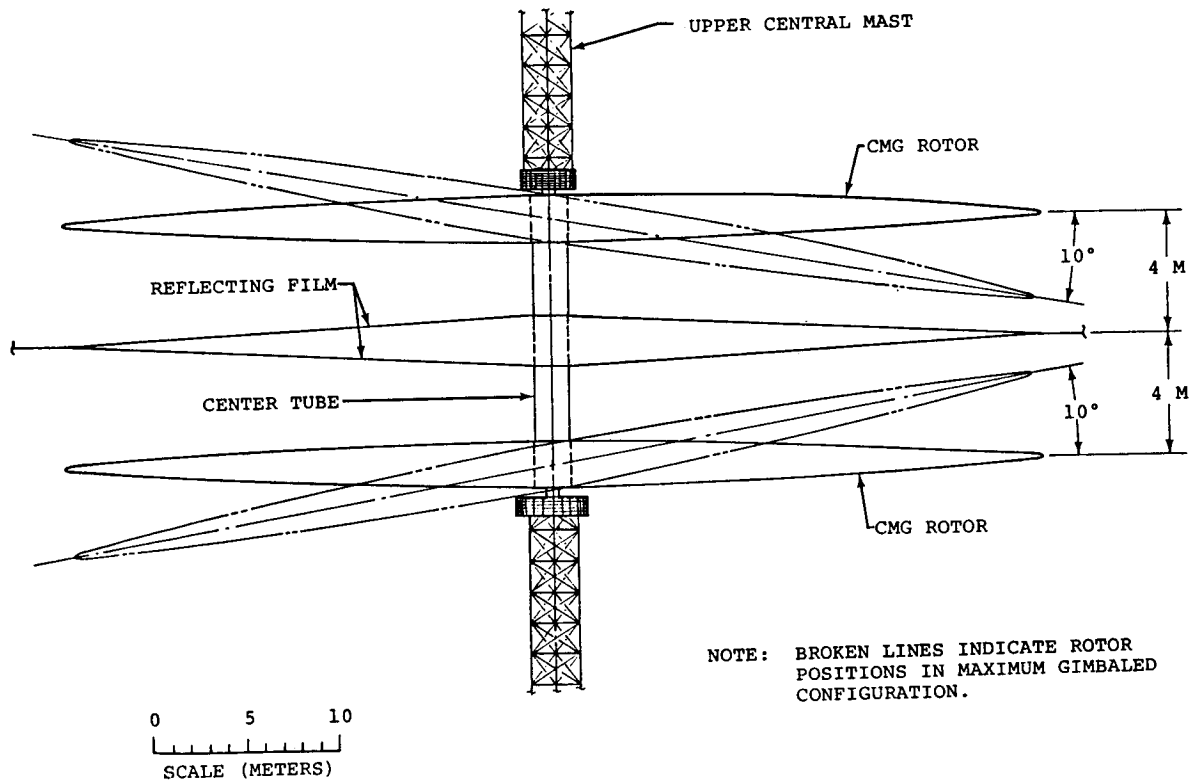


Figure 3.

DEPLOYABLE FILAMENTARY FLYWHEEL FOR CONTROL-MOMENT GYRO

Deployable flywheels were studied over 10 years ago and reported in ref. 4. They are composed of many filaments in the pattern shown in figure 4. This pattern is basically selected to put the filaments in a state of uniform tension. Note that a typical filament runs from one end of the hub out to the rim and then to the other end of the hub. The resulting wheel should have sufficient depth to ensure that it behaves essentially as a rigid body. Clearly, further work needs to be done on these types of control devices.

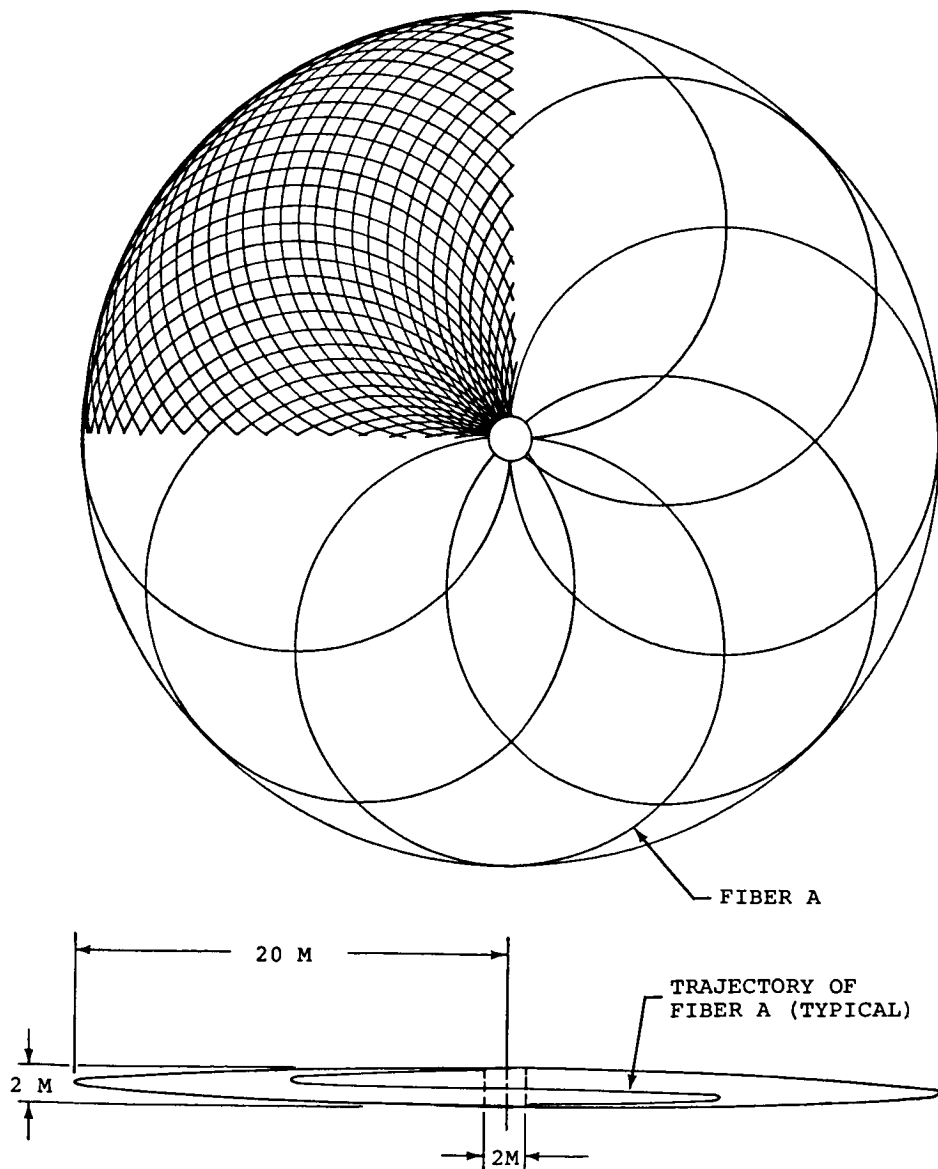


Figure 4.

MASS SUMMARY FOR BASELINE
1-KILOMETER-DIAMETER REFLECTOR SATELLITE
(flight condition)

A mass breakdown for the 1-kilometer-diameter satellite is shown in figure 5. Note that the mass of the reflector membrane which we consider to be the payload is slightly more than 3000 kg. An objective of the study was to determine whether the mass of the supporting structure could be made as light as that. In the earlier results (ref. 3), the structural mass was only about 2800 kg. Attention in the current study to the packaging and deployment requirements resulted in an increase of the structural mass to almost 3400 kg. As can be seen, the mass of the control system including a low torque electromagnetic loop system for desaturating the control-moment gyros and controlling orientation about the axis of symmetry is about 2400 kg. Including reasonable masses for other support systems, the total unit mass of the spacecraft is less than 12 g/m², well into the ultralightweight range.

<u>ITEM</u>	<u>MASS (KG)</u>	
<u>STRUCTURAL COMPONENTS</u>		
EDGE TENDONS (90)	12	
CORNER HARDWARE (90)	330	
RIM TRUSS	1760	
RIM HINGES AND MOTORS (6)	30	
STAY TAPES, FRONT AND BACK (180)	367	
TAPE REELS	42	
CENTRAL MASTS (500 M)	241	
STORAGE CANISTERS AND MECHANISMS	552	
CENTER BODY	<u>48</u>	
		3382
<u>REFLECTOR MEMBRANE</u>		
AREA = 785,400 M ² @ 4 GM/M ²	<u>3142</u>	
		3142
<u>CONTROL SYSTEM</u>		
CONTROL-MOMENT GYRO TWIN-ROTORS	1000	
CONTROL-MOMENT GYRO SUSPENSION	1000	
MAGNETIC LOOP CONTROL (90 CIRCUITS) (FOR 2400-KM ORBIT)	<u>335</u>	
		2335
<u>COMMUNICATIONS, POWER SUPPLY, AND CONTROL ELECTRONICS</u>		
SOLAR POWER SUPPLY	60	
HEMISPHERICAL ANTENNAS (2)	20	
RATE GYROS AND SENSORS	50	
COMMUNICATIONS AND DATA HANDLING	100	
COMPUTER	<u>46</u>	
		<u>376</u>
	TOTAL	9235

Figure 5.

SEQUENTIAL ERECTION

The deployment of the structural configuration presents a very severe problem. In the past, the rim was assumed to be packaged and deployed in a zigzag fashion in much the same manner as used in the Wire-Wheel or Hoop-Column concepts. In the present case, the difficulty is that the rim truss is over an order of magnitude larger in cross section than could be fit within the Shuttle with zigzag packaging. We deemed it unreasonable to expect that we could control the deployment of the cross section of the rim at the same time as controlling the radial deployment of the zigzag. Therefore, we reexamined the deployment and arrived at a principle of erection of large structures which is outlined in figure 6. We are convinced that all large structures must follow this principle of sequential erection.

1. *MOST OF THE MATERIAL IS EITHER SECURELY STOWED OR FULLY ERECTED AT ANY TIME DURING THE PERIOD OF ESTABLISHMENT.*
2. *ONLY A SMALL FRACTION OF THE MATERIAL IS IN TRANSITION AT ANY TIME.*
3. *PARTS IN TRANSITION ARE CLOSELY CONTROLLED.*
4. *STRUCTURAL PARTS IN TRANSITION ARE AVAILABLE FOR INSPECTION AND REPAIR*

Figure 6.

1-KILOMETER-DIAMETER REFLECTING SATELLITE
 PACKAGED FOR SHUTTLE CARGO BAY

Figures 7 through 11 illustrate a deployment concept which obeys the principle of sequential erection. The package shown here (figure 7) is made up of three sets of containers. Each set consists of two canisters, each containing a segment of the rim truss, joined together by a rectangular bin in which the reflector membrane is stowed. Each rim-truss canister contains one-sixth of the rim and the film stowage bin is long enough to contain also the expansion compensator attachment hardware.

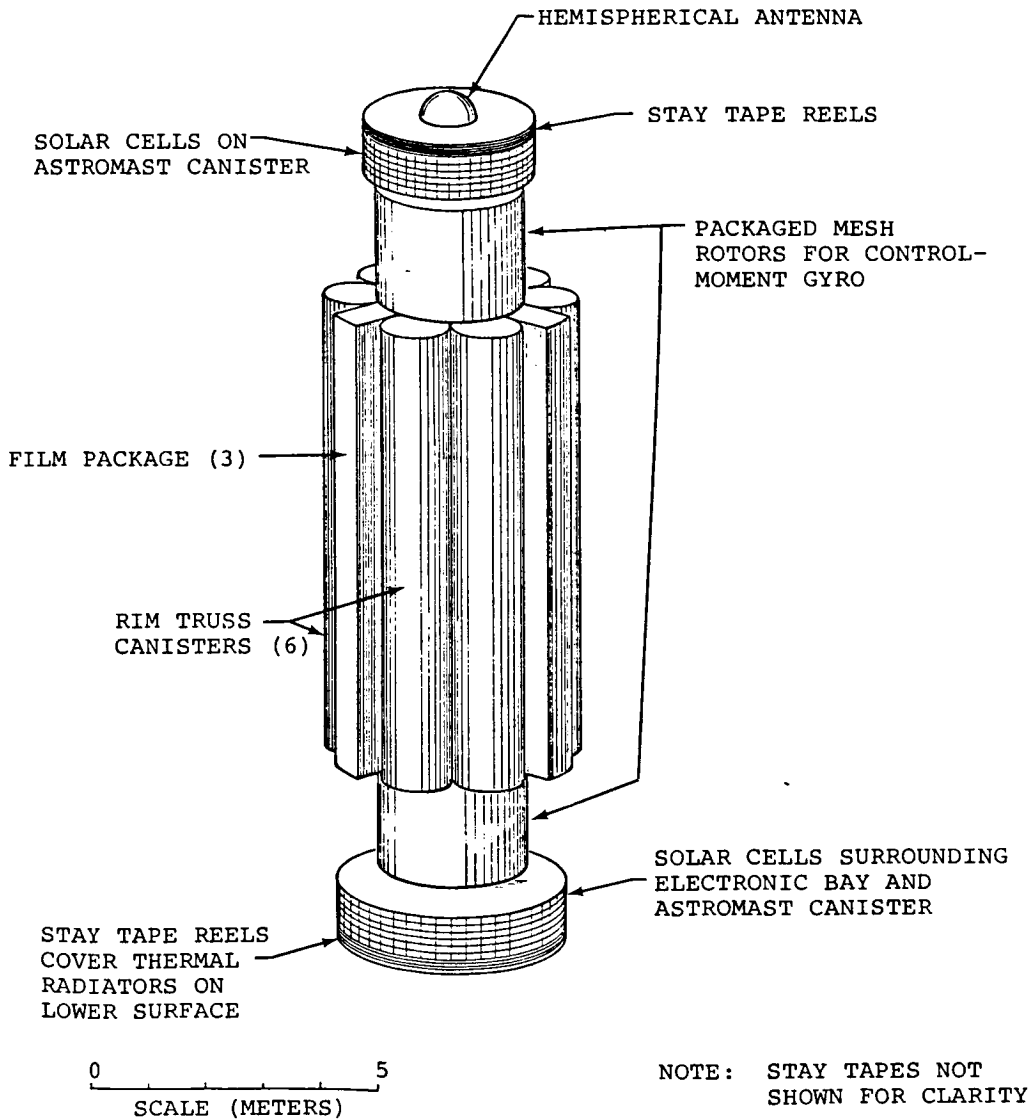


Figure 7.

FIRST PHASE OF DEPLOYMENT
SHOWING RIM-TRUSS CANISTERS AFTER 90° ROTATION

The first step in the deployment is to rotate the paired rim-truss canisters to a horizontal position (figure 8). The rim truss in this case is an Astromast, although other types of deployable trusses could be used. The tip ends of the Astromast are temporarily attached rigidly to the hub.

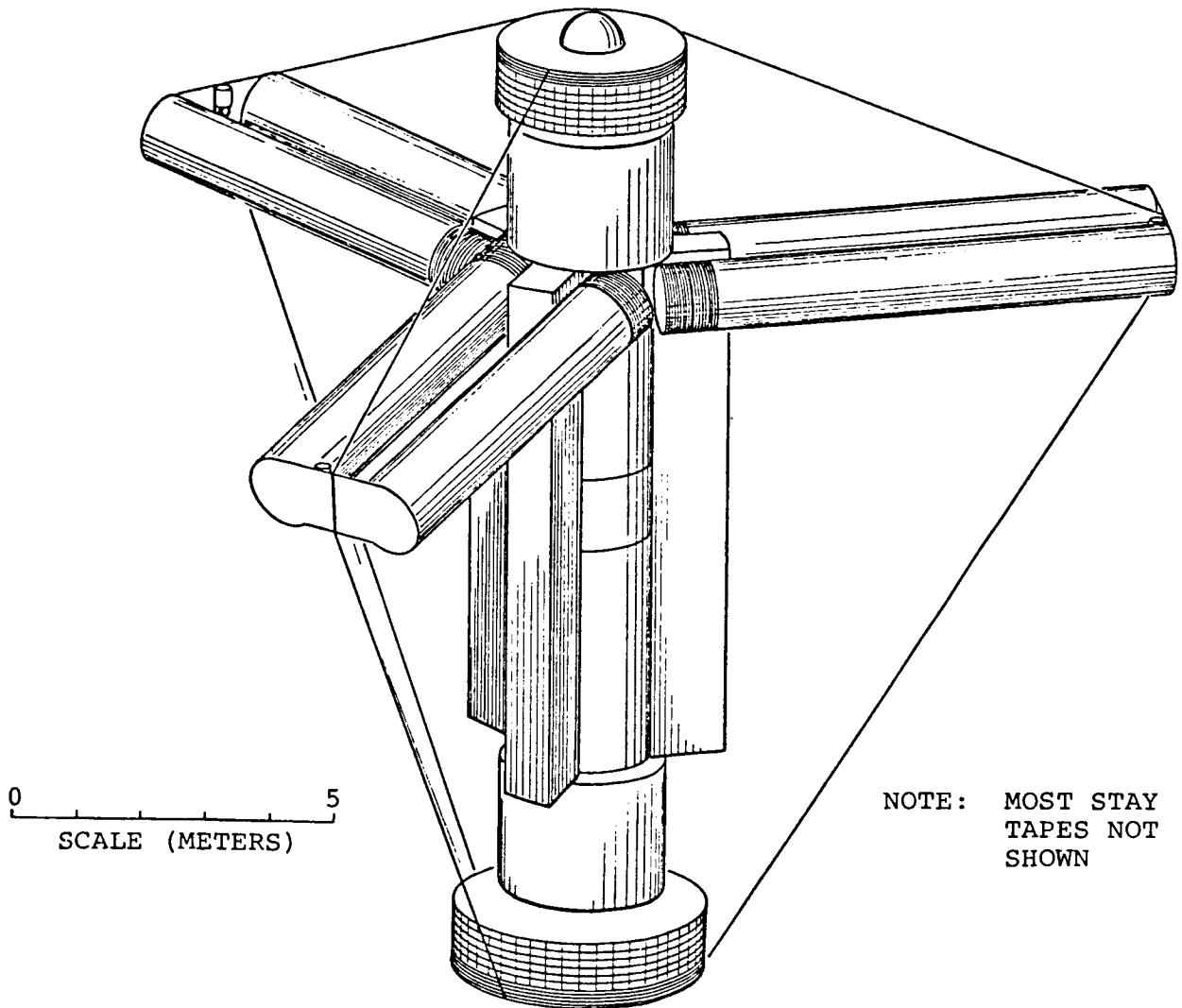
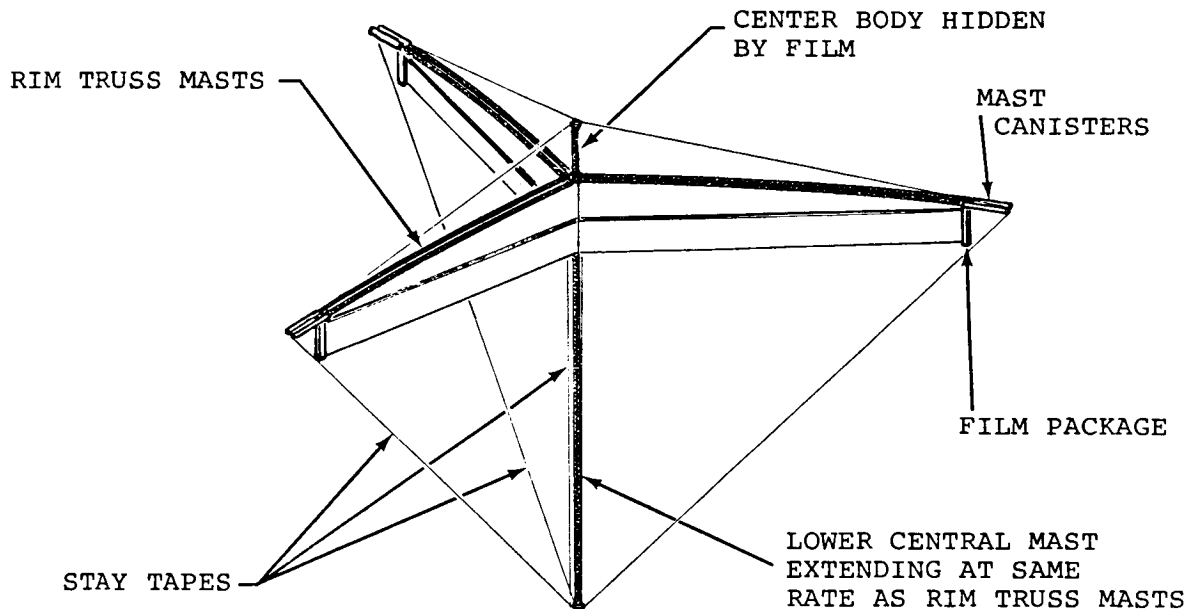


Figure 8.

SOLAR-REFLECTING SATELLITE
DURING EARLY PART OF SECOND DEPLOYMENT PHASE

Deployment continues by extending the pairs of Astromasts, transporting canisters outwards in pairs accompanied by the film bins (figure 9). As the film bins move outward, the membrane is allowed to unfold from the bin. Whenever a station on the rim is reached where an attachment of the membrane is required, an appropriate joint is made.



NOTE: MOST STAY TAPES
NOT SHOWN

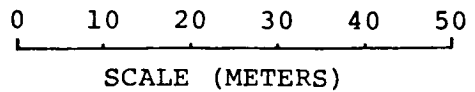


Figure 9.

PROGRESSIVE DEPLOYMENT OF MASTS AND FILM IN SECOND PHASE

Deployment of the rim and the central hub continued until the rim is fully deployed as shown in figure 10.

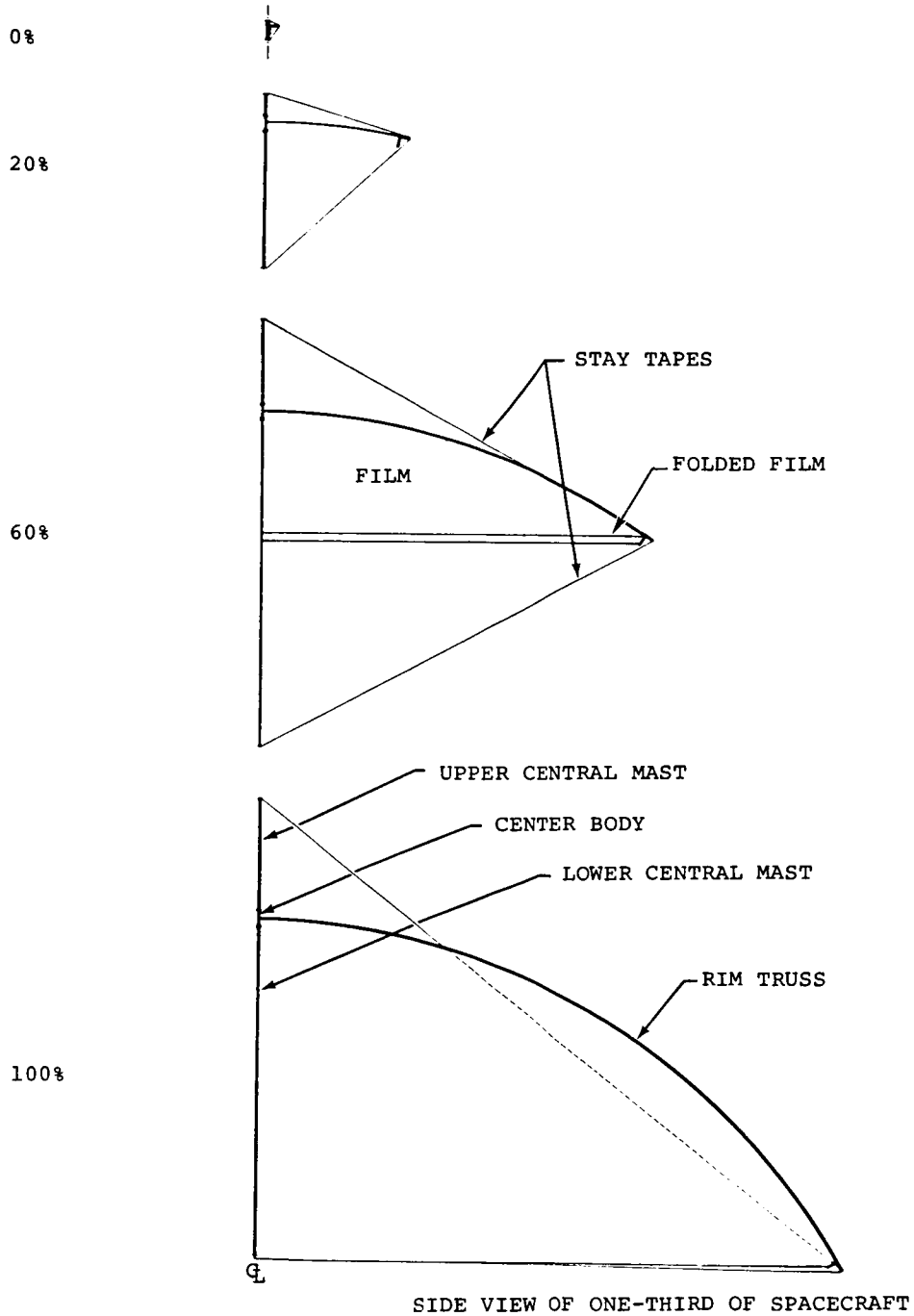
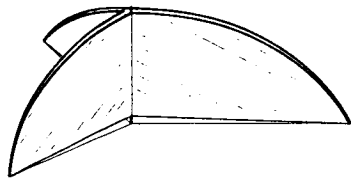


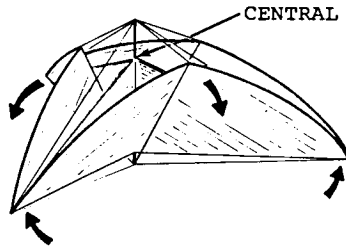
Figure 10.

THIRD PHASE OF THE DEPLOYMENT SEQUENCE

The final stage of deployment is to detach the Astromast tips from the central hub and to allow the rim to hinge at six points and thereby assume its final deployed position (figure 11). This last motion is designed to be driven by synchronized electric motors at the canister base. The stay tapes are controlled properly to position the centerbody with respect to the rim during this stage.

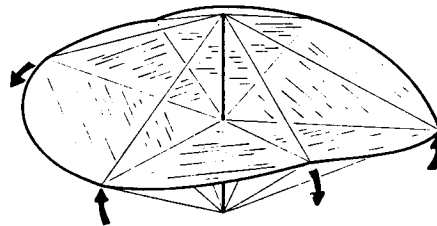


LOWER CENTRAL MAST AND RIM
TRUSSES FULLY EXTENDED



CENTRAL BODY
UPPER CENTRAL MAST
PARTIALLY EXTENDED

NOTE: MOST STAY TAPES
NOT SHOWN



UPPER CENTRAL
MAST NEARS
FULL EXTENSION

0 500
SCALE (METERS)

FILM AND RIM
FULLY DEPLOYED
IN FINAL CONFIGURATION

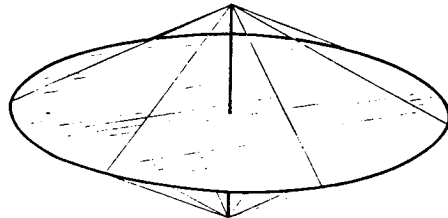


Figure 11.

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