DEPLOYMENT/RETRACTION MECHANISM FOR SOLAR MAXIMUM MISSION HIGH GAIN ANTENNA SYSTEM

By

Neal Bennett, Sperry Flight Systems
Peter Preiswerk, ASTRO Research Corporation

ABSTRACT

Accurate steering of a spacecraft communication antenna requires a stable platform. A mechanism called a Deployment/Retraction Assembly (DRA) which provides not only a stable, but a deployable platform for the High Gain Antenna System (HGAS) aboard the Solar Maximum Mission (SMM) spacecraft is described. The DRA also has the capability to retract the system upon command.

INTRODUCTION

The SMM spacecraft scheduled for launch into a 357 mile orbit in October 1979 will have aboard a high gain S-band antenna system capable of communicating with and tracking the TDRS system. This antenna system, called HGAS, must be stowed within a required envelope in the aft end of the spacecraft and withstand launch by a Delta launch vehicle. The spacecraft attitude does not allow the antenna to view the relay satellites when stowed. Consequently, once in orbit, the HGAS must be deployed to a position that allows the antenna to communicate with and track the relay satellites. The HGAS is shown in the deployed condition in Figure 1. When deployed, the deploy mechanism must maintain accurate support alignment for the antenna and articulation system while being exposed to the orbital space environment. Space Shuttle recovery of the SMM is planned and to facilitate this the HGAS is required to retract within its launch envelope so that the SMM spacecraft can fit within the Shuttle bay. If retraction is not possible, all portions of the HGAS outside the recovery envelope must be jettisoned from the spacecraft.

The DRA design described in this paper was selected based on the flight experience of the concept and its potential to satisfy the stringent HGAS requirements described above. Similar structures have flown successfully on the Air Force S-3 satellite and NASA's Voyager 1 and 2 as magnetometer booms of 20-foot length, 7-inch diameter and of 43-foot length, 9-inch diameter respectively. The deployable portion of the DRA, the Astromast, provides an ultralight, low profile structure with the deployed stiffness and stability required of HGAS.

DRA DESIGN DESCRIPTION

The DRA is a major subassembly mechanism of the High Gain Antenna System, weighing less than 23 pounds. The total deploy stroke is 60 inches, which positions the antenna at a point relative to the spacecraft that allows a view of the TDRS system. It has overall stiffness properties that yield major HGAS deployed resonant frequencies in excess of 8 Hz. Deployed alignment stability is expected to be better than .2 degrees over the required temperature range and deploy/retract cycle life. The required cycle life for ground operation will be approximately 30 cycles and for space, 1 cycle.

The DRA itself consists of five major subassemblies: (1) An Astromast Assembly which is the basic deploying and retracting support structure for the antenna and articulation system, (2) A servo assembly, which restrains the Astromast during deployment in a controlled manner, and provides the force required for retraction, (3) hardware that interfaces the HGAS with the SMM spacecraft, (4) a jettison mechanism that is capable of jettisoning certain portions of the HGAS, and (5) an antijettison caging mechanism that inhibits the jettison mechanism in the stowed condition.

ASTROMAST

The Astromast provides the key function in the DRA of structural support to the deployed antenna and articulation system. Its construction provides for maximum stiffness, minimum weight, and minimum volume.

Figure 2 is a layout of the Astromast showing the truss type construction. The basic members are the three main longitudinal members (longerons), triangular frames separating the longerons (batten frames), and pretensioned diagonal members connecting adjacent longerons and batten frames. The diameter through the longerons is 18.5 inches and the length between longeron pivot points is 62.16 inches. There are 5 batten frames, forming 6 bays, each 10.36 inches long. All members are fabricated from unidirectional S-glass/epoxy laminate to take advantage of the inherent high stiffness-to-weight ratio and thermal stability. The total weight of the Astromast is 3.7 pounds.

Stowed, the Astromast is coiled into a height of only 2.3 inches. The longerons develop, like coiled springs, a force tending to deploy the system and are restrained by a central lanyard. Figures 3 through 6 show the deployment sequence, as demonstrated by an engineering model, beginning with the fully stowed condition. Two different stages during the transition from stowed to deployed are shown in Figures 4 and 5. Since all or some portion of the longerons still form a helix, the Astromast is relatively weak during the transition phase. The maximum stiffness and strength properties are not achieved until full deployment, shown in Figure 6. Note the restraining lanyard located in the center. The top plate, representing the interface to the antenna and articulation system, rotates about the longitudinal axis a total of 382.5 degrees as the Astromast deploys.

In the deployed state, the longerons provide axial load capacity and bending stiffness, the battens stabilize the structure while in an elastically buckled condition, and the diagonals provide shear and torsional stiffness. Though the DRA will not be exposed to direct sunlight, the thermal alignment stability is designed to remain within .2 degrees with as much as 270 degrees R temperature differential between the two diagonals of each bay panel.

SERVO MECHANISM

The DRA servo mechanism controls the rate of deployment and provides the retracting force. A pully containing the restraining lanyard is attached to the output shaft of a simple worm gear assembly. The worm is casehardened steel and the driven helical gear is cast bronze; the mesh as well as the gear bearings are lubricated by Braycote 3L-38RP grease. The worm is driven by a brush type DC gear head motor, producing a total speed reduction of 2433:1. Motor brushes are redundant and of the longlife dry-lube type consisting of 85 percent silver, 12 percent molydisulfide, and 3 percent carbon. Figure 7 shows the location of the servo mechanism on the bottom of the DRA.

For launch the Astromast is not held in position by the lanyard, but by a pyrotechnic pin puller which absorbs the load directly. The pin puller is shown in Figures 7 and 9. Once the spacecraft is stabilized in orbit, the dual initiated pin puller is fired and the deploy sequence is started by commanding the DC motor on. The lanyard is in turn played out at a controlled rate allowing the DRA to deploy. Redundant microswitches are used to indicate the deployed state and are used to switch off the motor. A special bridle system, shown in Figure 8, is used in conjunction with a change in effective lanyard pully radius to prevent the DRA from "snapping" into the deployed state. This bridle system also serves to generate the initial rotation of the DRA about the longitudinal axis when retraction is commanded. Redundant stowed status microswitches, located so that they sense contact of the top structure with the base plate, are used to turn off the servo mechanism once stowage is complete.

INTERFACE HARDWARE

The interface between the DRA mechanism and the SMM spacecraft consists of a lightweight, stiff aluminum cylinder 28.3 inches long and 21 inches diameter, called the canister, shown in Figure 9. Three hat section stringers run the length of the canister carrying loads from the three Astromast longerons directly to three I-beams in the aft end of the spacecraft. The canister not only provides the static and dynamic interface with the spacecraft, but also acts as a guide tube during jettison.

JETTISON MECHANISM

The DRA is capable of jettisoning the antenna, articulation system, Astromast, servo mechanism, and control electronics. The jettison mechanism will only be activated in the event the DRA cannot be retracted to the fully stowed condition for Shuttle recovery. This capability is provided by three ball release/jettison spring assemblies, shown in Figure 10. A lightweight but structurally sound mechanism has resulted through extensive use of 7075 aluminum. A pyrotechnic cable cutter, shown in Figure 7, severs 3 stainless steel cables that release spring loaded plungers, unloading a set of steel balls in sockets. Once the ball loads are released, 3 jettison springs eject the base plate and all assemblies attached to it out of the canister. The spring stroke is 2.5 inches providing a terminal velocity of 12 in./sec. Spring forces are designed to yield a net force through the HGAS center of gravity to minimize the tendency to rotate. In addition to the jettison release cables, the pyrotechnic cable cutter severs all electrical and RF cables interfacing the HGAS to the SMM spacecraft.

CAGING MECHANISM

To prevent inadvertent jettisoning of the HGAS after Shuttle recovery, the jettison capability is inhibited by a unique but simple caging mechanism shown in Figure 9. Caging occurs only in the stowed condition, but the mechanism allows the DRA to deploy and retract normally. It consists of a pivoted wedge which, when the DRA is fully retracted, will not allow the base plate to move relative to the canister. Consequently, if the cable cutter is accidentally fired, the jettison springs are inhibited from forcing the baseplate out of the canister. After approximately .75 inches of deployment, the caging wedges are released, and jettison is possible.

CONCLUDING REMARKS

A unique mechanism, called a Deployment/Retraction Assembly, has been described that is capable of deploying and retracting the S-band antenna and associated articulation system aboard the SMM spacecraft. Once deployed, it provides a stable and stiff structure from which the antenna can track and communicate with the TDRS system.

At the time of writing, engineering model tests are underway and the protoflight DRA is being fabricated. Engineering models of the worm gear assembly, the jettison mechanism, and the Astromast have been tested and the following has been demonstrated:

- Worm gear design has load/cycle capability in excess of that required for ground and space operation.
- Jettison mechanism ball release concept works successfully.
- The Astromast has adequate cycle life and stiffness to meet mission requirements.

Acceptance testing of the protoflight DRA will begin in late January. At the time of the 12th Aerospace Symposium in April 1978, DRA acceptance tests will be complete and resulting data will be available.

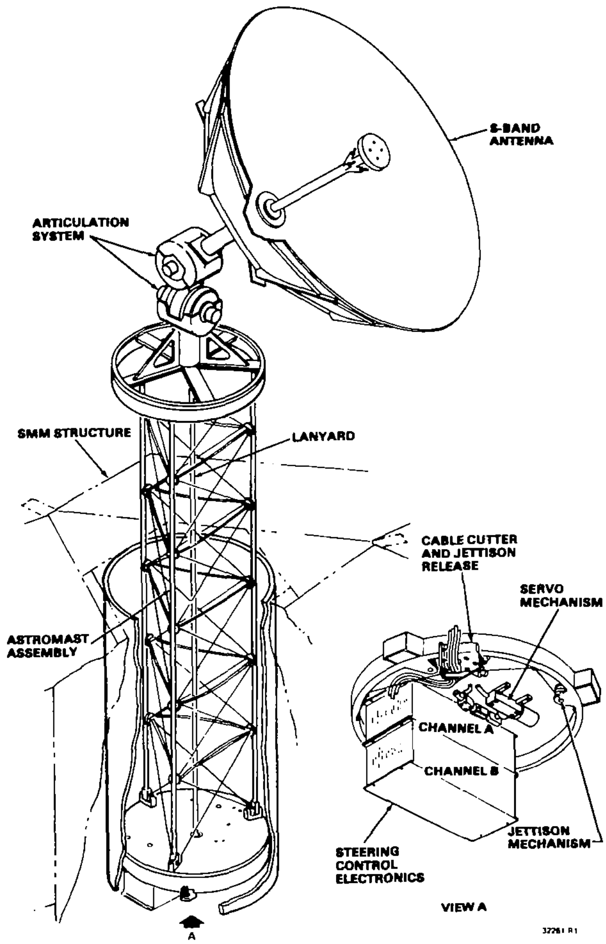

Figure 1
HGAS Deployed

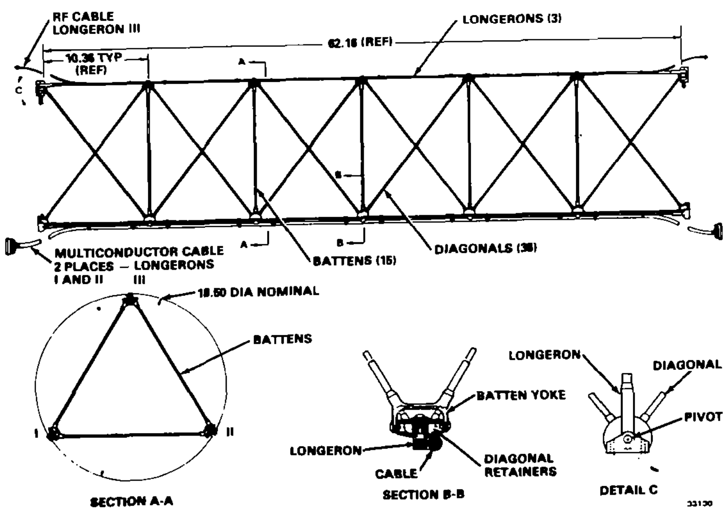

Figure 2
Astromast

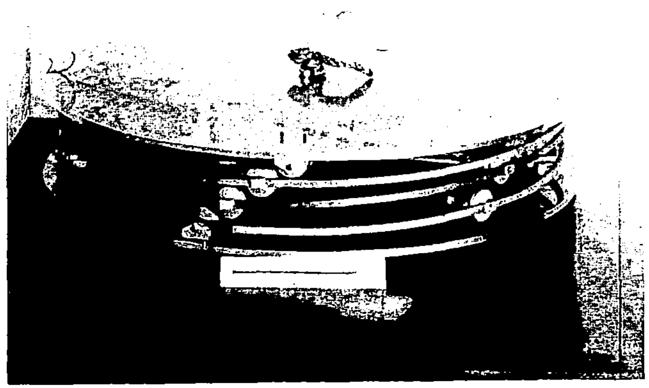

Figure 3 Astromast stowed.

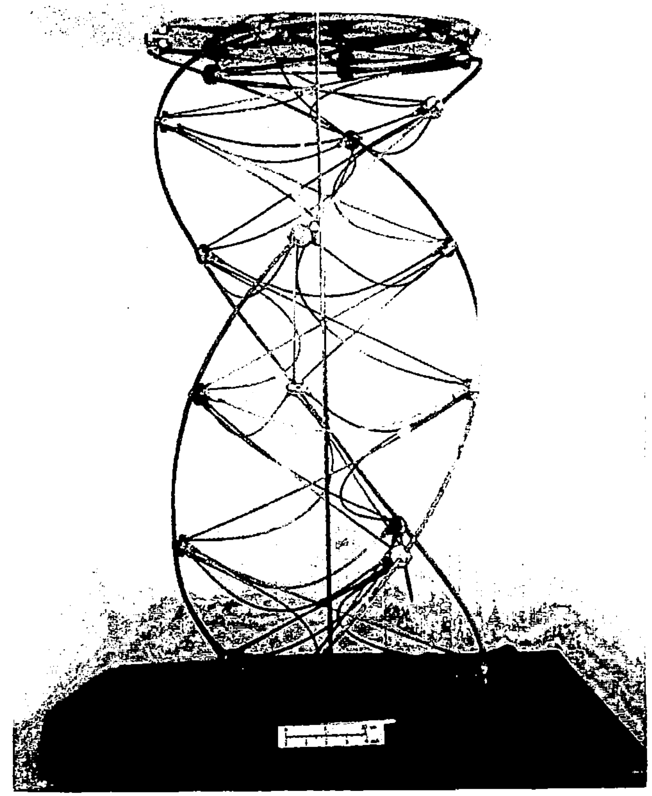

Figure 4 Astromast initial deployment stage.

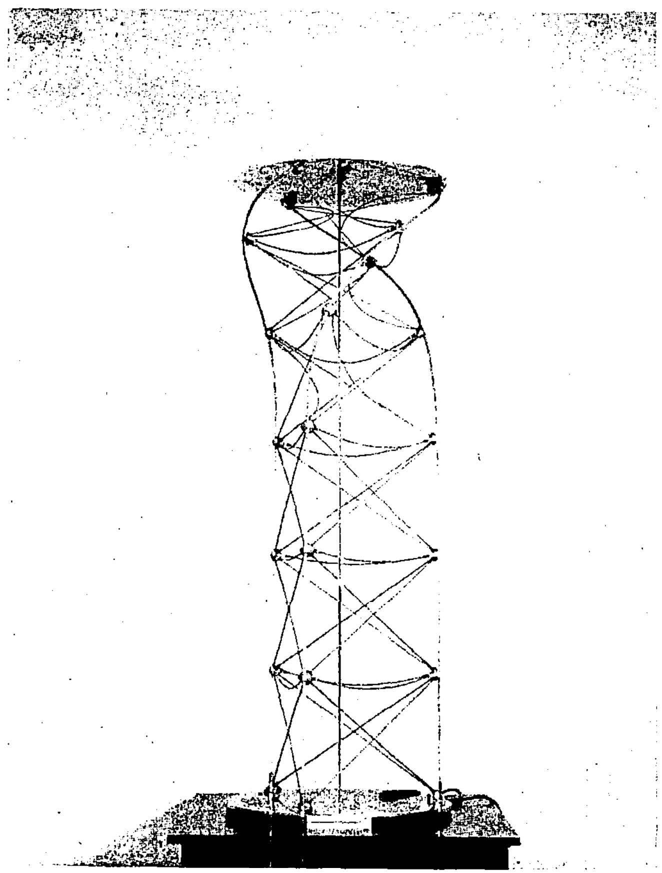

Figure 5 Astromast deploying.

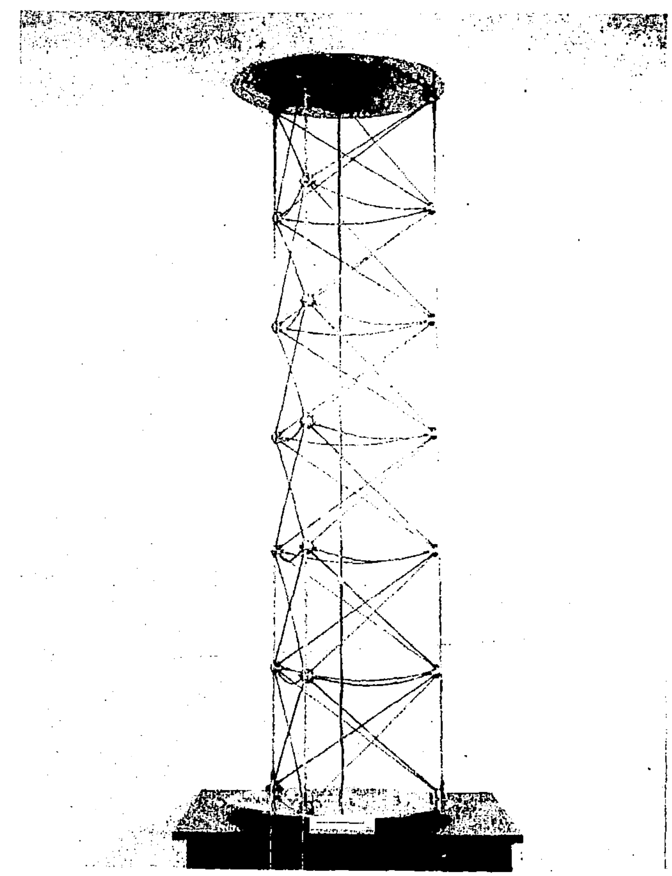

Figure 6 Astromast fully deployed.

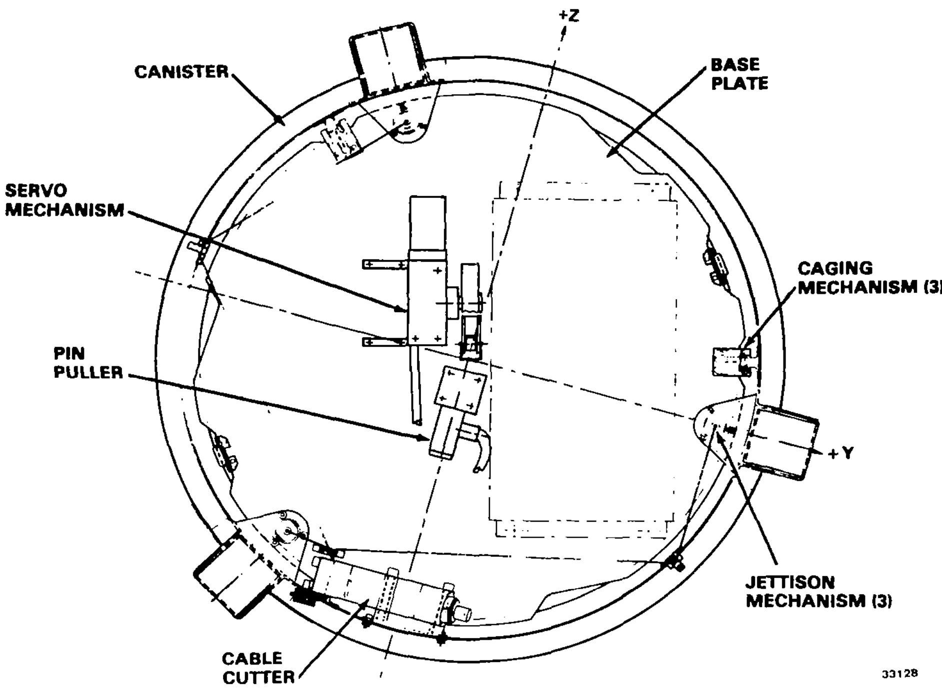

Figure 7
Bottom View of DRA

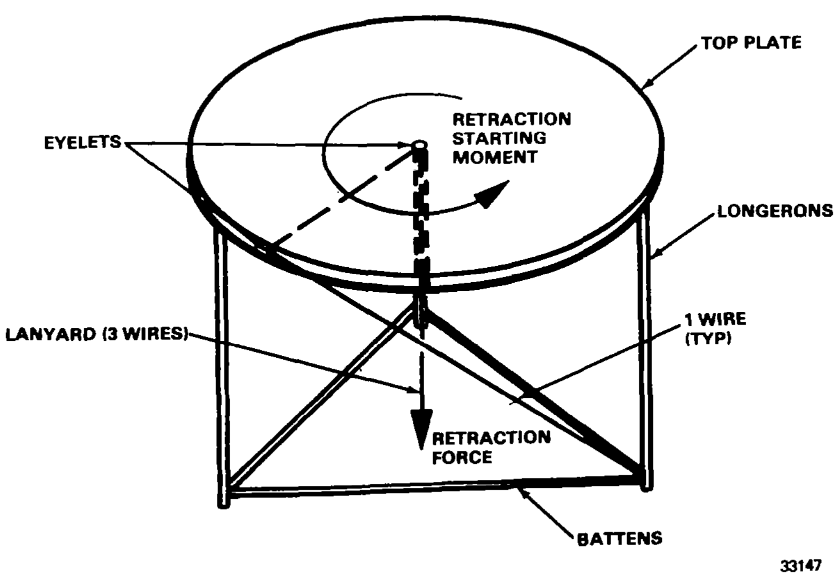

Figure 8
Bridle System

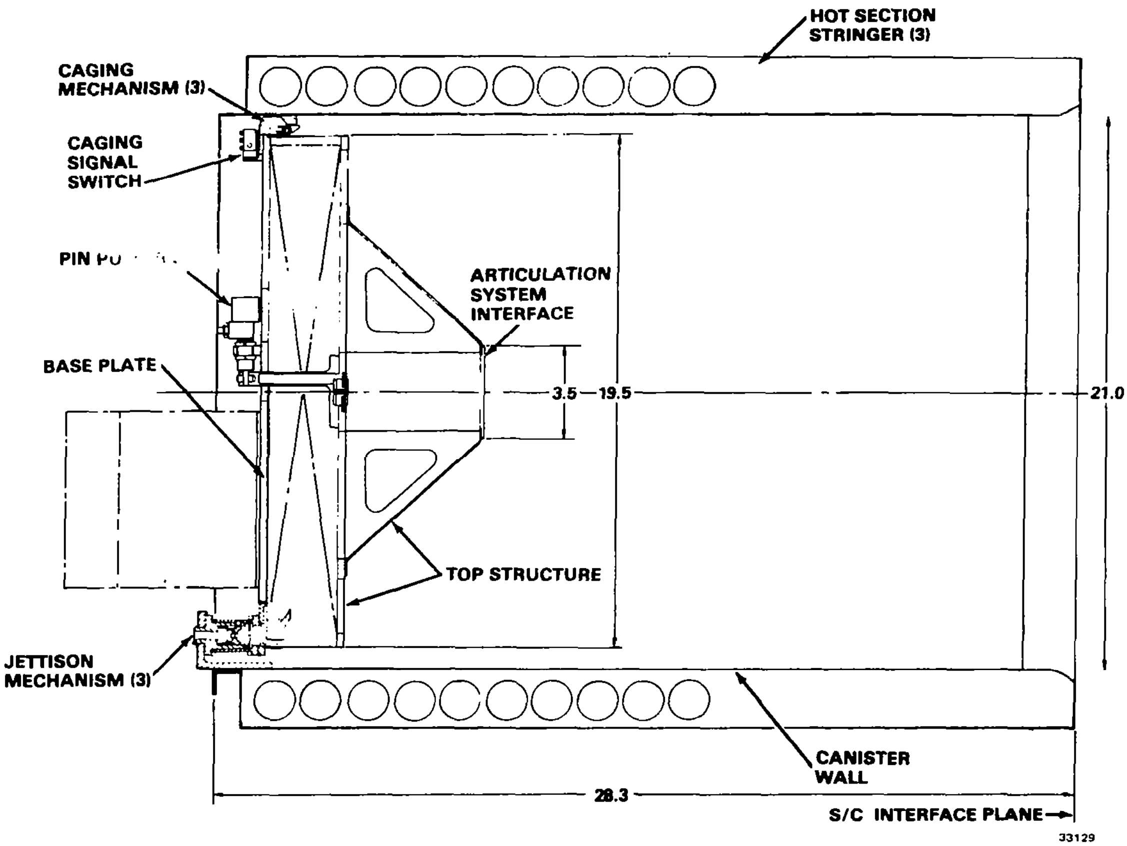

Figure 9
Side View of DRA

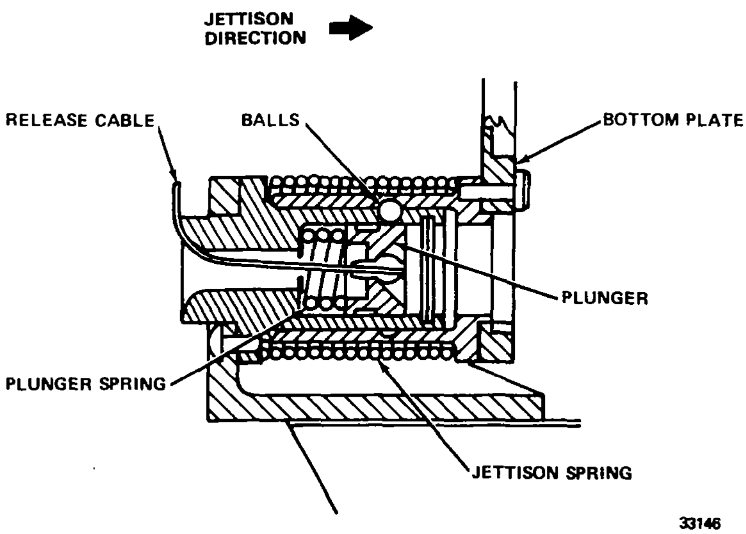

Figure 10
Jettison Mechanism