N88-21469

15-METER DIAMETER HOOP/COLUMN ANTENNA SURFACE CONTROL ACTUATOR SYSTEM

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ABSTRACT

The design, development, and implementation status of the Surface Control Actuator System (SCAS) for the Hoop/Column Antenna are described with the primary focus on the design of the mechanical elements. The SCAS is an electro-mechanical system that will automatically adjust the antenna shape by changing the length of control cords. Achieving and maintaining the proper surface shape and smoothness are critical to optimizing the electromagnetic characteristics of the antenna.

INTRODUCTION

Future space structures such as large space antennas and the Space Station will have to be assembled in orbit or deployed once they are clear of the launch system. As part of NASA's research program in Large Space Structures, Langley Research Center (LaRC) is proceeding with the development of concepts for deployment and control of these large structures.

The Hoop/Column Antenna is the focus at LaRC for research in the interaction of structures, controls, and electromagnetics for large space antennas. An antenna employing the hoop/column concept is a potential candidate for a future flight experiment. An antenna, possibly as large as 122 meters in diameter with an 85-meter column, could be stored in the STS cargo bay. It could then be deployed while in orbit with the option to be left on station or returned for further evaluation.

A 15-meter diameter Hoop/Column Antenna has been fabricated and has undergone structural and electromagnetic characterization. The antenna, shown in figures 1 and 2, consists of a telescoping column and an upper and lower cord system which suspends a 24-segment deployable hoop. A

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reflector mesh is connected between the hoop and column and shaped by 96 surface control cords to form four parabolic mesh apertures. A non-deployable feed mast with four feeds, which are directed toward the four apertures, is attached to the top of the telescoping column.

The hoop and column are held in relative position by 48 upper cords and 24 lower cords. The upper cords radiate in a bicycle spoke fashion from 24 equally spaced stations located on the bottom side of the upper cap structure to the ends of the 24 hoop sections. The lower cords (96 surface control cords and 24 hoop cords) are divided into 24 groups with four surface control cords and one hoop/cord per group. The cords radiate upward and outward from 24 equally spaced stations, located on the top side of the lower cap structure, to the antenna surface and the ends of the 24 hoop sections. The outer edge of the mesh surface is attached to the ends of the hoop segments and the inner edge is attached to the column.

During deployment the upper cords are stored on spools located on the top side of the upper cap structure and the lower cords (hoop cords and surface cords) are stored on spools on the bottom side of the lower cap structure. As the antenna deploys, see figure 3, the cords unwind from the two sets of spools through the stations. When the antenna is fully deployed a bead located at the end of each cord is captured in a housing. The location of the beads on the cords determines the effective length of the cords, thus defining the shape of the antenna surface.

Electromagnetic characterization tests have been completed. These characterization tests have confirmed the sensitivity of antenna performance to antenna surface contour. Fine tuning the antenna performance was limited by the surface refinement capability of the present manual adjustment system, which has a practical accuracy limit of .010 inch of cord length. Additionally, the manual process requires from 4-8 hours for each surface adjustment and cannot compensate for dynamic changes in the shape of the structure. Also, the need for in-flight adjustment and the limited accessibility of the current adjustment points preclude the use of the manual adjustment system. Therefore, an automated surface control actuator system is being added to the antenna.

DESIGN CRITERIA

The Surface Control Actuator System was designed to control the antenna surface by changing the length of surface cords. The research nature of this program has influenced the specific design requirements. Therefore, the resulting design criteria for this concept may exceed flight system requirements. The following is a general list of the requirements.

- o System must be a flight qualifiable concept.
- o System must not interfere with the stowed antenna's geometry.
- o System must control one parabolic mesh aperture (one quadrant) of the surface.
- o System must use the existing surface control cord stowage system.
- o Each surface control cord must have 1.5 inches of adjustment in length.
- o Cord length control accuracy must be .002 inch.
- o System must operate for cord loads ranging from 0-25 lbs.
- o Antenna must be protected from over tensioning of the cables.
- o Dynamic surface control capability must be 4 Hz at 1 inch peak to peak amplitude.

MECHANICAL DESIGN

The SCAS controls one parabolic mesh aperture of the antenna surface. Control of one quadrant, see figure 4, is accomplished through seven stations whose functions are to provide a mechanism to automatically adjust the length of the surface control cords. A mechanical station, see figure 5, consists of four basic subassemblies: Cylinder Block Assembly, Pulley Block Assembly, Take-up Spool Housing Assembly, and Motor Assembly Group.

The Cylinder Block Assembly, see figure 6, contains a cylinder block, piston assemblies, cylinder block springs and bushings, side plates, pulley shafts, and pulley sheaves. The purpose of the Cylinder Block Assembly is to position the piston and to direct the piston control cable below the lower cap structure to the Pulley Block Assembly. In order to achieve 1.5 inches of motion and satisfy the envelope requirements, each piston must be offset from the center line of the cylinder block. A piston assembly consists of the piston, piston control cable, piston retaining screw, and piston bushing. A bead at the end of each surface control cord is captured by the piston. The piston rides in the cylinder block on Teflon bushings which are bonded to the piston and cylinder respectively. The piston and cylinder bushings also form a cavity in the cylinder block for the cylinder block spring. The piston's axial and rotational travel is limited by the piston retainer screw which rides in a slot in the cylinder block. The piston control cable, bonded to the lower end of the piston, is a .036 inch diameter steel cable used to move the piston inside the cylinder block. The cylinder block spring preloads the piston control cable. The side plates provide attachment points for the pulley sheave axles. Slots in the side plates which match slots in the cylinder block provide view ports to observe the location of the piston.

The Pulley Block Assembly, see figure 7, consists of a pulley block, sheaves, axles, and a mounting plate. This assembly directs the piston cables to the proper take-up spools. The Pulley Block Assembly is mounted directly to the Take-up Spool Housing Assembly.

The Take-up Spool Housing Assembly, see figure 7, consists of the take-up spools, ball bearings, a motor mounting plate, and optical sensor assemblies for the surface control cords. The primary function of this assembly is to position the five take-up spools which control the piston control cables. The take-up spools operate in conjunction with the optical sensor assemblies to provide three absolute position reference points. The motor mounting plate, attached to the housing, is used to support and align the Motor Assembly Group with the take-up spools.

The Motor Assembly Group consists of four identical motor assemblies which drive the take-up spools that adjust the position of the piston. Each Motor Assembly consists of a motor plate, planetary gearhead motor, adaptor plate, incremental encoder, brake coupling, brake mount, brake, and two clamps (see figure 8). The motor plate attaches the motor to the Take-up Spool Assembly. The incremental encoder housing is attached to the motor by an adaptor plate. The encoder wheel is bonded to the adaptor shaft which is bonded to the rear motor shaft. The brake mount is attached to the adaptor plate, and the brake is secured to the mount with the clamps. A flexible coupling connects the brake output shaft to the adaptor shaft. Although a mechanical station assembly will accommodate control of the hoop cord, a motor drive assembly has not been implemented. A manual adjustment mechanism, see figure 7, has been incorporated at the station to change the hoop cord length.

The four subassemblies of a mechanical station function together to produce changes in the length of the surface control cords. A surface control cord captured by a piston is adjusted by a piston control cable which is routed through a series of pulleys to the take-up spool. As the piston control cable winds around the take-up spool the position of the piston in the cylinder block changes. The motor drives a surface control cord take-up spool in response to controller commands. An incremental encoder attached to the motor resolves the motion of the take-up spool to .001 degree. Actual control of the piston position should be .002 inch or better allowing for Controller deadband, gear bask lash, and uncertainty in the cable strain. A brake attached to the motor is used to prevent back drive when the power is removed from the motor and brake.

SYSTEM OPERATION

The SCAS control system consists of a host computer, System Interface Unit (SIU), Load Interface Unit (LIU), seven Station Controllers, and seven Mechanical Stations (see figure 9).

The host computer communicates with the system via a MIL-STD-1553B serial communication bus. The host computer provides commands to the control system and receives cord position, cord load, and status information from the system. The SIU handles communications between the system and the host computer, controls access to the system, handles power distribution to the stations, performs position and load limit checks, distributes commands to the stations, and collects and formats data from the stations. The LIU conditions the signals from the load cells located at the surface end of the cords and digitizes, formats, and transmits load data to the SIU and Station Controllers.

Each Station Controller contains four cord controllers. The cord controllers use the signals from the incremental encoders and the three position absolute encoders to determine the positions of the take-up spools. The controllers correct the position command for strain in the piston control cables, operate the brakes, and provide drive signals to the motors as required to obtain the desired piston displacements.

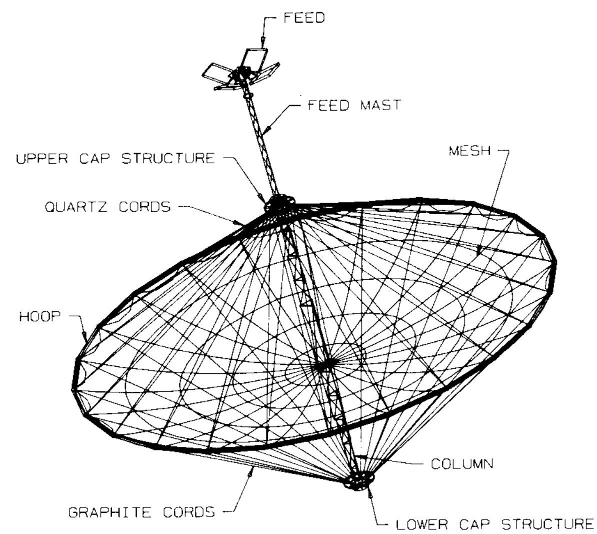
Several safety features have been incorporated into the system to protect personnel and equipment. The cord controllers and the SIU monitor both the position and tension of each cord and compare these values to safe limit values determined by analysis. In the event that either the position or load limits are exceeded the controller and SIU are independently capable of disabling the offending cord actuator. Programmable warning limit checks are also performed by the SIU if requested by the investigator. In the event the electronic control system fails to disable the actuator, two mechanical stops have been incorporated.

STATUS

A prototype SCAS station has been built to evaluate the system sensitivity to fabrication tolerances. The system design has been updated to reflect changes made to the prototype station. The SCAS mechanical parts have been fabricated and are currently being assembled. The mechanical system is scheduled to be integrated into the antenna by early 1988. A prototype of the System Interface Unit, Load Interface Unit, and Station Controller is expected to be completed by early 1988. Total SCAS integration and checkout are expected by the middle of 1988.

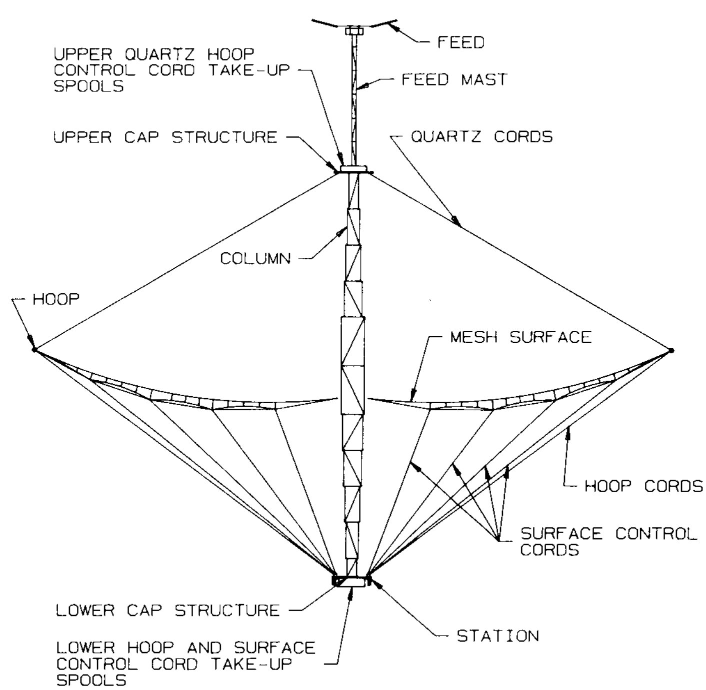
CONCLUSIONS

A surface control actuator system has been designed which meets all system requirements. A prototype of the mechanical subsystem has been fabricated and used to verify the feasibility of this concept. It is anticipated that proper control on the antenna surface will lead to a better understanding of the interaction between antenna structures, control, and electromagnetics. Due to the uniqueness of this design, a patent application has been submitted.



HOOP/COLUMN ANTENNA

FIGURE 1



HOOP/COLUMN ANTENNA PROFILE

FIGURE 2

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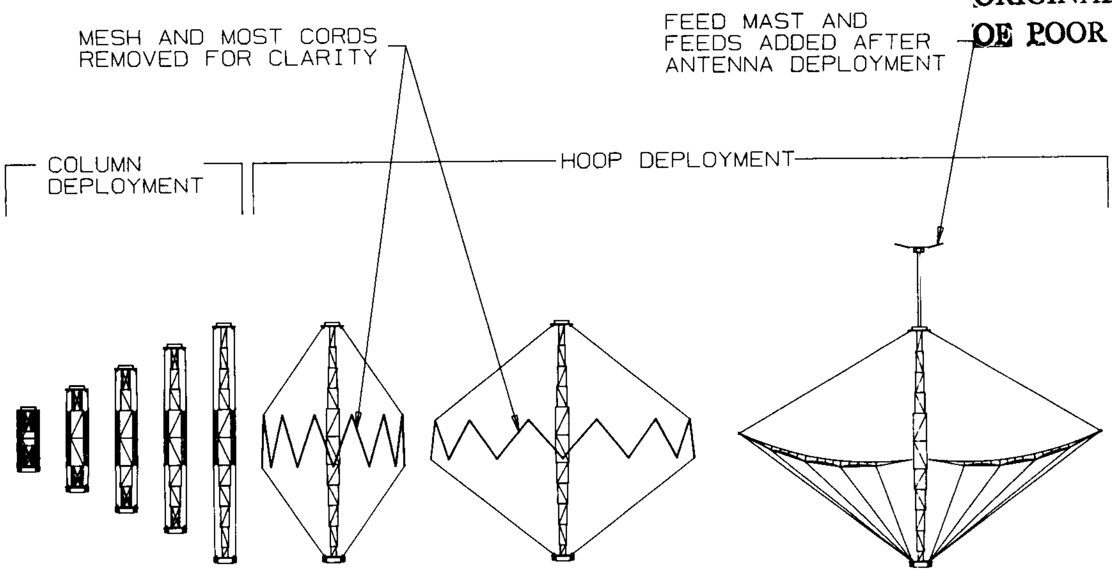
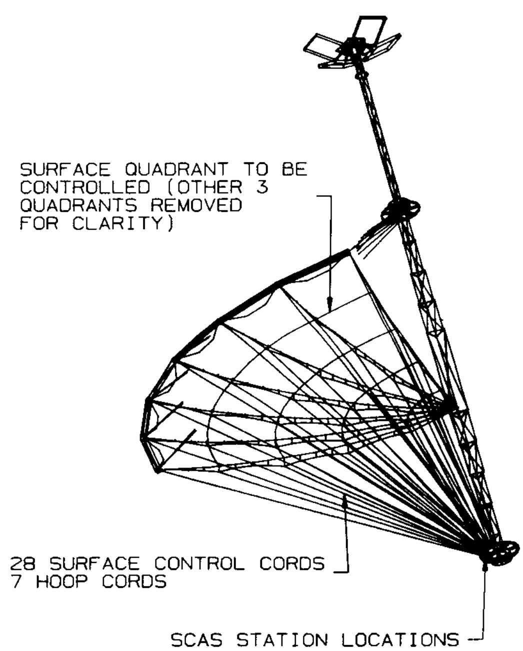


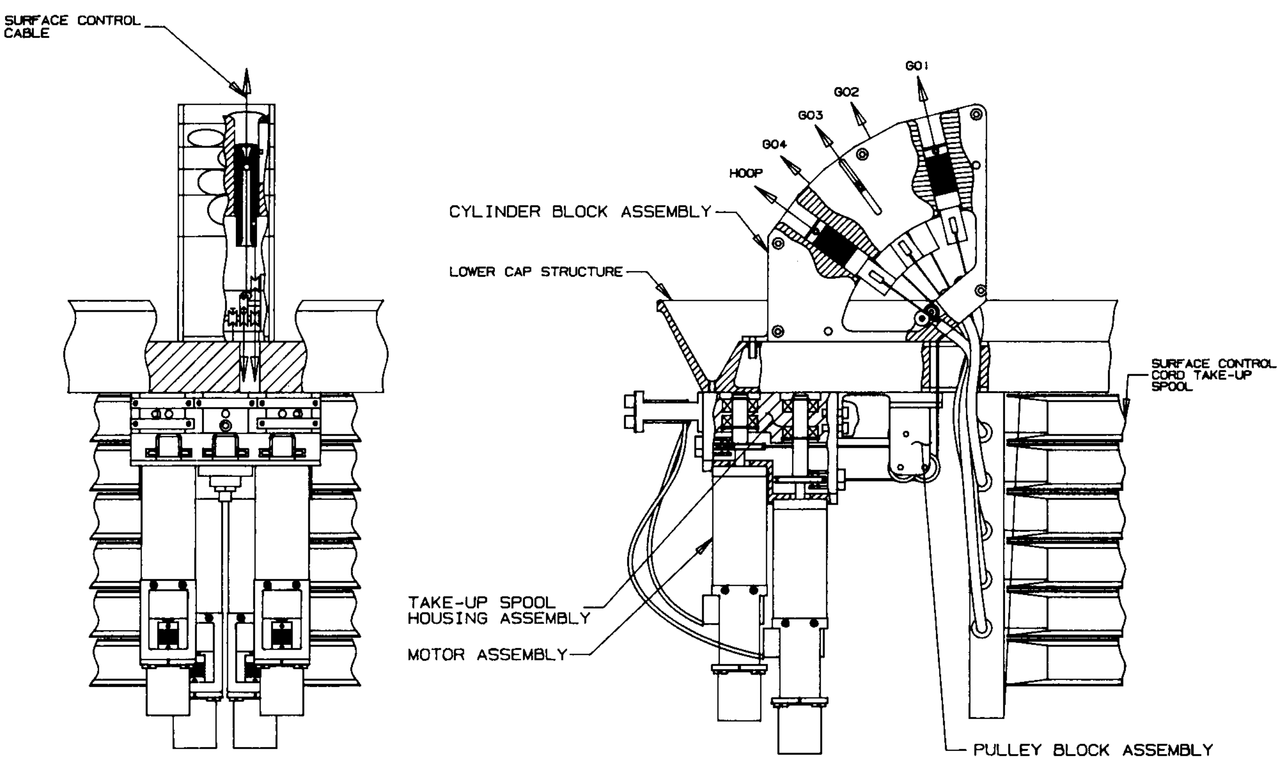
DEPLOYMENT SEQUENCE

FIGURE 3



SINGLE QUADRANT WITH CORDS

FIGURE 4



MECHANICAL STATION

FIGURE 5

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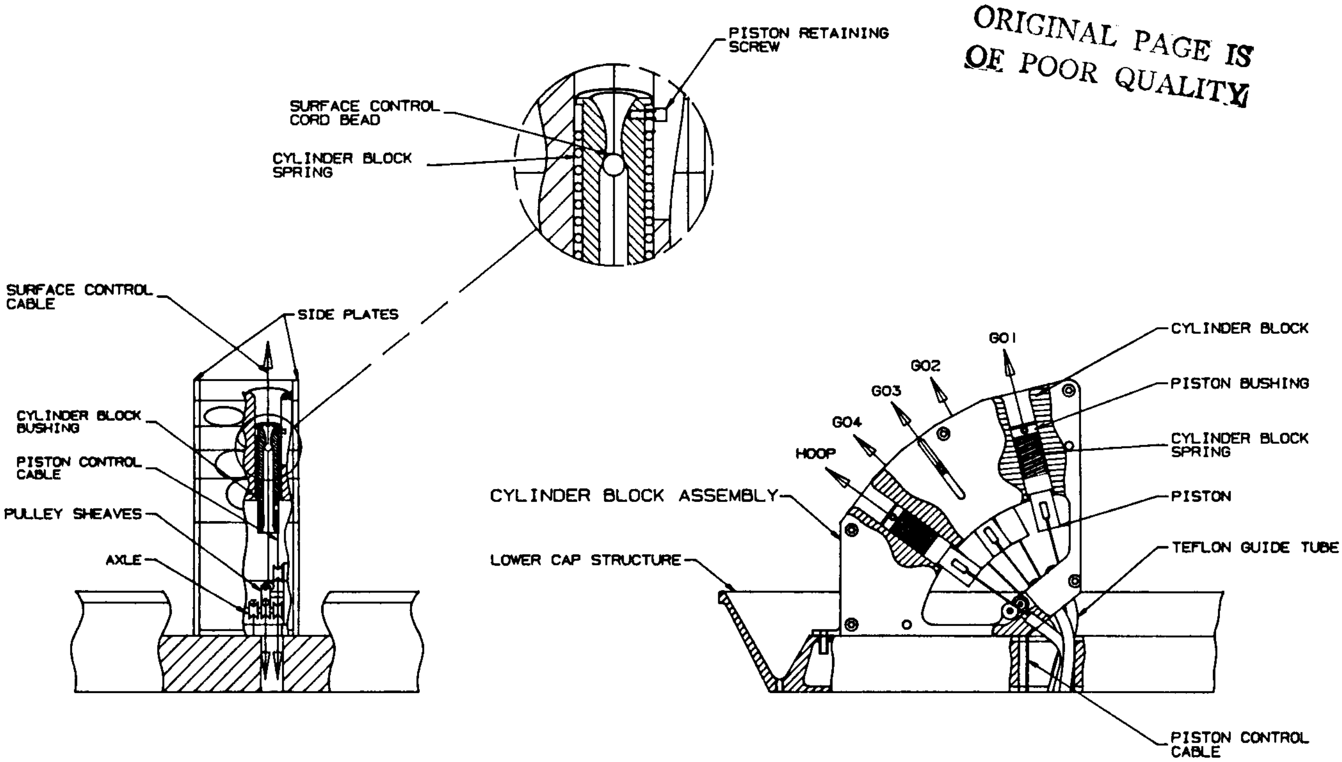
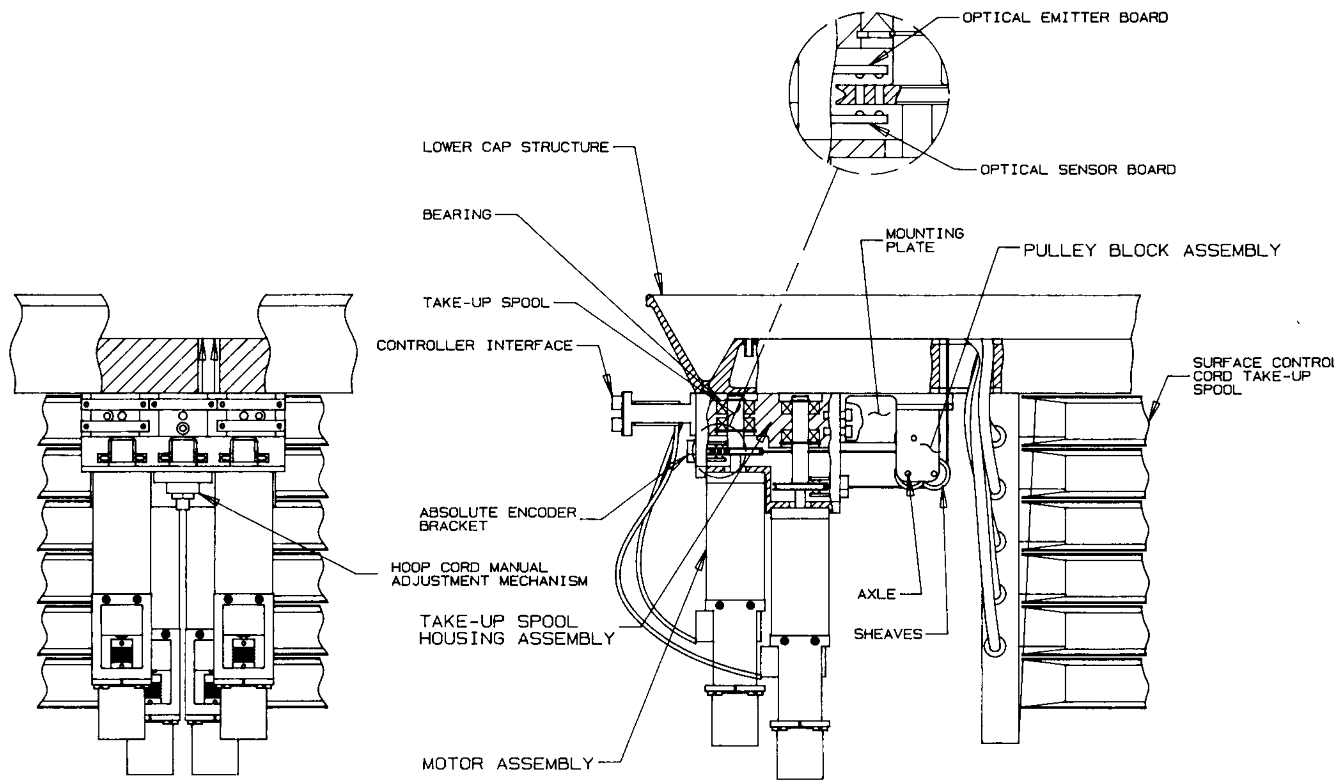


CYLINDER BLOCK ASSEMBLY

FIGURE 6



TAKE-UP SPOOL HOUSING ASSEMBLY
AND PULLEY BLOCK ASSEMBLY

FIGURE 7

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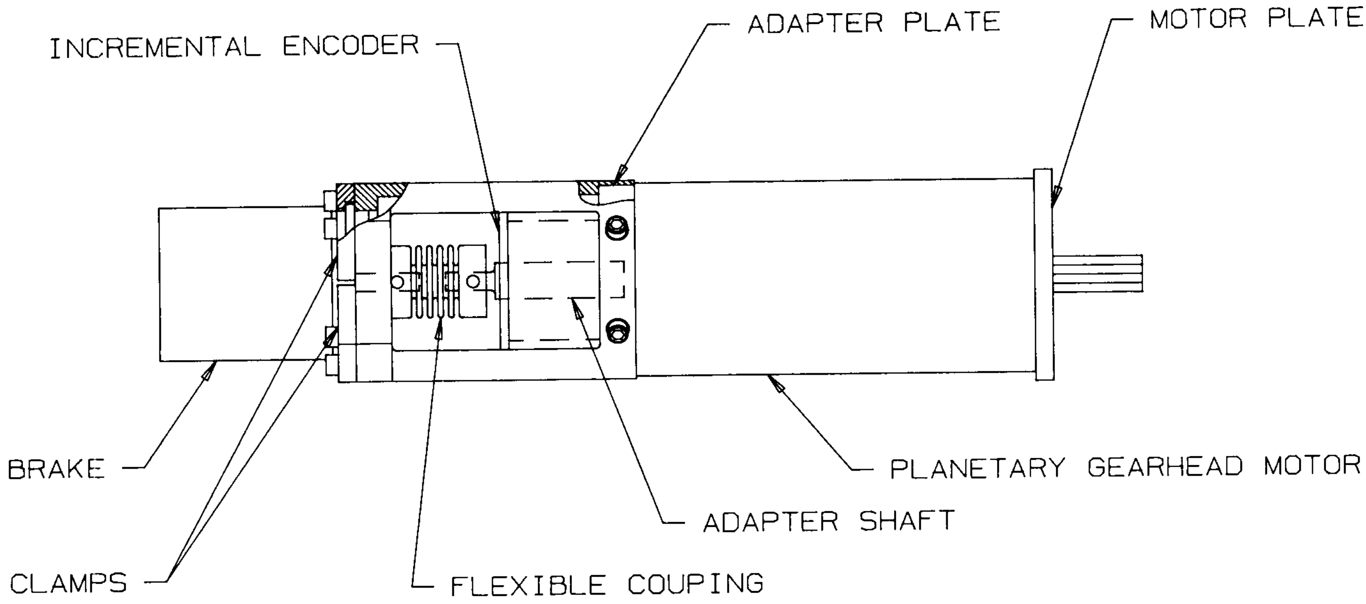
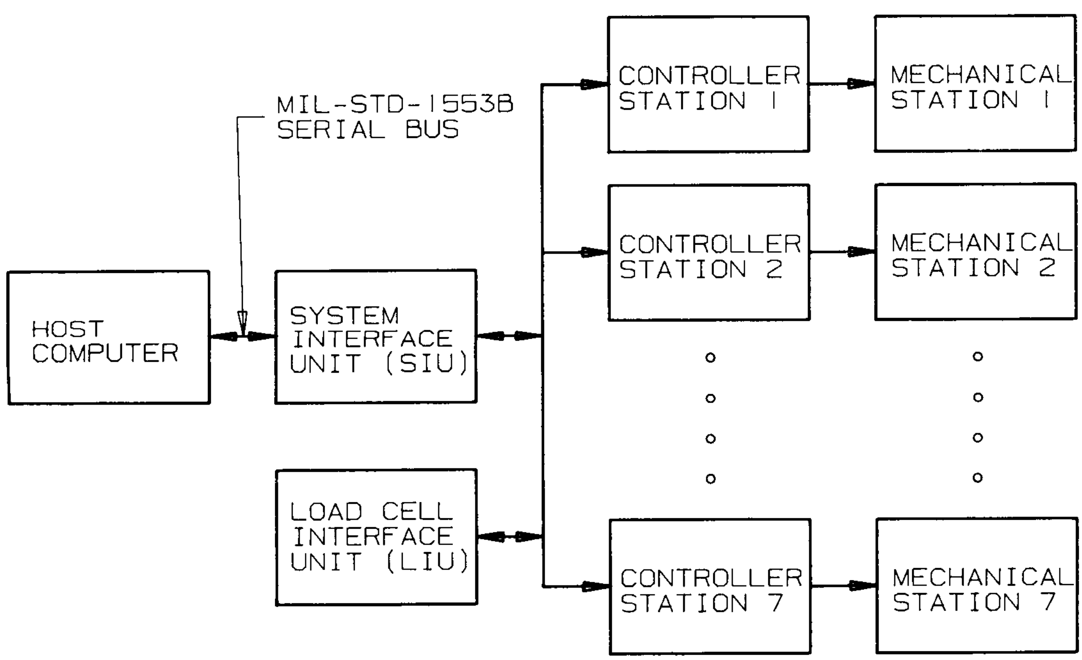


MOTOR ASSEMBLY

FIGURE 8



SURFACE CONTROL SYSTEM

FIGURE 9