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SURFACE CONTROL SYSTEM FOR THE 15 METER HOOP-COLUMN ANTENNA

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INTRODUCTION

The 15-meter hoop-column antenna shown in figure 1 was fabricated by the Harris Corporation under contract to the NASA Langley Research Center. The antenna is a deployable and restowable structure consisting of a central telescoping column, a 15-meter-diameter folding hoop, and a mesh reflector surface. The hoop is supported and positioned by 48 quartz cords attached to the column above the hoop, and by 24 graphite cords from the base of the antenna column. The RF reflective surface is a gold plated molybdenum wire mesh supported on a graphite cord truss structure which is attached between the hoop and the column. The surface contour is controlled by 96 graphite cords from the antenna base to the rear of the truss assembly. The antenna is actually a quad-aperture reflector with each quadrant of the surface mesh shaped to produce an offset parabolic reflector. A detailed description of the antenna development is given in references 1, 2, and 3.

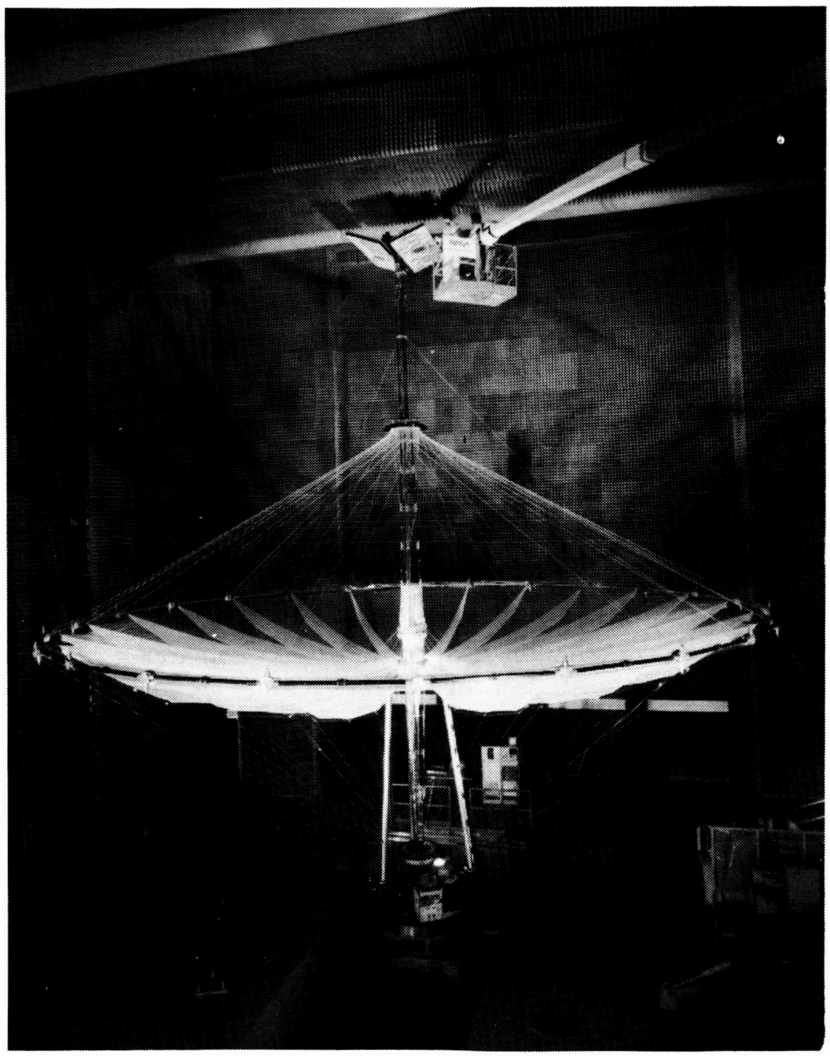

Figure 1

NEAR-FIELD AND STRUCTURAL TESTS

Tests to determine the trueness of the surface, RF characteristics, and limited structural characteristics of the antenna were conducted at the Martin Marietta Near Field Test Facility in Denver, Colorado (reference 4). Tests to more completely investigate the structural characteristics of the antenna were conducted at the NASA Langley Research Center (reference 5). The tests included adjustment of the antenna surface control cords to improve the surface quality of the reflector. This was a manual operation requiring as much as 8 hours to perform, and was limited in accuracy to approximately 0.01 inch. The time required to perform the photogrammetric measurement of the reflector surface and to perform the adjustment limited the number of adjustments which could be performed. Results of the tests indicate that: the first side lobes are dependent on the quality of the surface, large space antennas should be provided with surface adjustments, a linear approximation to the structural model provides adequate predictions for small movements of the control cords, further testing requires an improvement in both the speed and accuracy of the surface adjustment, and real time surface measurement is required.

SUMMARY OF TEST RESULTS

- Antenna performance is high.
- First side lobes are dependent on surface quality.
- RMS surface errors reduced more than 34% by control cord adjustment.
- Linear analysis adequate to predict small length changes.
- Large space antennas should be designed to permit surface adjustment.

Figure 2

A new series of CSEI tests will begin in the fall of 1987. These tests will be performed on the existing antenna with the addition of a single quadrant surface control system and surface measurement sensors. Investigations will focus on improving the reflector surface figure, the use of adaptive feed for distortion compensation, real time surface figure measurements, real time closed-loop surface figure control (reference 6).

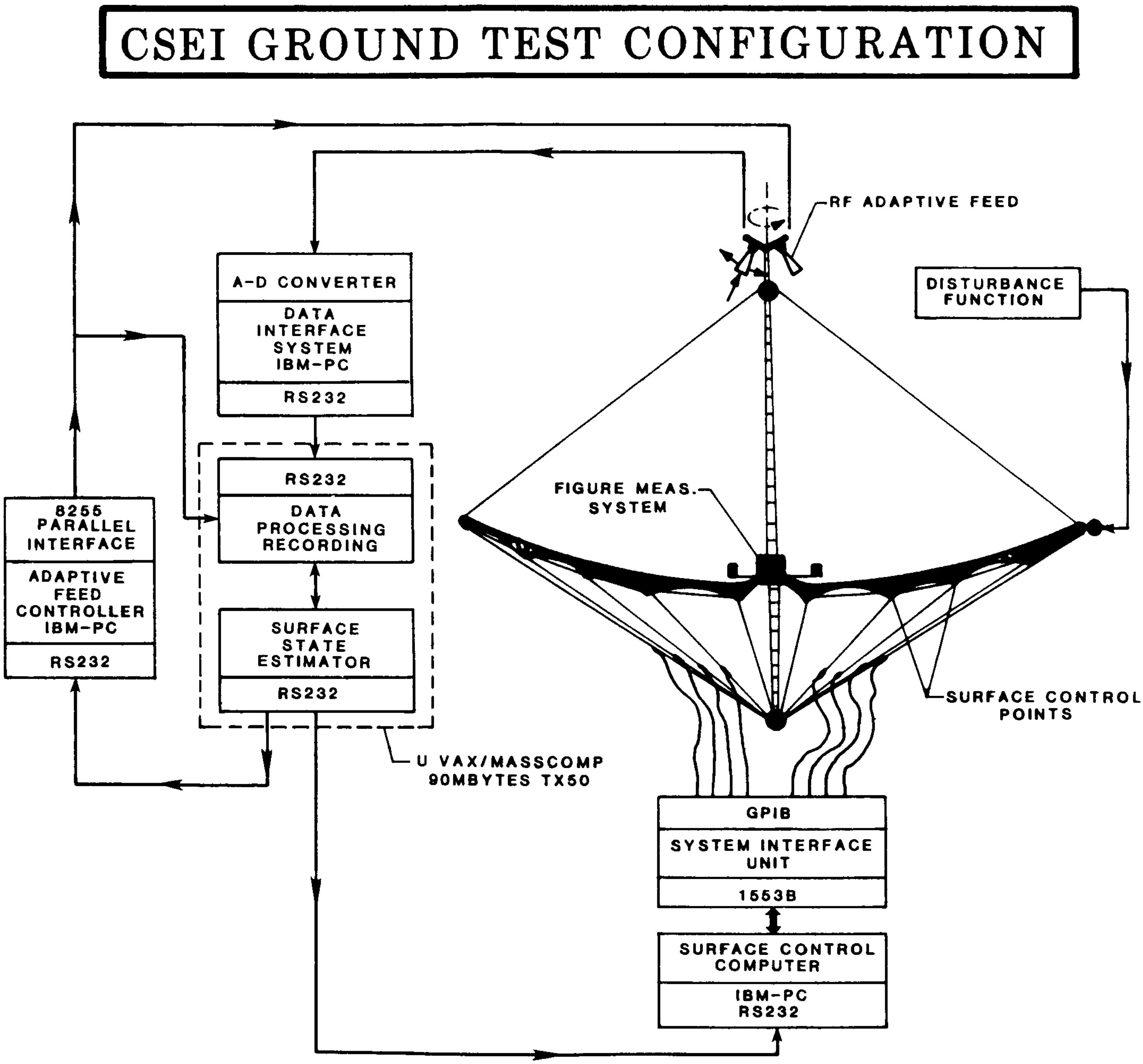

Figure 3

SURFACE CONTROL SYSTEM REQUIREMENTS

The requirements for the surface control system have evolved from the CSEI program requirements. The surface control system serves a dual role in the context of the CSEI program. It is the object of investigation in the case of surface control and control dynamics, and is a test vehicle in the adaptive feed and the real time surface measurement investigations. The primary requirement driving the design is that the surface control system must fit into the existing base structure and permit deployment and restow of the antenna. The actuator control system requirements are summarized in figure 4. The range of motion has to be maximized to the mechanical limits to permit correction for, or introduction of, large variations of the surface contour. The accuracy and resolution have been set based on the results of simulations and test results. Actuator bandwidth is being maximized to permit operation of the control actuators into the range where dynamic interactions between the surface control system and surface structural modes can be examined. System update rate has been selected to minimize the time required to make small changes in the surface contour for the adaptive feed and surface measurement tests. Load monitoring is provided for personnel and equipment safety.

SYSTEM REQUIREMENTS

- Retrofit to existing antenna base.
- Antenna must deploy and restow.
- Control one quadrant (28 cords).
- Stroke : ± 0.75″
- Load : 25 lb
- Accuracy/Resolution :±0.002/0.0001″
- Actuator bandwidth : 4 Hz (0.50″)
  10 Hz (small signal)
- System Update Rate : 100 Hz
- Provide Load Monitoring.
- Provide a standard computer interface.

Figure 4

The surface contour of each quadrant is controlled by 28 graphite cords which are attached between the antenna base and the surface rear truss assemblies. Each of the rear trusses has 4 control cords attached to it (figure 5). The desired adjustment is achieved by controlling the length of these cords. As noted earlier, adjustment of the present manual system requires extended periods of time and is limited in accuracy to approximately 0.010 inch.

SURFACE CONTROL GEOMETRY

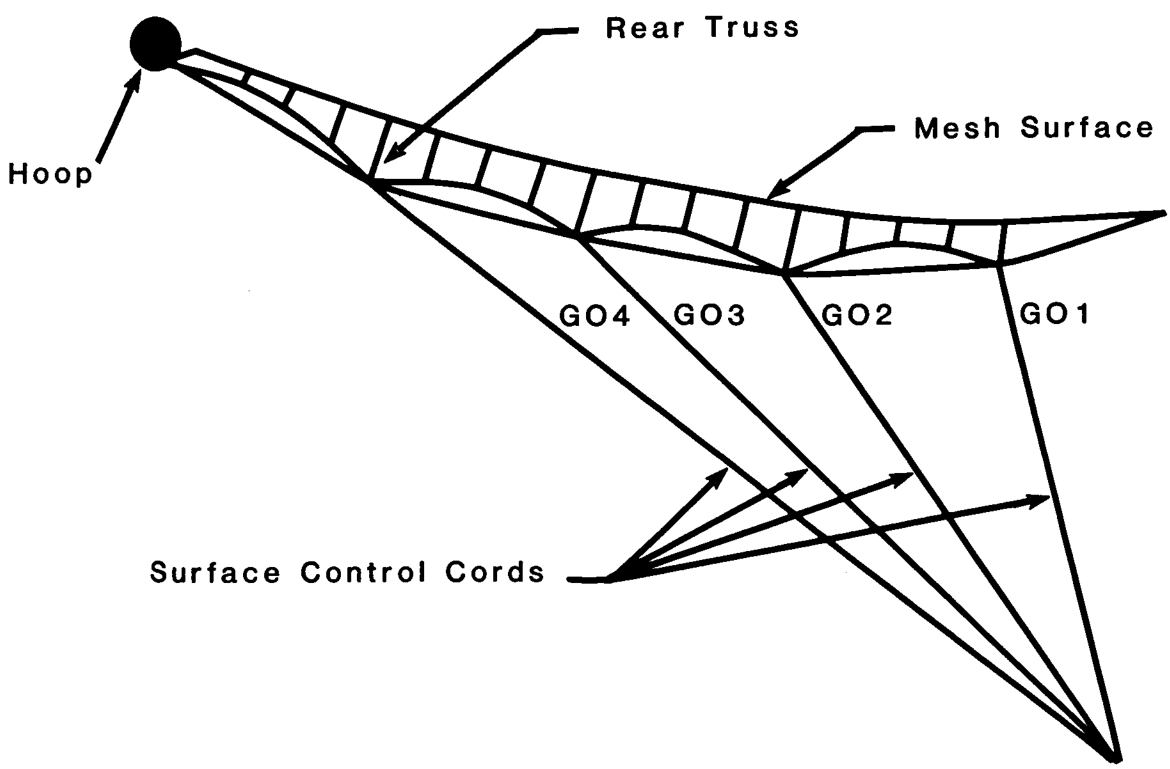

Figure 5

ANTENNA BASE AND STOP BLOCK ASSEMBLIES

Each of the surface control cords and the lower hoop cords pass through the stop blocks on the antenna base assembly (figure 6). In the stowed configuration, the cords are wound onto drums under the base plate. As the antenna is deployed, the cables unwind from the drums and feed through the stop blocks. When the cords reach full extension, a bead which is bonded to each cord is engaged in the stop block (figure 7). The space available for the automatic surface adjustment mechanism is limited to the area occupied by the stop block assemblies and the area under the base plate.

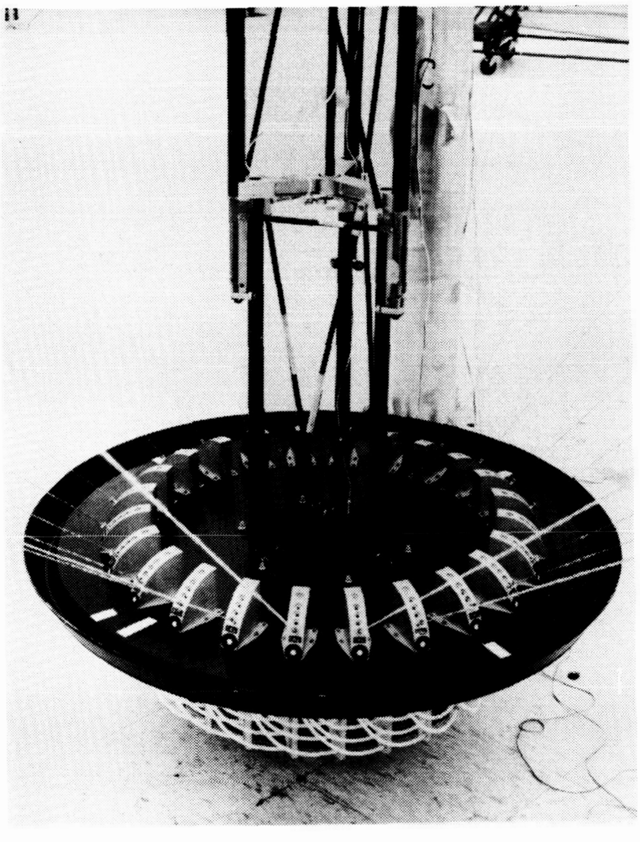

Figure 6

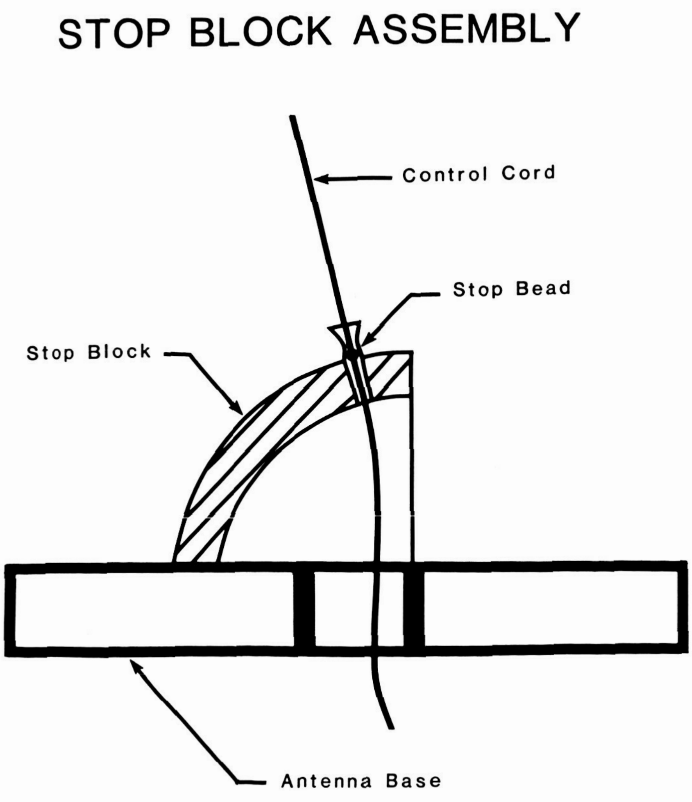

Figure 7

SURFACE CONTROL SYSTEM ACTUATOR ASSEMBLY

The surface control system consists of the 28 cord position control actuators located in 7 actuator assemblies, and the control electronics. Each of the actuator assemblies contains four motor driven actuators and a modified stop block assembly. Each actuator consists of a torque motor, gearhead, incremental encoder, brake, arcsector/encoder, actuator cable and a spring-loaded position control piston (figure 8).

Position commands from the host computer are compensated for variations in actuator cable strain and converted to arcsector position commands. The position of the arcsector is sensed by the encoder attached to the motor shaft and referenced to a simple absolute position sensor which is incorporated in the arcsector assembly. The controller drives the torque motor to position the arcsector to the commanded position. The actuator cable which is attached to the arcsector positions the spring-loaded control piston which in turn positions the actuator surface control cord. The control piston captures the surface control cord bead in the same manner as in the original stop block assembly. The brake is used to prevent back driving of the system when the torque motor is not energized.

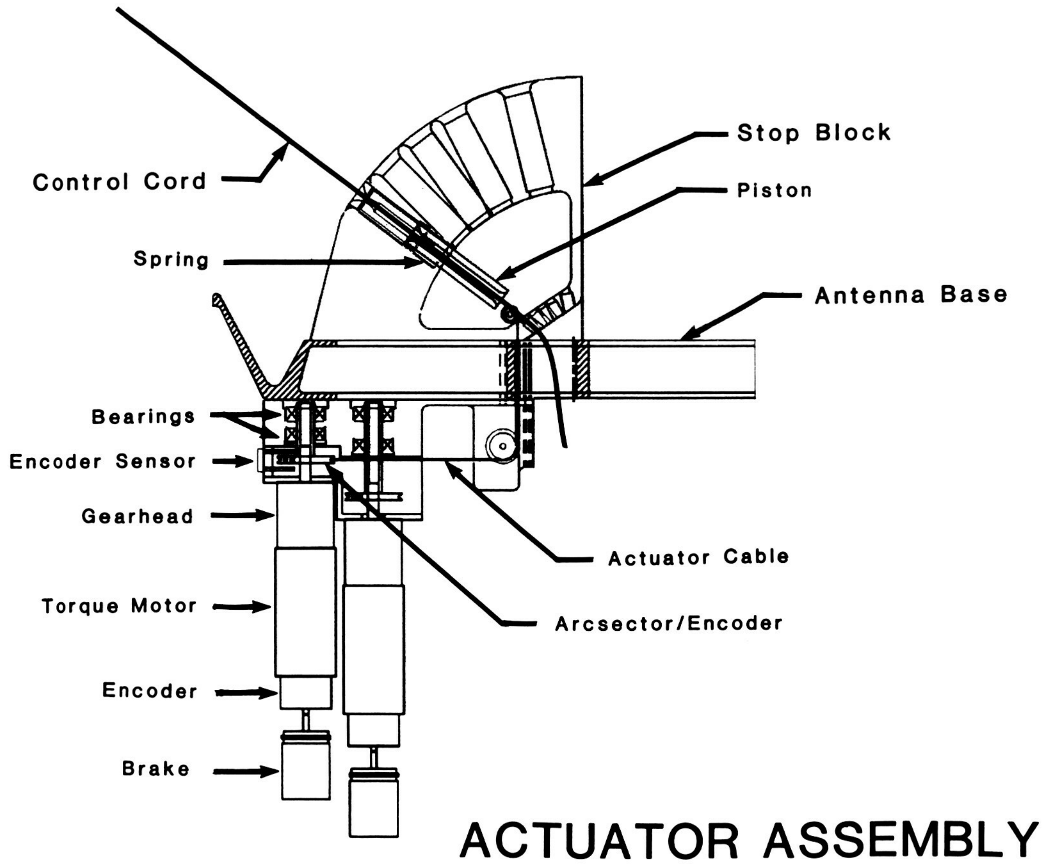

Figure 8

The control electronics consist of seven station controllers and a system interface unit (figure 9). The system is interfaced to the host via a MIL STD-1553B serial communications bus. The seven station controllers are connected to the system interface via an IEEE-488 general purpose parallel interface bus. The dual bus structure was selected to provide ease of development, flexibility in test, upward host computer compatibility, and acceptable cost. The MIL-1553B bus provides a redundant, error detecting, noise immune interface from the antenna base to the host computer. The MIL-1553B bus requires only a dual twisted shielded pare cord, so it is ideal for large space structure applications. The IEEE-488 bus provides a simple inexpensive fast local interface to the seven station controllers which are located within a few inches of one another. The IEEE-488 bus also permits the individual station controllers to be interfaced directly to a host during development testing.

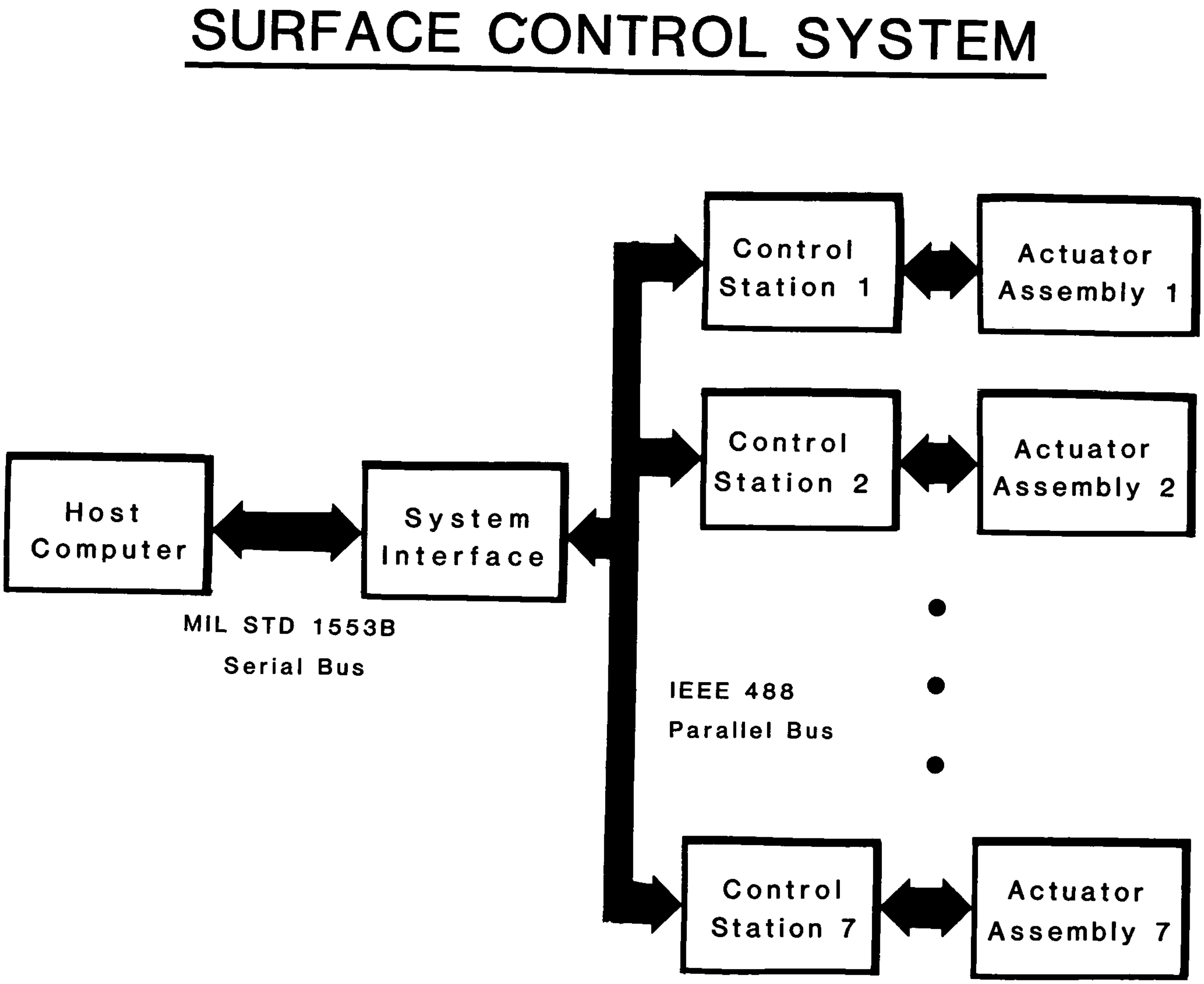

Figure 9

The system interface unit appears to the host as a remote terminal on the MIL-1553B bus. It interprets commands and data arriving on the MIL-1553B bus and routes them to the appropriate controllers via the IEEE-488 bus. The system interface also collects data from the controllers and formats it for insertion onto the MIL-1553B bus.

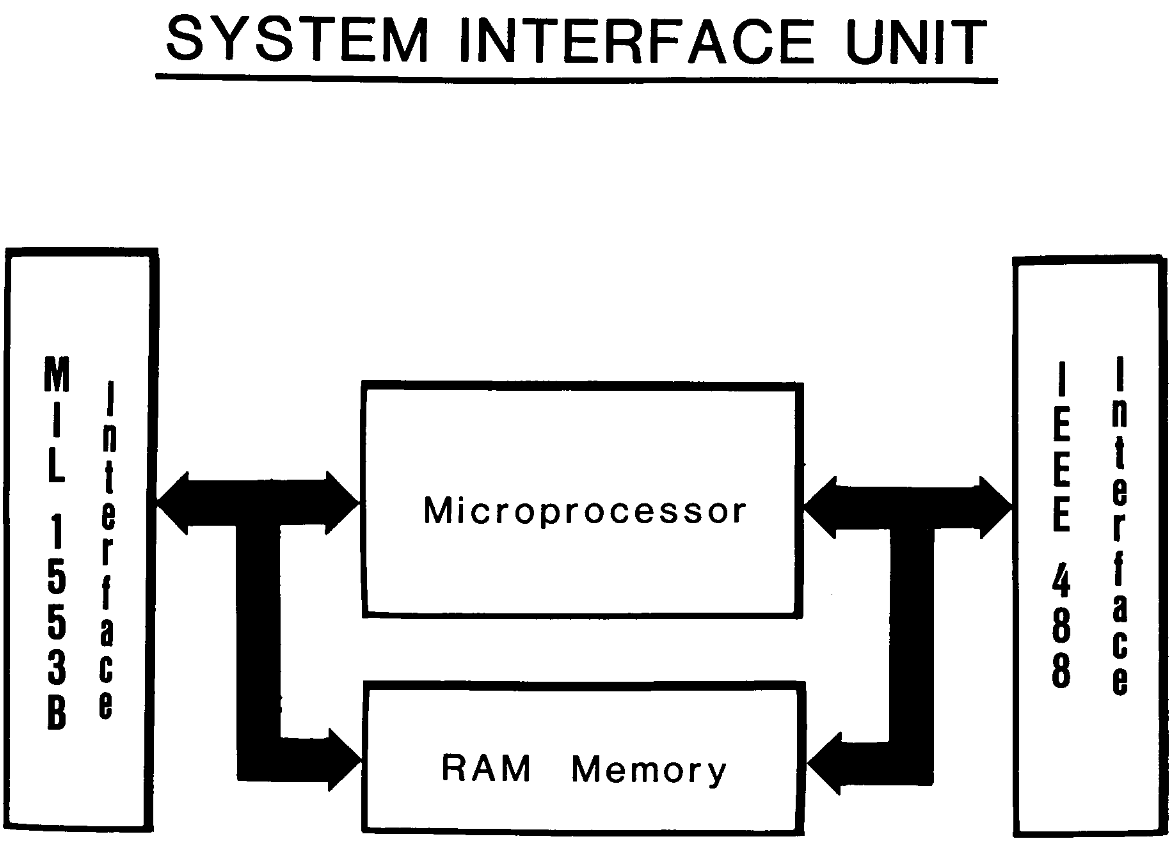

Figure 10

CONTROL STATIONS

Each control station contains an IEEE-488 bus interface, a microcontroller, four motor controllers and drivers (figure 11). The microcontroller interprets incoming commands and data, performs compensation for cord strain, collects and formats output data, controls operation of the brake, monitors the cord position and load limits, and provides operational error detection and recovery. The motor controllers keep track of the encoder position, compute position/velocity errors, compensate the error signals, and produce a pulse width modulated (PWM) drive command to the motor drive circuit. The motor drive circuit is a modified H bridge circuit which provides current drive to the motor which is proportional to the PWM command.

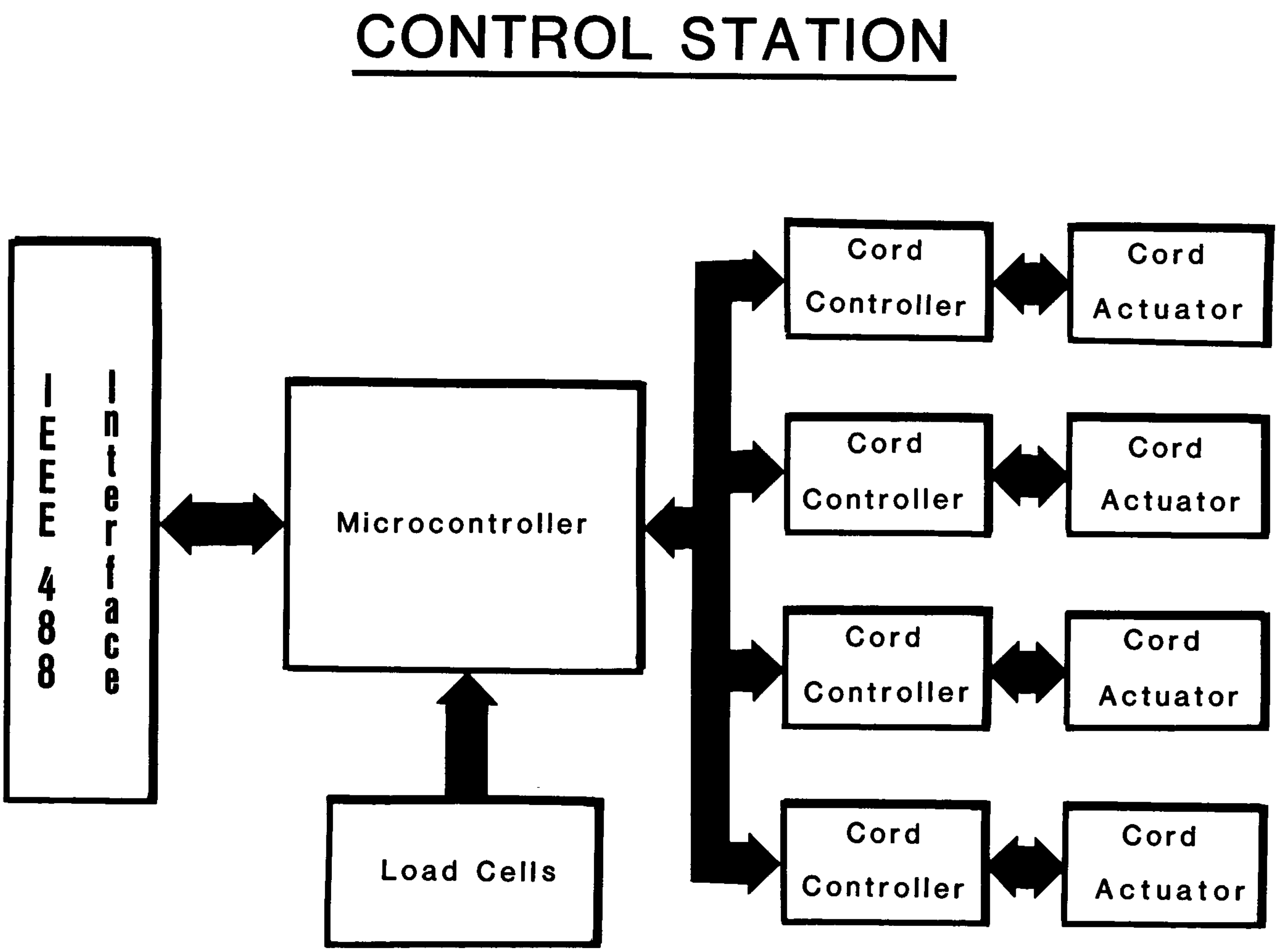

Figure 11

The surface control system actually consists of three cascaded systems (figure 12). The measurement of the surface contour in real time is in itself an area which will be investigated during the CSEI program, and could not be incorporated into the initial control system design. Thus, the position of each cord junction at the rear truss assembly is an open-loop function of the position of the control piston. Since the limited space available on the base prevented direct measurement of the cord control pistons, these, too, formed open-loop systems cascaded onto the closed-loop arcsector position controllers. To minimize the effect of the actuator cable and piston spring mass system, the piston assembly has been designed to maintain a preload on the actuator control cable, arcsector, and gearhead; and the piston assembly has been designed with a resonance more than a decade higher than the desired control bandwidth. As noted earlier, corrections are made to minimize the effects of actuator cable strain on the accuracy of piston positioning.

Analysis and simulations have been performed which indicate that the position control system, a prototype of which is presently being fabricated, will meet or exceed all of the system requirements.

SIMPLIFIED CONTROL BLOCK DIAGRAM

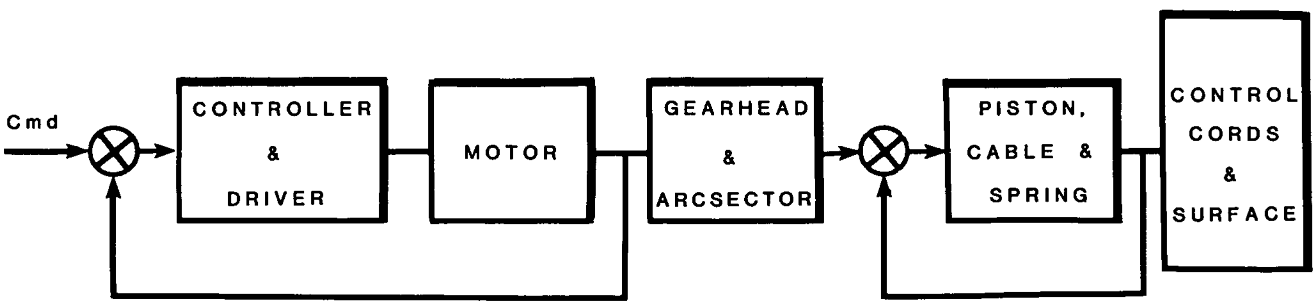

Figure 12

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