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Dynamic and Thermal Response Finite Element Models of Multi–body Space Structural Configurations

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DYNAMIC AND THERMAL RESPONSE FINITE ELEMENT MODELS OF MULTI-BODY SPACE STRUCTURAL CONFIGURATIONS

By

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Presented is structural dynamics modeling of two multi-body space structural configurations. The first configuration is a generic space station model of a cylindrical habitation module, two solar array panels, radiator panel and central connecting cube. The second configuration is a 15 meter hoop column antenna. Test and analytical eigenvalues for both configurations are referenced. Discussed is the special joint elimination sequence used for these large finite element models, so that eigenvalues could be extracted.

The generic space station model aided test configuration design and analysis/test data correlation. The model consisted of six finite element models, one of each substructure and one of all substructures as a system. Static analysis and tests at the substructure level fine-tuned the finite element models.

The 15 meter hoop column antenna is a truss column and a structural ring interconnected with tension stabilizing cables. To the cables, pretensioned mesh membrane elements were attached to form four parabolic shaped antennae, one per quadrant. Imposing thermal preloads in the cables and mesh elements produced pretension in the finite element model. Thermal preload variation in the ninety six control cables was adjusted to maintain antenna shape within the required tolerance and to give proper pointing accuracy.

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SUMMARY

The purpose of this paper is to present the recent application of structural modeling of a generic space station test configuration and a 15 meter hoop column antenna utilizing the Engineering Analysis Language (EAL) finite element program, Ref. 1.

The technical areas of interest are:

1. Development of the generic space station finite element model.
2. Development of the 15 meter hoop column antenna finite element model.
3. Development of the joint elimination sequence order that was required to reduce the large number of degrees-of-freedom EAL models to manageable computational size.
4. Comparison of derived frequencies and mode shapes with test.

The first section of this report discusses the development of the generic space station finite element model. For a more detailed description of the generic space station model see Ref. 10.

The second section of this report discusses the development of the 15 meter hoop column finite element model. This includes the details of the full 8816 degree of freedom model and the reduced 996 degree of freedom model.

The third section of this report discusses the joint elimination sequence order used for the generic space station model and for the 15 meter hoop column antenna.

The fourth section of this report compares the dynamic response data from test with the analytical data for the generic space station model and for the 15 meter hoop column antenna. Shape control test and analytical data for the 15 meter hoop column antenna is included in this section.

Results indicate that the EAL models give good agreement between analytical and measured data. In both models, the static test data was found to be useful in defining some of the finite element input data. Also, the joint elimination sequence order was found to be important in order to perform the eigenvalue solution of large finite element models using EAL.

GENERIC SPACE STATION MODEL

Verification of space station structural dynamic mathematical models requires careful analysis and ground testing. The size and flexibility of the space station conceptual configuration, Ref. 1, may defy conventional testing of assembled flight hardware. Verification of the analysis must be performed through ground tests of scale models and/or full scale substructures. Even so, these ground test articles may be quite flexible. The interaction of this flexibility with the suspension system, which is required to react gravity loads, may lead to uncertainties in the ground test results.

The vibration characteristics of a structure can be affected during ground testing by a number of factors such as suspension system response, residual gravity effects and ambient air loading. Suspension systems add stiffness to the structure and often result in coupling of low frequency structural modes and suspension system modes. Gravity loads can either increase or decrease the overall stiffness of a structure. Ambient air has both an apparent mass effect and a viscous damping effect. Scale model testing reduces the magnitude of these effects; however, joints and other key components of structures are difficult to scale due to minimum gage and tolerance restrictions.

The NASA Langley Research Center has a continuing program to improve ground test and analysis methods for extraction of the vibration characteristics of structures. As part of this program, a generic dynamic model has been designed and fabricated to assess the accuracy of analysis and test methods currently used in ground vibration testing. The configuration of the test model is a multi-body system consisting of five substructures. The substructures are a semi-monocoque cylindrical habitation module, a square honeycomb sandwich radiator panel, two long slender honeycomb sandwich solar arrays and a connecting cube. The interfaces among the four functional substructures and the connecting cube are identical allowing complete interchangeability for different configurations.

This report describes the analytical models used to predict the structural response. The finite element models used for prediction of test data are described in more detail in Ref. 10.

INTRODUCTION

Prior to the design of the space station reference configuration, Ref. 1, numerous space station concepts were evaluated. Typical among these concepts was the Space Operation Center (SOC), Ref. 2. The SOC configuration consisted of cylindrical modules, solar array and radiator panels and interconnecting tunnels. The study herein used the elements of the SOC configuration to form a generic model as shown in Fig. 1. Photographs of the generic model are shown in Ref. 10. The model generality was maintained by designing each substructure with common interfaces. This scheme permitted the substructures to be rearranged to form different configurations. The substructures are attached with quick release marmon clamps. Marmon clamps allow each of the functional substructures to be rotated relative to the connecting cube and result in additional configuration flexibility.

The design of the substructure dimensions and stiffness was based on the expected use of the model. The intent was to simulate the general vibration characteristics of scaled space station models. Although no scale factor could be chosen in the absence of a full scale design, the frequencies of full scale components could be estimated by preliminary calculations as shown in Ref. 3. The estimated full scale fundamental flexible body frequencies are

Habitation Module	≈	10. Hz
Radiator	≈	1. Hz
Solar arrays	≈	0.1 Hz

To simulate a dynamically scaled model, the vibration frequencies of the model are increased inversely proportional to the scale factor. The substructures of the test model were designed with an approximate dynamic scale factor of 1/10. Thus, model substructure frequencies were chosen in the range of one order of magnitude greater than full scale.

The model habitation module is a relatively stiff substructure ($f_1 \approx 100$ Hz) and acts as a rigid body relative to the other substructures. Since preliminary calculations showed minimal changes in stiffness due to internal pressure, the habitation module was not pressurized during analysis or test. The radiator panel is a structure of moderate stiffness ($f_1 \approx 10$ Hz) whereas the solar arrays are quite flexible ($f_1 \approx 1$ Hz). The solar arrays were constructed with six nearly square honeycomb sandwich panels that were bolted together at their tongue-and-groove interface joints. This construction allows flexibility to add or remove panels to change the frequency of the solar arrays as desired. The connecting cube used to attach the assemblage is very stiff ($f_1 = 300$ Hz) and can be treated as rigid.

A major design consideration was the ability to test and correlate with analysis the substructures separately and as an assemblage of substructures. The modular concept described above permits these tests provided a ground test suspension system can be designed to prevent overstress of the structures due to their own weight. Two suspension systems were designed for the tests. First, a backstop fixture with a marmon clamp interface was designed to permit each substructure to be attached to a backstop for static and dynamic cantilever tests. The second suspension system consisted of cables attached to the substructures at strategic locations to simulate, as far as possible, free-free boundary conditions. Cable suspension was used during each substructure test and during the assemblage tests.

The final consideration of the design was to permit the ability to slue the solar arrays. Sluing is a large-angle transient maneuver that can produce substantial vibrations in flexible structures. For example, Ref. 4 describes the sluing response of flexible beam-like structures. The solar array support structures were hinged so the solar arrays could be rotated out-of-plane 180 degrees. However, all modal vibration tests were performed with the solar arrays locked in the position shown in Fig. 1 and 2. Vibration suppression tests have been performed using the root torque motor as an actuator.

The assembled generic model is shown in Ref. 10 suspended in the NASA Langley Research Center 16-meter vacuum chamber. The structure schematic, shown in Fig. 1, indicates the principal dimensions and design features. The assembled configuration weighs about 195 pounds. The solar panel tip-to-tip width of the model is 348.60 inches and the overall length is 144.31 inches. All of the major components are made from 6061-T6 aluminum. This material was selected because of ease of fabrication, cost, and high strength-to-weight ratio. The 25.75 in. diameter by 68.61 in. long habitation module has a 0.032 in. thick skin and is a semi-monocoque 3-bay ring stiffened cylinder with conical ends. The solar arrays are made of six nearly square aluminum honeycomb sandwich panels that are bolted together at the tongue-and-groove joint interfaces to make a total panel size of 150.47 in. by 25.24 in. The radiator is a single 46.75 in. square aluminum honeycomb sandwich panel oriented 90 degrees relative to the plane of the solar panels. The connecting cube consists of a framework of welded stiffeners with six interface rings all of the same size for interchangeability so that substructures can be attached to any of the six sides.

For a more detailed description of the substructure hardware and fabrication detail see Ref. 10. Data contained in Ref. 10 may be used to determine exact dimensions. Also, mass information for the experimental model may be obtained in the mass properties section.

SPACE STATION ANALYTICAL MODEL

The Engineering Analysis Language (EAL) finite element program, Ref. 5, was chosen to study and evaluate the generic model vibration modes and natural frequencies. Prestressed vibration analysis was performed to include gravity load effects. Six analytical models were developed, one for the assemblage of substructures and one for each substructure. The assemblage model is formed by rigidly connecting the substructure models at the appropriate interface nodes. Assemblage model interface nodes and substructure interface nodes have identical grid point numbers.

Figure 2 shows the undeformed shape of the analytical EAL space station model without the cable suspension system. Figure 3 shows the model divided into its five substructure models and also indicates the degree of grid refinement used. The assembled model has 621 grid points with 3726 degrees of freedom. There are 652 beam elements, 2 rod elements, 56 three-node plate elements, and 472 four-node plate elements. Rigid link offsets have been used to model beam members whose neutral axis was offset from the grid point locations. The origin of the global coordinate system for the assemblage model is located at the center of the connecting cube with the positive 1-axis in the direction of the right solar array and the positive 3-axis in the direction of the radiator as shown in Fig. 2.

The grid point locations are defined for each model in Ref. 10. The complete tabulation of all of the grid point locations can be found in Tables 1-5 of Ref. 10. The plate, beam, and rod elements that connect these grid points are also defined for each substructure. The EAL section properties of the beam elements are shown in Ref. 10. The assemblage model will be described implicitly during the discussion of the five substructure models. If there is an element in substructure A and another element in substructure B at a common interface, the assemblage model has both the A and B elements at this interface.

Habitation Module

The first substructure model discussed is the three-bay habitation module. The habitation module was modeled in detail so that it would be available for future static analysis and provide accurate mass properties. The longitudinal station location of the plate elements and rings are shown in Fig. 4. The overall length is 68.61 in. and the maximum cylinder diameter is 25.57 in. The two end diameters are 6.50 inches. The longitudinal station locations are measured in the negative 3-direction from the origin which is located at the center of the connecting cube.

There are eight rings, each modeled as 16 straight beam elements around the circumference at each of the eight longitudinal stations shown in Fig. 4. All these rings, except the two end rings, are internal to the 0.032 in. thick skin. The two end rectangular rings at station -8.20 and -76.81 represent the lip of the marmon clamp and the stiffness of one half the marmon clamp. The two rectangular cross-section rings at the intersection of the smaller end cylindrical section and the conical section at station -10.00 and -75.01, represent the tapered part of the machined end ring that mates with the conical section. The two angle rings at the intersection of the conical sections and the center cylindrical section, at station -18.89 and -66.12, represent the tapered-flange angle of the internal splice ring. The two center internal tee rings at station -34.63 and -50.38, in the cylindrical section represent the stabilizing rings.

The plate elements consist of 0.032 in. thick rectangular plate elements in the center cylindrical portion and 0.032 in. thick trapezoidal plate elements in the two conical sections. The 0.100 in. thick plate elements at each end represents the wall thickness of the cylindrical portion of the machined end ring that has the marmon clamp lip at one end and a conical ring cross-section at the other end.

Connecting Cube

The second EAL substructure model to be discussed is the connecting cube shown in Fig. 5. The origin of the global coordinate system is at the geometric center of the connecting cube. The grid points on each facing of the cube are located 6.40 in. from the origin and represent the center line of the 0.064 in. thick skin. Each cylinder extends 1.80 in. from the cube facing so that the attachment interfaces are 8.20 in. from the origin. The model has six attachment cylinders that have their grid points located on a 6.50 in. diameter. In Fig. 5, the aft, top and left faces are shown. Some of the grid points are shown.

There are six clamp rings located 8.20 in. from the origin on each of the six faces. There are 16 rectangular beam elements located at each interface location. At the intersection of the facing and the attachment cylinder there is a second ring of rectangular beam elements that represents the ring flange of the machined connecting cylinder subassembly. The cylindrical portion of this subassembly is represented in the model by sixteen 0.100 in. thick plate elements.

Along each of the twelve edges there are angle beam elements used to support the 0.064 in. thick skin. Also, there are 24 internal I-beam bending stiffeners. Four of these bending stiffeners connect the ring on each of the six faces to the edge beams. On the aft face there are 4 I beams connecting grid points 500 to 402, 504 to 406, 508 to 410 and 496 to 398. This I beam arrangement stiffens the entire connecting cube so that it can withstand the gravity induced bending loads when the substructures are attached to the connecting cube which is attached to the backstop.

There are 96 plate elements, sixteen on each face, connecting the ring beam members to the edge beam members as shown in Fig. 5. This figure shows the location of the 96 attachment cylinder plate elements, sixteen on each side of the connecting cube. On the aft face the first row 382, 383, etc. is at the clamp ring 8.20 in. from the origin while the second row 398, 399, etc. is at the ring 6.40 in. from the origin. There are 4 triangular stiffeners normal to each face, for a total of 24.

Radiator

The third EAL substructure model to be discussed is the radiator model shown in Fig. 6. As previously stated, the origin of the global coordinate system is at the center of the connecting cube, not shown. The interface, at station 8.20, has the same 6.40 in. diameter as the connecting cube and has the same grid points. The 2.15 in. long truss support cylinder is represented by sixteen plate elements between station 8.20 and 10.35. From station 10.35 to 20.75, the tubular truss structure is modeled with six beam elements. The aluminum sandwich honeycomb radiator is 46.75 in. square and subdivided into 64 five layer plate elements as shown in Fig. 6. There are beam elements around the four edges to represent the stiffness of the aluminum honeycomb edge stiffeners. The base beam along station 20.75 is a stiff T-shaped beam to which the tubular truss rings are welded and to which the sandwich honeycomb panel is attached. This beam is modeled using eight beam elements. Around the other three sides, the smaller sandwich aluminum edge members are all the same and are represented by 24 beam elements in the finite element model.

The 64 radiator sandwich honeycomb plate elements are shown. The five layer laminate plate elements have the same dimensions through the thickness as shown in Fig. 8. The same honeycomb sandwich was used for the radiator and the solar arrays. These layers consist of the two 0.020 in. thick facings, the two 0.007 in. thick adhesive layers and the center honeycomb core. The total thickness is 0.260 in. Young's Modulus for the 6061-T6 aluminum facing was 10.0E+6 psi and for the 0.007 in. adhesive layers the value of 3.0E+6 psi was used. The 5052 aluminum honeycomb core had a 0.125 in. hex cell size and a 0.001 in. wall thickness and contributed little to the total bending stiffness. Therefore, the extensional stiffness and bending stiffness of the core was set equal to zero and with the above properties, the effective adhesive thickness of 0.007 in. was calculated from static bending test data.

The radiator sandwich edge and base beam configurations consist of the eight T-shaped base beam elements that are 2.00 in. wide and the 24 rectangular edge beam elements that extend around the other three sides.

The radiator truss and ring beam elements and their connecting grid point locations are shown in Fig. 6. There are 6 tubular truss beam elements connecting the ring at station 10.35 with the base beam at station 20.75. There are 16 rectangular beam elements representing the truss ring at station 8.20 and 16 rectangular beam elements representing the interface ring at station 10.35. The 16 plate elements are 0.30 in. thick to represent the cylinder wall. The grid points are located at the center line of this wall thickness where the radius is 3.20 in.

Right Solar Array

The fourth EAL substructure model is the right solar array model shown in Fig. 7. The connecting cube-right solar array interface is 8.20 in. in the positive 1-coordinate direction from the center of the connecting cube. The solar array interface consists of a connecting cylinder with a bulkhead at the end closest to the solar array panels. A 5.00 in. by 0.50 in. L-shaped bearing and motor support beam is fastened to this bulkhead. A shaft, connected to the motor and supported by two bearings, is attached to the solar array panel assembly through a tubular truss structure. The size of the six bay panel assembly is 150.47 in. by 25.24 in.

The connecting cylinder has a 3.625 in. radius compared with the 3.25 in. radius of the connecting cube. To account for this difference in radius, the solar array connecting ring grid points were located at a radius of 3.25 in. and the cylinder plate element grid points were connected to a second row of grid points at a radius of 3.625 in. The interface ring grid points are common for the connecting cube and the right solar array. The ring grid points and the cylinder plate grid points were connected by stiff radial beam elements.

The six bay aluminum sandwich honeycomb panels were subdivided into 24 plate elements, four in each bay. There are beam elements along the four edges and cross beam elements at every second plate joint to represent the stiffness of the tongue and grove bolted joint that is used to attach the six bays together. A five layer laminate plate element was used as indicated in Fig. 8. These layers consist of the two 0.020 in. thick facings, the two 0.007 in. thick adhesive layers and the center honeycomb core. The total thickness is 0.260 in. This is the same sandwich honeycomb configuration used in the the radiator model.

The right solar array edge and cross beams consist of two T-shaped base beam elements, which are stiff 2.00 in. deep beams, so that the distributed panel loads can be transferred to the tubular truss. The 24 rectangular edge beam elements extend along the two sides. The ten (10) rectangular cross beams represents the tongue beam of one of the adjacent bays combined with the groove beam of the other adjacent bay. The two end cross beams represent the T-shaped tongue beam at the end of the last bay.

The right solar array truss, shaft and L support beam elements and their connecting grid point locations are shown in Fig. 9. There are four tubular truss beam elements connecting the shaft at 15.08 in. with the base beam at 23.83 in. There are five square shaft beam elements located at 15.08 in. The actual shaft is square in the center with a circular cross section machined at each end where the bearings and motor attachments are located. There are six rectangular beam elements representing the L support beam. This beam has a depth of 5.00 in. and a width of 0.50 in. and has an arm to support the motor at grid point 548 making it L shaped. The two bearing beam elements from grid point 542 to 546 and 541 to 544 had the same cross section as the support beam. The rotation of the shaft was modeled by defining two grid points at the same bearing location connected by a zero length beam element. These grid points are circled in Fig. 9. The zero length beam element stiffness properties are represented by a stiffness matrix (K). All of the off-diagonal terms of K are set equal to zero, whereas, the diagonal terms of K are set to zero for a pinned connection or to 1.0E+9 lb/in for a rigid connection.

The first bearing has common grid point numbers 546 and 547 and the second bearing has common grid points 544 and 545. The three extensional and two of the rotational degrees of freedom have a diagonal stiffness value of 1.0E+9 lb/in while the value of zero was used in the direction where free rotation was allowed. The model was also constructed so that a torsional spring could be inserted at the motor-shaft interface connecting grid points 548 and 549. Again, these are common grid point locations connected by a zero length beam.

There are 2 rectangular attachment stiffener beams that connect the center line of the L support beam at grid point 539 to the bolt locations at grid point 538 and 540. These beams were added to introduce the proper loads into the bulkhead shown in Fig. 10 at grid point 538 and 540 where the bulkhead is bolted to the L support beam. The 0.50 in. thickness is the thickness of the L support beam and the 1.75 in. width is set equal to the length of the beam. The two clamp stiffener beams represent two clamp angles which were used to lock the solar arrays at 90 degrees. These beams connected the bulkhead bolts at grid point 538 and 540 to the shaft grid point 3 to restrict relative rotation between the shaft and the bulkhead. The cable attachment and loop beam are described in the Cable Suspension System section.

The right solar array support bulkhead and support cylinder plate elements and their connecting grid points are shown in Fig. 10. There are four four-node plate elements and sixteen three-node plate elements in the bulkhead that are 0.440 in. thick. The support cylinder plate element connecting grid points are mapped in Fig. 10 so the first row of grid point numbers represent the connection to the bulkhead located 12.42 in. from the origin in the 1 direction. This row is designated $A_o, B_o....P_o$ in the figure. The second row of grid point numbers are located at the interface plane located 8.20 in. from the origin. This row is designated $A_i, B_i.....P_i$ in the figure. All grid points are located at a radius of 3.625 in.

The interface ring beams are located 8.20 in. from the origin. There are 16 circumferential beam elements representing the interface ring and half of the marmon clamp. These beam elements connect the inner row of grid points that are common with the connecting cube interface grid points. There are 16 radial beam elements that connect the ring beam elements at a radius of 3.25 in. to the cylinder plate elements located at a radius of 3.625 in.

Left Solar Array

The fifth EAL substructure model is the left solar array model shown in Fig. 11. This substructure is nearly identical to the right solar array model shown in Fig. 7. If the right solar array is rotated 180 degrees around the global 2 axis, the left model is the same as the right model except the location of the motor and the cable attachment points are pointing in the wrong direction along the 3 axis. The grid point locations for the right solar array were generated using the right solar array coordinate system while the grid point locations for the left solar array used the left solar array coordinate system. The right solar array coordinate system is rotated 90 degrees about the global 2 axis while the left solar array coordinate system is rotated -90 degrees about the global 2 axis.

SPACE STATION CABLE SUSPENSION SYSTEM

To support the test models in a gravity environment, a cable suspension system was used. Free-free boundary conditions were desired; however, cable suspension systems produce pendulum modes that can couple with flexible model modes. Preliminary analysis indicated that the first flexible structural frequency of the generic model would be about .5 Hz compared to the pendulum modes ranging from .05 to .15 Hz. Since the amount of dynamic coupling between suspension modes and structure modes is strongly influenced by the frequency separation, Refs. 7 and 8, it was felt that the suspension system would affect the free-free structure vibration characteristics. Therefore, the suspension system was included in the analytical models. The philosophy was to test and correlate with analysis all the modes including the suspension modes and then determine the free-free modes of the structure using the verified analytical models.

In the test program, two cables were attached to the vacuum test chamber ceiling and the other end was attached to the model. Dimensions of the suspension system are shown in Fig. 12. Each cable was offset 49.25 in. from the point where the 3 axis intercepts the ceiling and had a total length of 572. in. The cables were nominally 0.125 in. diameter steel with helically wrapped 3X7 strand construction. The cable density was measured to be 0.002447 lb/in. The same cables were used for the assemblage tests as for each of the substructure tests.

In the analytical models it was necessary to include the differential stiffness of the suspension system due to the gravitational loading. These cables were modeled as rod elements from the fixed attachment points at grid points 652 and 653 to the model attachment points. The cable to model attachment grid points for the substructure tests are identified in Ref. 10.

In the assemblage model, the cable to model attachment was formed by looping the cable around the solar array L support beams, as shown in Fig. 12. The cable loop triangle extends from grid point 1 to grid point 543 on the right L support beam, shown in Fig. 9. It was determined that the loop triangle produced rotational stiffness in the plane of the triangle. Thus, the two cables of the loop were modeled as a single beam element where the in-plane bending stiffness was set equal to the effective in-plane stiffness of the cable loop triangle.

SPACE STATION MASS PROPERTIES

The masses of the analytical models were based on weight measurements of selected parts and on area calculations from fabrication drawings. Each complete substructure also was weighed and this weight was compared with the analytical model weights. The measured and analytical model weight comparison is given in Table 1. The total weight of all substructures was measured to be 194.9 lbs and the analysis model predicts 196.45 lbs.

The assemblage model center of gravity is located only 0.334 inches from the origin, close to the center of the connecting cube. The mass moments of inertia in mass units, lb-sec^2-in, and center of gravity locations in the global coordinate system for all six models are given in Table 2.

15 METER HOOP COLUMN ANTENNA MODEL

INTRODUCTION

Verification of preloaded antenna structural dynamic mathematical models requires careful analysis and ground test methods. The vibration characteristics of antenna structures can be affected during ground testing by a number of factors such as the preload tension, gravity and ambient air. Preloads must be in static equilibrium. These preloads, plus the change in preloads due to gravity, must be in agreement with the preloads in the test structure. Gravity loads can either increase or decrease the overall stiffness of a structure. Ambient air has both an apparent mass effect and a viscous damping effect.

The NASA Langley Research Center has a continuing program to improve ground test and analysis methods for extraction of the vibration characteristics of structures. As part of this program, the 15 Meter Hoop Column Antenna with its flexible characteristics was used to assess the accuracy of analysis and test methods currently used in ground vibration testing. The configuration of the test model is a four quadrant parabolic antenna that has shape control by altering the tension in the control cables. The graphite and quartz cables are stretched between the outer hoop and the column mast. The mast is a triangular telescoping truss construction.

This report describes the analytical model of the 15 Meter Hoop Column structure. The dynamic test and analysis correlation was reported in Ref. 13.

The 15 Meter Hoop Column Antenna model is shown in Fig. 13. The design of the dimensions and stiffness was based on a scale model that could be tested in existing test facilities. The model is a relatively flexible structure ($f_1 \approx .07$ Hz) with a large number of mesh modes. The telescoping triangular truss mast has joint flexibility that couples with the flexible tripod support to mast attachment, making the bending mode difficult to correlate with the finite element model.

The suspension system designed to assimilate the free-free vibration test consisted of a single cable attached to the structure at a point above the center of gravity on the mast with a sleeve near the top of the mast to give the model rotational stability. Although cable suspension cannot completely simulate free-free conditions the analysis indicated that good correlation existed.

The deployment of the experimental model is shown in Ref. 11. The fully deployed vibration test configuration model supported on the tripod support is shown in Fig. 14. This structure schematic indicates the principal components and design features with the tripod support. The hoop ring diameter of the model is 295.275 inches(15m). All of the cables are either graphite or quartz. The hoop beam and mast truss elements are made of composite materials. The feed mast is a steel truss construction.

The 15 meter hoop is made of composite construction that has hinges located at 24 locations at 15 degree intervals around the hoop. The joints are partially fixed so that the joints are softer in bending then the basic ring elements. Because the joint stiffness could not be tested, it was assumed that the overall bending stiffness was close to a stiff joint condition so the finite element model treated these joints as fixed.

The following sections describe the analytical model. The hardware is described in Ref. 11. Mass information for the experimental model may be obtained from Tables 30 and 31.

The Engineering Analysis Language (EAL) finite element program, Ref. 5, was chosen to study and evaluate the 15 Meter Hoop Column model vibration modes and natural frequencies. Prestressed static and vibration analysis was performed. Gravity load effects were included. Analytical models were developed, one for a 45 degree segment and one with the complete 360 degree model. Unreduced models are labelled "full" in this report while reduced degree of freedom models are labelled "reduced". A procedure was used to reduce the number of degrees-of-freedom in the 360 degree model. In addition, there were three variations of the 360 degree model. One is supported by the tripod support structure and does not contain the feed mast; another is supported with the tripod support structure and includes the feed mast; and a third is supported by a steel cable and includes the feed mast.

FULL ANALYTICAL MODEL

Figure 14 shows the undeformed shape of the full analytical EAL 15 Meter hoop column model. The full model without the feed mast has 2096 grid points with 8816 degrees of freedom. There are 286 beam elements, 4664 rod cable elements and 2880 three-node web membrane elements. The origin of the global coordinate system for the model is located at the center of the triangular truss column at the vertical location 47.016 in. below the hoop with the Global 1 axis in the direction of the zero degree hoop location, the Global 2 axis in the direction of the 90 degree hoop location and the Global 3 axis up in the direction of the feed mast as shown in Fig. 14. The 3 legs of the tripod support structure and the corners of triangular truss construction are located at 37.5 degrees, 157.5 degrees and 277.5 degrees relative to the zero degree location on the hoop.

Each 90 degree segment of in-plane grid points define a parabolic antenna shape. In this report the first parabolic shape from 0 to 90 degrees is called the A quadrant. The B quadrant is from 90 to 180 degrees, the C quadrant is from 180 to 270 degrees and the D quadrant is from 270 to 360 degrees.

The analytical models will be described by first defining the grid point locations with a figure showing the grid points to establish visual orientation. The complete tabulation of the grid point locations can be found in Tables 3 and 4. Secondly, the membrane, beam, and rod elements that connect these grid points are tabulated in the subsequent Tables.

Grid Point Numbering System and Relative Locations

The finite elements and grid point locations in the 45 degree model, 1/2 of the A quadrant, will be described in detail. The 45 degree model can be expanded to the 360 degree model using the method of expansion discussed later.

To expand the 45 degree model to a 360 degree model, the new grid points in the 45 to 90 degree sector were located as mirror images of the grid points in the 0 to 45 degree sector. As shown in Fig. 15, the Global 1 and Global 2 dimensions in Table 3 were interchanged and the grid point number was incremented by 570. To complete the 360 degree model, all of the grid points with 7 repeats in Table 3 are incremented by 550, seven times and the Global 1 and Global 2 dimensions are changed as shown in Fig. 15. The Global 3 dimension for all 7 repeats remained the same. The grid points with 0 repeats in Table 3 are at the center line of the mast and only appear once in the 360 degree model. The grid points in Table 3 with 3 repeats are on the 0 or 45 degree locations. These grid points were incremented by 1140 with 3 repeats, one for each of the other three quadrants. To determine the interchangeability of the Global 1 and Global 2 dimensions use the first 45 degrees of each quadrant in Fig. 15.

The grid points in Table 4 are located in the cylindrical coordinate system. Most of these grid points are on the mast with no repeats. The grid points with 3 repeats have their grid point numbers incremented by 1140 and have their angular dimension increased by 90 degrees for each of the 3 increments. The grid points with 7 repeats have their grid points incremented by 570. The first angular dimension is increased to 90 degrees minus the angular dimension in Table 4. This gives the 2 mirror image grid points located in the A quadrant. To obtain the grid points in the other three quadrants, these 2 grid point numbers are incremented by 1140 and the angular dimensions are incremented by 90 degrees, three times.

For the feed mast grid points in Table 4 with two repeats, the grid point numbers are incremented by 1 and the angular dimension is increased by 120 degrees, two times.

The surface grid points from 0 to 90 degrees define the shape of the first parabolic antenna in the A quadrant. The grid point expansion method described above takes the 0 to 90 degree A quadrant and rotates it 90 degrees, three times, to complete the 90 to 180 degree B quadrant, the 180 to 270 degree C quadrant, and the 270 to 360 degree D quadrant. The grid pont numbers in the 90 degree to 180 degree B quadrant were incremented by 1140 from the grid point numbers in the A quadrant. The grid point numbers in the 180 degree to 270 degree C quadrant were incremented by 2280 from the grid point numbers in the A quadrant. The grid point numbers in the 270 degrees to 360 degree D quadrant were incremented by 3420 from the grid point numbers in the A quadrant. These surface grid points define the four parabolic antenna shapes.

Sets of Cables at 15 Degree Increments

The first subset of the structural model discussed is the sets of cables at 15 degree increments around the hoop. The 45 degree model had four sets at 0, 15, 30 and 45 degrees located in the first half of the A quadrant. The 360 degree model had 24 sets of cables at each 15 degree increment around the 360 degree hoop.

These cables are used to control and stabilize the four parabolic shapes of the antenna. They are defined in this report as the 1st ray at 0 degrees shown in Fig. 16, as the 2nd ray at 15 degrees shown in Fig. 17, as the 3rd ray at 30 degrees shown in Fig. 18 and as the 4th ray at 45 degrees shown in Fig. 19. The numbers in these figures represent the grid point locations. The grid point locations are tabulated in Table 3.

Each ray of cables consists of 12 rod elements for surface control cables, 13 rod elements for beam cables, 19 rod elements for edge chord cables, 16 rod elements for catenary cables, 16 rod elements for vertical ties and 1 spreader bar cable, from grid point 7 to 147 for the 1st ray as shown in Fig. 16. The cable element connectivity, extensional stiffness, preload and weight per inch of length is tabulated in Table 5 through 8.

As described in the section titled "Grid Point Numbering System and Relative Locations", the 1st ray grid points at 0 degrees (Fig. 16) are incremented by 1140 to obtain the grid points at the 7th ray at the 90 degree location, the 13th ray at the 180 degree location and the 19th ray at the 270 degree location. The 2nd and 3rd ray shown in Fig. 17 and 18 have 7 repeats. The 4th ray as shown in Fig. 19 has 3 repeats. The grid point numbering system and coordinate locations are described in the previous section titled " Grid Point Numbering System and Relative Locations".

In-plane Cables, 1st Gore to 3rd Gore

The second subset of the structural model is the sets of in plane cables in each of the 24, fifteen degree arc segments, called gores in this report. The 45 degree model had 3 gores as shown in Fig. 20, 21 and 22. The 360 degree model has 24 gores. The grid point locations are tabulated in Table

3. The 1st gore in Fig. 20 shows the cables between the first ray at 0 degrees and the second ray at 15 degrees. The second gore and third gore are shown in Fig. 21 and 22 respectively. In these figures, the solid lines represent the cables in the parabolic surface, while the dashed lines represent the diagonal cables that slope down to the catenary cables shown in Fig. 17, 18, 19 and 20. The cable element connectivity, extensional stiffness, preload and weight per inch of length is tabulated in Table 9 through 11.

To expand the 45 degree model shown in Fig. 20, 21 and 22 to the 360 degree model, the three gores shown are duplicated for the remaining twenty one gores as shown in these figures. The 1st gore, shown in Fig 20, is repeated 7 times to establish the 6th, 7th, 12th, 13th, 18th, 19th and 24th gore. The 2nd and 3rd gore are also repeated 7 times as shown in Fig. 21 and 22. The grid point numbering system and coordinate locations are described in the section titled " Grid Point Numbering System and Relative Locations".

Hoop Beam Elements, Hoop Support Cables and Spreader Bars

The third subset of the structural model is the sets of hoop beam elements and the hoop support cables that connect the hoop to the top and bottom of the mast. There are 3 hoop beam elements in the 45 degree model. There are 24 hoop beam elements in the 360 degree model. At each of the 24 hoop beam grid points there are two upper hoop support cables attached to the top of the mast and a single lower hoop support cable attached to the bottom of the mast. The 45 degree model had 4 sets as shown in Fig. 23. The 360 degree model has 24 sets. The grid point locations are tabulated in

Table 3. The first set of three cables in Fig. 23 at 0 degrees shows the cables between the first ray grid point 6 on the hoop and grid points 2 and 119 at the top of the mast and to grid point 10 at the bottom of the mast. The second, third and fourth sets are also shown in Fig. 23. These mast grid points are located in Fig. 29 and 30. The two upper cables in each set have a spreader bar represented by two beam elements in the model. The center grid point 147 attaches to the spreader bar cable shown in Fig. 16. The hoop beam and spreader bar properties are tabulated in Table 15. The cable element connectivity, extensional stiffness, preload and weight per inch of length is tabulated in Table 12. The hoop beam elements were massless and their weight was represented by lumped masses.

The repeats are the same as those discussed for the rays. The 1st ray is repeated three times for the 7th, 13th and 19th ray location. The second ray is repeated seven times for the 6th, 8th, 12th, 14th, 18th, 20th and 24th ray location. The 3rd ray is repeated seven times for the 5th, 9th, 11th, 15th, 17th 21st, and 23rd ray location. The 4th ray is repeated three times for the 10th, 16th and 22nd ray locations. The grid point numbering system and coordinate locations are described in the section titled " Grid Point Numbering System and Relative Locations".

Triangular Web Mesh Membrane Elements

The fourth subset of the structural model is the sets of in-plane triangular membrane elements in each of the 24 fifteen-degree arc segments, called gores in this report. The 45 degree model had 3 gores as shown in Fig. 24, 25 and 26. The 360 degree model has 24 gores. The grid point locations are tabulated in Table 3. The 1st gore in Fig. 24 shows the web elements between the first ray at 0 degrees and the second ray at 15 degrees. The second gore and third gore are shown in Fig. 25 and 26 respectively. In these figures, all of the elements are in the first half of the parabolic surface A quadrant. The 1st, 2nd and 3rd gore triangular web properties are tabulated in Table 13. The first three columns identify the three corner grid points of each element. The fourth column denotes the membrane extensional stiffness in the direction from grid point A to B in pounds per inch of width. The fifth column denotes the extensional stiffness at 90 degrees to the A-B direction. The sixth and seventh column shows the web preload in pounds per inch of width in the A-B direction and 90 degrees to the A-B direction respectively. The shear stiffness of all elements is 0.41 pounds per inch of width. The mesh weight is 0.345E-04 pounds per square inch.

The repeats for the triangular web elements are identical to the gore cable elements. See the section titled "In-plane Cables, 1st Gore to 3rd Gore".

Mast Truss Beam Elements

The fifth subset of elements are the mast truss beam elements shown in Fig. 27. The grid point locations are tabulated in Table 3 and 4. The beam element connectivity, the bending stiffness, cross sectional area, torsional stiffness and type of mast truss element are tabulated in Table 14. The initial preloads in the mast truss beam elements, with the grid points fixed, was set to zero. When the correct boundary conditions with the preloads are imposed, the longerons and the diagonals are in compression. The Young's Modulus for all of the truss beam elements was 16.72E+06 psi.

The Global 3 dimensions of the mast grid points are shown in Fig. 27. Because the mast is deployable, the truss sections have different diameters. Each bay is made up of 3 longerons, 3 battens and 3 diagonals. The bays were attached to each other with semi-rigid radial beam elements, labeled "radial" in Section A-A of Fig. 27. There are nine additional semi-rigid beam elements connecting the truss to central grid points at the lower cable attachment location at grid point 1, at the center cable attachment location at grid point 196, and at the upper cable attachment grid point location at grid point 221.

Semi-Rigid Beam Elements

The sixth subset of elements are the semi-rigid beam elements used to offset the cable attachment points from the truss centerline grid point with beam elements as shown in Fig. 28.,29. and 30. In Fig. 28, there are 24 center cable/mast semi-rigid beam elements connecting the center grid point 196 to the 24 grid points on the circle. In Fig. 29, there are 48 upper cable/mast semi-rigid beam elements connecting the center grid point 221 to the 48 grid points on the two circles. The upper hoop support cables attach to these outer grid points as shown. In Fig. 30, there are 48 lower cable/mast semi-rigid beam elements connecting the center grid point 1 to the 48 grid points on the two circles. At the bottom of Fig. 30, the 24 lower hoop support cables attach to these outer grid points. At the top of Fig. 30, the 96 shape control cables attach to these outer grid points, 4 to each grid point. The grid point locations are shown in Table 3 and 4. The beam connectivity, the area moment of inertia,the cross sectional area, the torsional stiffness, and the type are indicated in Table 15. The hoop [illegible] preload compression stress was 925.21 psi. The mast to cable semi-rigid beam elements had a tensile stress of 3.509 psi. The Young's Modulus for the semi-rigid beam elements was 10.6E+06 psi. The elements and connectivity in Table 15 is for the 45 degree model. The section of the report titled "Grid Point Numbering System and Relative Locations" explains how this 45 degree model can be expanded to the 360 degree model.

Tripod Support Structure Beams Elements

The seventh subset of elements are the support structure beam elements shown in Fig. 31. The grid point locations are tabulated in Table 3. The beam element connectivity, the bending stiffness, cross sectional area, torsional stiffness and type of support structure element are tabulated in Table 16. The initial preloads in the support structure beam elements with the grid points fixed was set to zero. The Young's Modulus was 10.0E+06 psi.

Feed Mast Beam Elements

The eighth subset of elements are the feed mast truss beam elements shown in Fig. 32. The grid point locations are tabulated in Table 4. The beam element connectivity, the bending stiffness, cross sectional area, torsional stiffness and type of mast truss element are tabulated in Table 17. The initial preloads in the mast truss beam elements, with the grid points fixed, was set to zero. The Young's Modulus was 30.0E+06 psi. The weight density was .282 lb/cu in.

Lumped Masses at Grid Points

The lumped masses for the full hoop column antenna model are tabulated in Table 18 for the grid points of the 45 degree model. The number of repeats and the grid point increments are included, so that with Fig. 15, the 45 degree model can be expanded to the 360 degree model.

REDUCED 15 METER ANTENNA MODEL

The reduced analytical model was used to perform static and dynamic analysis in a more cost effective manner and the full analytical model was used when more exact results were desired for deflection and influence coefficient analysis for shape control and pointing accuracy.

Fig. 14 shows the undeformed shape of the reduced analytical EAL 15 Meter hoop column model. The reduced model, without the feed mast, has 241 grid points with 996 degrees of freedom. There are 75 beam elements, 600 rod cable elements and 96 four-node web membrane elements. The global coordinate system for the reduced model is identical to the full model as shown in Fig. 14. The 3 legs of the support structure and the corners of triangular truss construction are located at 37.5 degrees, 157.5 degrees and 277.5 degrees relative to the zero degree location on the hoop.

The reduced analytical models will be described in two steps. First the grid point locations are defined by a figure showing the grid points to establish visual orientation. The complete tabulation of the grid point locations can be found in Tables 19 and 20. Secondly, the membrane, beam, and rod elements that connect these grid points are tabulated in the Tables.

Grid Point Numbering System and Relative Locations

Most of the grid point locations in the reduced model are defined in the global coordinate system. The grid points in the first 90 degrees are described and tabulated in the tables. To expand the 90 degree model to the 360 degree model, the 0 to 90 degree segment was rotated 90 degrees, three times, to complete the 90 to 180 degree segment, the 180 to 270 degree segment, and the 270 to 360 degree segment. The grid pont numbers in the 2nd quadrant were incremented by 60 from the grid point numbers in the 1st quadrant and the angular 2 dimension is increased by 90 degrees. The grid point numbers in the 3rd quadrant were incremented by 120 from the grid point numbers in the 1st quadrant and the angular 2 dimension was increased by 180 degrees. The grid point numbers in the 4th quadrant were incremented by 180 from the grid point numbers in the 1st quadrant and the angular 2 dimension was increased by 270 degrees. For all quadrants, the radial 1 and vertical 3 dimensions remained the same.

To find the 1st through 6th ray grid point numbers and the cylindrical coordinate dimensions, use Table 20 for the the grid points located at 0, 15, 30, 45, 60 and 75 degrees. The 7th through 12th ray grid point numbers are incremented by 60 and the angular dimension is increased by 90 degrees. The 13th through 18th ray grid point numbers are incremented another 60 degrees and the angular dimension is increased another 90 degrees. The same procedure is used in the fourth quadrant for the grid points in 19th ray to the 24th ray. The tripod support and the feed mast grid points are incremented by 1 and the angular dimensions are incremented by 120 degrees. The upper ring grid point numbers are incremented by 10 and the angular dimension is incremented by 15 degrees. See Fig. 33,34,35 and 37 to see the location of the grid points in Table 20.

The grid points tabulated in Table 19 are dimensioned in the global cartesian coordinate system. All of these grid points on the centerline of the hoop column antenna. See Fig. 36,37 and 39 for the location of these grid points.

Sets of Cables at 15 Degree Increments

The first subset of the structural model discussed is the sets of cables at 15 degree increments around the hoop. The first set is shown in Fig. 33. The 360 degree reduced model has 24 sets of cables at each 15 degree increment around the 360 degree hoop. The grid point locations are tabulated in Table 20.

Each ray of cables consists of 4 rod elements for surface control cables, 5 rod elements for beam cables, 5 rod elements for edge chord cables, and 4 rod elements for vertical tie cables as shown in Fig. 33. The cable element connectivity, extensional stiffness, preload and weight per inch of length is tabulated in Table 21.

In the 360 degree model, the grid point locations at every 15 degree ray have the grid point numbers incremented by 10 and have identical properties as those shown in Table 21. The grid point numbering system is described in the previous section.

In-Plane Cables, 1st Gore

The second subset of the structural model is the sets of in plane cables in each of the 24, fifteen degree arc segments, called gores in this report. The first gore is shown in Fig. 34. The 360 degree model has 24 sets. The grid point locations are tabulated in Table 20 while the properties and connectivity are in Table 22. The 1st gore in Fig. 34 shows the cables between the first ray at 0 degrees and the second ray at 15 degrees. Each subsequent gore has their grid point numbers incremented by 10. The cable element connectivity, extensional stiffness, preload and weight per inch of length is tabulated in Table 22.

Hoop Beam Elements and Hoop Support Cables

The third subset of the structural model is the sets of hoop beam elements and the hoop support cables that connect the hoop to the top and bottom of the mast shown in Fig. 35. There are 3 hoop beam elements shown in Fig. 35. At each of the 24 hoop beam grid points, there are two upper hoop support cables attached to the top of the mast and a single lower hoop control cable attached to the bottom of the mast. The intermediate grid points were eliminated for the reduced model. The 45 degree model had 4 sets as shown in Fig. 35. The 360 degree model has 24 sets. The grid point locations are tabulated in Table 19 and 20. The first set of three cables, at the 0 degree location in Fig. 35, shows the cables between the first ray grid point 5 on the hoop and grid points 70 and 190 at the top of the mast and to grid point 253 at the bottom of the mast. The second, third and fourth sets are also shown in Fig. 35. The upper cable spreader bars have been removed from the reduced model. The hoop beam connectivity and beam properties are tabulated in Table 26. The cable element connectivity, extensional stiffness, preload and weight per inch of length is tabulated in Table 23.

Web Mesh Membrane Elements

The fourth subset of the structural model is the sets of in plane membrane elements in each of the 24, fifteen degree arc segments, called gores in this report. The first gore is shown in Fig. 34. The 360 degree model has 24 sets. The grid point locations are tabulated in Table 20. The 1st gore in Fig. 34 shows the web elements between the first ray at 0 degrees and the second ray at 15 degrees. The 1st gore web properties are tabulated in Table 24. The first four columns identify the four corner grid points of each element. The fifth column denotes the membrane extensional stiffness in the direction from grid point A to B in pounds per inch of width. The sixth column denotes the extensional stiffness at 90 degrees to the A-B direction. The seventh and eighth column shows the web preload in pounds per inch of width in the A-B direction and 90 degrees to the A-B direction respectively. The shear stiffness of all elements is 0.41 pounds per inch of width. The mesh weight is 0.345E-04 pounds per square inch.

Effective Mast and Semi-Rigid Beam Elements

The fifth subset of elements are the effective mast truss and semi-rigid beam elements shown in Fig. 36. The grid point locations are tabulated in Table 19 and 20. The mast effective beam element connectivity, the bending stiffness, cross sectional area, torsional stiffness and type of mast truss element are shown in Table 25. The initial preloads in the mast truss beam elements with the grid points fixed was set to zero. When the correct boundary conditions with the preloads are imposed the longerons and the diagonals are in compression.

The 24 semi-rigid beam elements are used to offset the cable attachment points from the mast centerline grid point with beam elements as shown in Fig. 36. There are 24 upper cable/mast rigid beam elements connecting the upper grid point 241 to the 24 grid points on the circle. The upper hoop control cables attach to these outer grid points as shown in Fig. 35. The grid point locations are shown in Table 20. Also, the beam connectivity, the area moment of inertia,the cross sectional area, the torsional stiffness, and the type are indicated in Table 26. The hoop element compression stress was 925.21 psi. The mast to cable beam elements had a tensile stress of 3.509 psi. The elements and connectivity in Table 26 is for the first 45 degrees of the full model. The section of the report titled "Reduced Model Grid Point Numbering System and Relative Locations" explains how this 45 degree model can be expanded to the 360 degree model.

Tripod Support Structure Beams Elements

The sixth subset of elements are the tripod support beam elements shown in Fig. 37. The grid point locations are tabulated in Table 20. Also, the beam element connectivity, the bending stiffness, cross sectional area, torsional stiffness and type of support structure element are found in Table 27. The initial preloads in the support structure beam elements with the grid points fixed was set to zero.

Feed Mast Beam Elements

The ninth subset of elements are the feed mast truss beam elements shown in Fig. 38. The grid point locations are tabulated in Table 19 and 20. Also, the beam element connectivity, the bending stiffness, cross sectional area, torsional stiffness and type of mast truss element are tabulated in Table 28. The initial preloads in the mast truss beam elements, with the grid points fixed, was set to zero.

Lumped Masses at Grid Points

The reduced model had the same lumped masses at the hoop and mast grid points as the full model. The single mast grid point on the mast center line combines the mass of the three grid points at the same station of the full model. The torsional mass moments of inertia were added to account for the radial mass offset to keep the torsional mass effects the same.

The lumped masses that were located on the cable and mesh full model grid points were removed from these locations, and 1/4 of these masses were assigned to the grid points on the hoop and 3/4 to the grid point where the center cables attach to the mast. The total mass being retained the same.

The reduced model lumped masses are tabulated in Table 29.

ANTENNA CABLE SUSPENSION SYSTEM

To support the test models in a gravity environment, a cable suspension system was used. Free-free boundary conditions were desired; however, cable suspension systems produce pendulum modes that can couple with flexible model modes. Preliminary analysis indicated that the first flexible structural bending frequency of the 15 meter hoop column antenna model would be low. Since the amount of dynamic coupling between suspension modes and structure modes is strongly influenced by the frequency separation, Refs. 7 and 8, it was felt that the suspension system would affect the free-free structure vibration characteristics. Therefore, the suspension system was included in the analytical models. The philosophy was to test and correlate with analysis all the modes including the suspension modes and then determine the free-free modes of the structure using the verified analytical models.

In the test program, a single cable was attached to the vacuum test chamber ceiling and the other end was attached to the model. Dimensions of the suspension system are shown in Fig. 39. The cable passes through a sleeve at the mast/feed mast interface to give the model rotational stability. The total length of the cable is 444 in. The cable was nominally 0.125 in. diameter steel with helically wrapped 3X7 strand construction. The cable density was measured to be 0.002447 lb/in.

In the analytical models, the cables were modeled as two rod elements. The first rod element was from the fixed attachment point to the cable to sliding grid point at the sleeve location. The second rod element extended from this sliding grid point to the cable attachment point. The two grid points with the identical coordinate locations, one attached to the mast and [illegible] second attached to the cable were used to impose multi point constraints such that there was relative sliding in the Global 3 direction with no relative motion in the Global 1 and Global 2 directions.

Analysis indicated that the pendulum modes did not agree with test. A closer examination indicated that the cable passed through a clearance ring at the top of the feed mast that did not have enough clearance causing a change in the pendulum modes. It was determined from the analysis that if the effective sleeve point was moved up 70. inches to station 281.00 on the feed mast, that the analytical modes matched the test modes. This location is shown in Fig. 38 and 39.

ANTENNA MASS PROPERTIES

The masses of the analytical models were based on weight measurements of selected parts and drawing weights. The measured and analytical model weight comparison for the full model is given in Table 30. The total weight of all substructures was measured to be 1142 lbs and the analysis model predicts 1141 lbs.

The model center of gravity with the hoop column and feed mast only is located 120.2244 inches from the origin in the Global 3 direction, or approximately 73.2 inches above the hoop. The mass moments of inertia in mass units, lb-sec^2-in, and center of gravity locations in the global coordinate system for the reduced model with hoop column and feed mast only are given in Table 31.

JOINT ELIMINATION SEQUENCE ORDER FOR EAL

The large number of degrees of freedom in the space station model and the hoop column antenna model required special elimination sequences to be developed. The EAL processor SEQ, which automatically determines the joint elimination sequence, produced a decomposition sequence that required excessive computer storage during stiffness matrix decomposition. To circumvent this problem, a user-defined elimination sequence was developed using the technique given in Ref. 6.

For the space station model the user-defined sequence was formed by first eliminating the grid points on the habitation module, starting at the end farthest from the connecting cube. Next, all of the grid points of the right solar array, starting at the end farthest from the connecting cube were eliminated. This procedure was repeated with the left solar array, then with the radiator and finally the remaining grid points of the connecting cube were eliminated.

For the hoop column antenna model, the large number of degrees of freedom required a special elimination sequence to be developed. The EAL processor SEQ, which automatically determines the joint elimination sequence, produced a decomposition sequence that required excessive computer storage during stiffness matrix decomposition and the eigenvalue solution could not be completed. The user-defined sequence was formed by first eliminating the grid points on the 1st ray at zero degrees shown in Fig. 16, then the in-plane grid points, shown in Fig. 20 between the 1st ray and the 2nd ray. Next, the grid points shown in Fig. 17 on the 2nd ray and then the in-plane grid points shown in Fig. 21 between the 2nd ray and the 3rd ray were eliminated. This procedure was repeated until the 360 degrees of the model was traversed. The final elimination was to eliminate the grid points on the mast, the support structure and the feed mast.

COMPARISON OF TEST AND ANALYTICAL DATA

The generic space station dynamic test and analysis correlation and the experiment method was reported in Ref. 9. This reference describes the effects of the coupling between the cable suspension system and the model and explains how the static and dynamic test data was used to verify substructure analysis models. Verification of analytical models on a substructure level reduced the uncertainty of the generic model analysis. The solar array substructure when refined using static test data, reduced the average frequency error from 8.1 percent to 2.8 percent.

The 15 meter hoop column antenna dynamic test and analysis correlation was reported in Ref. 12. This reference reports the comparison of test and analytical vibration modes of the full antenna model supported on the tripod without the feed mast. Also, the same configuration using the reduced model resulted in very good correlation of the global modes. The comparison of the test and analytical vibration modes for the configuration with the feed mast hanging on a single steel cable gave good correlation of pendulum and global modes using the reduced analytical model.

The 15 meter hoop column antenna quasi-static shape adjustment test and analysis is reported in Ref. 13. The full antenna model was used to derive the influence coefficients that were inputs to least squares error analyses used to minimize the surface distortion from a true parabolic shape. Application of the procedure resulted in a reduction of surface error by 38 percent.

SUMMARY REMARKS

A generic space station dynamic model and a 15 meter hoop column dynamic model have been designed and fabricated to study ground vibration test and analysis methods. Finite element models have been developed using the Engineering Analysis Language (EAL) program to predict the structural vibration modes and frequencies. Detailed descriptions of the test and analytical models are presented in this report and Ref. 10 and 11.

The generic space station dynamic test model consists of five substructures which can be interconnected in many configurations. Special features of the test model include quick release marmon clamps to fasten substructures together, torque motors to allow solar array sluing and vibration frequencies of less than one Hertz. Cable suspension systems were used in the ground vibration tests to simulate free-free boundary conditions.

Six analytical models were developed, one of each substructure and one of the assemblage. Special features of the analytical models are modeling of the effective honeycomb adhesive thickness, inclusion of the cable suspension system and modeling of distributed gravity loads.

Results of the generic space station modal vibration tests and analysis are documented in Ref. 9.

The 15 meter hoop column dynamic test model consists of three test configurations. Special features of the test model include adjustable surface control cables and vibration frequencies of less than one Hertz. A cable suspension systems was used in the ground vibration tests to simulate free-free boundary conditions.

Analytical models were developed, one of each test configuration and reduced models for cost effective dynamic analysis. Special features of the analytical models are the large size of the model (8816 degrees of freedom), inclusion of the cable suspension system modeled with differential stiffness, using thermal loadings to obtain correct preloads for shape control, and modeling of distributed gravity loads.

Results of the 15 meter hoop column modal vibration tests and analysis are documented in Ref. 12 and 13.

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Table 1. Measured and Predicted Model Weights

Substructure		Analysis (lbs.)	Measured (lbs.)
Habitation Module	plates	16.931	
	beams	4.703	
	lumped mass	2.530	
Total		24.164	23.9
Connecting Cube	plates	8.090	
	beams	9.896	
Total		17.986	17.6
Radiator	plates	12.620	
	beams	15.484	
Total		28.104	27.2
Right Solar Array	motor	8.010	
	bearings	6.380	
	plates	26.264	
	beams	22.446	
Total		63.100	63.1
Left Solar Array			
Total		63.100	63.1
Total Substructure Weight		196.454	194.9

Table 2. Center of Gravity and Mass Inertia Properties

Model	Global Coordinate (in.) X	Y	Z	Mass Inertia ($lb-s^2/in$) Ix	Iy	Iz
Habitation Module	0.0	0.0	-42.506	29.513	29.513	8.180
Connecting Cube	0.0	0.0	0.0	2.22	2.22	2.22
Radiator	0.0	0.0	28.535	33.812	24.181	9.935
Right Solar Array	54.26	0.0	1.915	9.741	441.6	432.01
Left Solar Array	-54.26	0.0	1.915	9.741	441.6	432.01
Assemblage	0.0	0.0	0.334	261.42	2073.6	1842.5

TABLE 3. JOINT LOCATIONS ON 15 METER ANTENNA IN GLOBAL CARTESIAN COORDINATE SYSTEM
(0 to 45 degrees)

Joint Number	Repeats	Global 1 (in.)	Global 2 (in.)	Global 3 (in.)	Location
1	0	0.0	0.0	-161.565	mast
2	3	0.0	-12.0	210.473	upper ring
3	3	99.0141	-7.97127	155.13864	upper cable
4	3	196.89198	-3.98877	100.58151	upper cable
5	3	284.70625	-.41575	51.75414	upper cable
6	3	295.27274	0.0	47.01624	1st ray
7	3	283.486	0.0	49.36211	1st ray
8	3	201.03582	0.0	-22.7908	lower cable
9	3	106.69911	0.0	-92.4641	lower cable
10	3	14.02286	0.0	-160.70894	lower ring
11	7	3.10583	-11.59111	210.473	upper ring
12	7	97.76369	17.94458	155.26049	upper cable
13	7	191.3067	47.1324	100.77115	upper cable
14	7	275.69011	73.46219	51.67947	upper cable
15	7	285.21689	76.42369	47.01639	2nd ray
16	7	273.82336	73.37073	48.09903	2nd ray
17	7	194.13702	52.01889	-22.72786	lower cable
18	7	103.0158	27.60302	-92.39989	lower cable
19	7	13.54504	3.62938	-160.70894	lower ring
20	7	280.14954	5.89783	48.14054	1st gore
21	7	276.8855	11.80834	46.94709	1st gore
22	7	273.69547	17.74	45.78215	1st gore
23	7	271.33927	7.93885	44.95163	1st gore
24	7	270.98993	16.00562	44.80345	1st gore
25	7	269.74807	29.54953	44.53913	1st gore
26	7	268.18637	41.29599	44.36476	1st gore
27	7	268.93757	53.71882	45.20513	1st gore
28	7	270.49018	60.27311	46.14109	1st gore
29	7	272.11812	66.82326	47.10542	1st gore
30	3	271.65974	0.0	45.12999	1st ray
31	3	273.25102	0.0	40.70862	1st ray
32	7	270.59696	23.68441	44.65177	1st gore
33	7	268.94521	35.4196	44.44367	1st gore
34	7	267.47336	47.1778	44.30306	1st gore
35	7	263.2872	72.64008	40.14499	2nd ray
36	7	262.4479	70.30456	43.90992	2nd ray
37	7	265.8925	54.70603	44.1696	1st gore
38	7	264.1644	62.57412	44.02186	1st gore
39	3	264.2249	0.0	42.60014	1st ray
40	3	257.30698	0.0	40.266	1st ray
41	3	260.20529	0.0	32.11605	1st ray
42	7	256.35646	22.46023	39.80852	1st gore
43	7	254.89427	33.5877	39.58455	1st gore
44	7	253.41494	44.71312	39.42739	1st gore
45	7	251.00392	68.38491	31.78037	2nd ray

Joint Number	Repeats	Global 1 (in.)	Global 2 (in.)	Global 3 (in.)	Location
46	7	248.58399	66.58947	39.09129	2nd ray
47	7	263.74698	11.53857	42.30813	1st gore
48	7	263.18519	23.04332	42.13195	1st gore
49	7	261.62881	34.39186	41.87018	1st gore
50	3	242.86232	0.0	35.62844	1st ray
51	3	247.18336	0.0	22.42525	1st ray
52	7	241.95583	21.18763	35.21131	1st gore
53	7	240.58054	31.69058	34.98313	1st gore
54	7	239.19143	42.19243	34.85002	1st gore
55	7	238.5174	64.57352	22.20966	2nd ray
56	7	234.62285	62.86138	34.53046	2nd ray
57	7	260.16379	45.89776	41.76754	1st gore
58	7	257.76901	57.12664	41.53271	1st gore
59	7	255.26714	68.38229	41.41376	2nd ray
60	3	228.32	0.0	31.25287	1st ray
61	3	233.78644	0.0	11.37091	1st ray
62	7	227.46437	19.90695	30.87086	1st gore
63	7	226.17326	29.78141	30.65215	1st gore
64	7	224.87088	39.65535	30.53078	1st gore
65	7	225.78166	60.72369	11.34823	2nd ray
66	7	220.57266	59.10149	30.23392	2nd ray
67	3	274.78653	0.0	35.11855	1st ray
68	3	254.29074	0.0	23.2374	1st ray
69	7	265.48076	71.21033	35.16294	2nd ray
70	3	213.70718	0.0	27.1396	1st ray
71	3	217.78908	0.0	12.04885	1st ray
72	7	212.90644	18.62955	26.78379	1st gore
73	7	211.69582	27.87179	26.58445	1st gore
74	7	210.48015	37.11407	26.46691	1st gore
75	7	210.07671	56.43163	12.01241	2nd ray
76	7	206.45748	55.3198	26.18768	2nd ray
77	7	206.59882	55.55866	6.34238	2nd ray
78	7	187.14932	50.32183	1.28751	2nd ray
79	7	245.74654	65.99748	23.32037	2nd ray
80	3	199.01342	0.0	23.30577	1st ray
81	3	202.4185	0.0	9.78583	1st ray
82	7	198.26793	17.34675	22.97525	1st gore
83	7	197.14076	25.95358	22.79124	1st gore
84	7	196.01042	34.5606	22.67875	1st gore
85	7	195.25785	52.4214	9.73517	2nd ray
86	7	192.26533	51.51633	22.41712	2nd ray
87	3	213.69754	0.0	6.28314	1st ray
88	3	193.59824	0.0	1.23658	1st ray
90	3	184.24559	0.0	19.74633	1st ray
91	3	187.74709	0.0	4.56589	1st ray
92	7	183.55545	16.05571	19.44102	1st gore
93	7	182.51319	24.02401	19.27181	1st gore
94	7	181.46848	31.99247	19.16618	1st gore
95	7	181.12689	48.63758	4.48977	2nd ray
96	7	178.00144	47.69377	18.9232	2nd ray

Joint number	Repeats	Global 1 (in.)	Global 2 (in.)	Global 3 (in.)	Location
97	3	159.62094	0.0	-46.3594	1st ray
98	3	85.45447	0.0	-104.0897	1st ray
100	3	169.40878	0.0	16.46393	1st ray
101	3	173.48859	0.0	-3.76855	1st ray
102	7	168.77441	14.75255	16.18259	1st gore
103	7	167.81951	22.0792	16.02788	1st gore
104	7	166.8598	29.40626	15.93245	1st gore
105	7	167.55581	45.04622	-3.78387	2nd ray
106	7	163.67011	43.85349	15.70872	2nd ray
107	7	154.1557	41.45631	-46.37452	2nd ray
108	7	82.52947	22.18893	-104.09726	2nd ray
110	3	154.50518	0.0	13.46014	1st ray
111	3	157.05486	0.0	-.25522	1st ray
112	7	153.1997	20.16851	13.08953	1st gore
113	3	153.5345	0.0	-7.22026	1st ray
114	3	133.41437	0.0	-10.64207	1st ray
115	7	151.47248	40.85247	-.1519	2nd ray
116	7	149.27717	39.99702	12.77633	2nd ray
117	3	119.42172	0.0	-56.45236	1st ray
118	3	65.35486	0.0	-109.13618	1st ray
119	3	0.0	12.0	210.473	upper ring
120	3	139.53946	0.0	10.77672	1st ray
121	3	141.46379	0.0	-.77371	1st ray
122	7	138.3612	18.21028	10.43728	1st gore
123	7	148.27358	39.85277	-7.20609	2nd ray
124	7	128.84543	34.62003	-10.62493	2nd ray
125	7	136.499	36.75687	-.8163	2nd ray
126	7	134.81797	36.12338	10.15284	2nd ray
127	7	115.33833	31.00467	-56.46258	2nd ray
128	7	63.12085	16.96311	-109.14129	2nd ray
129	7	-3.10583	11.59111	210.473	upper ring
130	3	124.5177	0.0	8.37869	1st ray
131	3	126.53016	0.0	-5.37254	1st ray
132	7	123.46848	16.24723	8.07479	1st gore
133	3	78.40972	0.0	-63.4227	1st ray
134	3	44.84886	0.0	-112.62135	1st ray
135	7	122.10078	32.84359	-5.48481	2nd ray
136	7	120.30756	32.23638	7.81997	2nd ray
137	7	75.73695	20.33849	-63.42936	2nd ray
138	7	43.32016	11.63002	-112.62468	2nd ray
140	3	109.44545	0.0	6.26842	1st ray
141	3	111.97058	0.0	-14.22404	1st ray
142	7	108.51407	14.28389	6.00109	1st gore
143	3	92.48747	0.0	-13.24531	1st ray
144	3	71.70626	0.0	-12.13277	1st ray
145	7	108.15375	29.04697	-14.23404	2nd ray
146	7	105.74062	28.32618	5.7786	2nd ray
147	3	284.70625	0.0	51.75414	1st ray
148	7	275.58766	73.84359	51.68079	2nd ray
150	3	94.33028	0.0	4.45137	1st ray

Joint Number	Repeats	Global 1 (in.)	Global 2 (in.)	Global 3 (in.)	Location
151	3	95.55405	0.0	-7.13851	1st ray
152	7	93.52067	12.31271	4.25163	1st gore
153	7	89.32956	23.98557	-13.21427	2nd ray
154	7	69.26182	18.58982	-12.08903	2nd ray
155	7	92.18254	24.73364	-6.75369	2nd ray
156	7	91.1485	24.42053	4.04775	2nd ray
157	3	284.70625	.41575	51.75414	upper cable
158	3	196.89179	3.98878	100.58162	upper cable
159	3	99.01401	7.97128	155.13869	upper cable
160	3	79.17012	0.0	2.98751	1st ray
161	3	79.74959	0.0	-3.91377	1st ray
162	7	78.49285	10.33603	2.80374	1st gore
165	7	77.03244	20.6571	-4.03141	2nd ray
166	7	76.50669	20.49879	2.62968	2nd ray
167	7	275.48567	74.22517	51.67947	upper cable
168	7	189.24262	54.83566	100.77115	upper cable
169	7	93.63812	33.34147	155.26048	upper cable
170	3	63.97855	0.0	1.81723	1st ray
171	3	64.40925	0.0	-5.17249	1st ray
172	7	63.42978	8.35267	1.66129	1st gore
173	3	36.6234	0.0	-61.17398	1st ray
174	3	23.9557	0.0	-111.49699	1st ray
175	7	62.2375	16.68692	-5.40978	2nd ray
176	7	61.83319	16.56794	1.52032	2nd ray
177	7	35.38357	9.48841	-61.17654	2nd ray
178	7	23.14347	6.20498	-111.49827	2nd ray
180	3	48.76123	0.0	.93931	1st ray
181	3	49.29109	0.0	-10.85096	1st ray
182	7	48.32059	6.36344	.82716	1st gore
185	7	47.62368	12.77183	-10.8548	2nd ray
186	7	47.13359	12.62987	.72119	2nd ray
187	3	3.9	0.0	4.93987	center ring
188	7	3.76711	1.00939	4.93987	center ring
189	7	-6.0	10.3923	210.473	upper ring
190	7	247.40994	142.84212	51.6187	3rd ray
191	7	247.21901	143.17282	51.6187	upper cable
192	7	168.63492	101.96566	100.85193	upper cable
193	7	81.83493	56.45033	155.30115	upper cable
196	0	0.0	0.0	4.940	mast
201	7	6.0	-10.3923	210.473	upper ring
202	7	89.80489	42.64592	155.30115	upper cable
203	7	172.62237	95.05923	100.85192	upper cable
204	7	247.60087	142.51142	51.6187	upper cable
205	7	255.71846	147.63918	47.01663	3rd ray
206	7	245.50814	141.74387	47.28788	3rd ray
207	7	174.05877	100.49291	-22.72814	lower cable
208	7	92.36172	53.32508	-92.40025	lower cable
209	7	12.14415	7.01143	-160.70894	lower ring
210	7	269.08204	78.21042	46.9147	2nd gore
211	7	264.40403	83.07554	45.75671	2nd gore

Joint Number	Repeats	Global 1 (in.)	Global 2 (in.)	Global 3 (in.)	Location
212	7	259.78995	87.97878	44.62619	2nd gore
213	7	260.04328	77.88465	43.76083	2nd gore
214	7	257.61553	85.58975	43.6503	2nd gore
215	7	252.92371	98.36344	43.45927	2nd gore
216	7	248.37157	109.30404	43.36636	2nd gore
217	7	245.87933	121.49529	44.28419	2nd gore
218	7	245.68429	128.22714	45.25792	2nd gore
219	7	245.56122	134.97478	46.25903	2nd gore
221	0	0.0	0.0	211.328	mast
222	7	255.26002	92.91769	43.52947	2nd gore
223	7	250.62794	103.82511	43.40497	2nd gore
224	7	246.15562	114.79941	43.34374	2nd gore
225	7	235.99178	136.78086	40.29684	3rd ray
226	7	235.30342	135.84491	43.14884	3rd ray
227	7	242.67697	121.66043	43.27259	2nd gore
228	7	238.96687	128.8166	43.19103	2nd gore
232	7	241.80171	88.03572	38.79362	2nd gore
233	7	237.51271	98.40656	38.6335	2nd gore
234	7	233.2053	108.76968	38.55301	2nd gore
235	7	224.74997	130.08907	31.87529	3rd ray
236	7	222.87355	128.67266	38.36387	3rd ray
237	7	251.7758	79.39732	41.1722	2nd gore
238	7	248.25351	90.37284	41.06466	2nd gore
239	7	243.81434	100.92988	40.87685	2nd gore
242	7	228.22325	83.07797	34.24927	2nd gore
243	7	224.17826	92.86794	34.08651	2nd gore
244	7	220.12094	102.65298	34.01979	2nd gore
245	7	213.58984	123.4988	22.20857	3rd ray
246	7	210.35718	121.45056	33.84471	3rd ray
247	7	239.4223	111.66484	40.8524	2nd gore
248	7	234.19797	121.89845	40.70003	2nd gore
249	7	228.84941	132.1218	40.66397	3rd ray
252	7	214.55383	78.09775	29.96848	2nd gore
253	7	210.75256	87.30266	29.8109	2nd gore
254	7	206.94073	96.50356	29.75251	2nd gore
255	7	202.4594	116.93956	11.34745	3rd ray
256	7	197.761	114.18013	29.5869	3rd ray
259	7	238.03313	137.44499	35.16301	3rd ray
262	7	200.82305	73.09653	25.93724	2nd gore
263	7	197.26316	81.71142	25.79551	2nd gore
264	7	193.69875	90.32462	25.73569	2nd gore
265	7	188.24754	108.70572	11.99035	3rd ray
266	7	185.10582	106.87359	25.58204	3rd ray
267	7	185.26771	106.98423	6.34211	3rd ray
268	7	167.83713	96.89056	1.28736	3rd ray
269	7	220.34958	127.25183	23.32007	3rd ray
272	7	187.01653	68.06827	22.18349	2nd gore
273	7	183.70166	76.09095	22.05376	2nd gore
274	7	180.3839	84.11259	21.99529	2nd gore
275	7	174.98074	101.02196	9.6978	3rd ray

Joint Number	Repeats	Global 1 (in.)	Global 2 (in.)	Global 3 (in.)	Location
276	7	172.38153	99.52669	21.85318	3rd ray
282	7	173.14	63.01312	18.70648	2nd gore
283	7	170.07263	70.44107	18.58758	2nd gore
284	7	167.00262	77.86801	18.5317	2nd gore
285	7	162.34131	93.7035	4.44514	3rd ray
286	7	159.593	92.14274	18.40097	3rd ray
292	7	159.19939	57.9291	15.50864	2nd gore
293	7	156.38274	64.75959	15.39768	2nd gore
294	7	153.56168	71.5879	15.34799	2nd gore
295	7	150.27758	86.72221	-3.78423	3rd ray
296	7	146.74394	84.72403	15.22864	3rd ray
297	7	138.2315	79.8410	-46.37504	3rd ray
298	7	74.0036	42.7425	-104.09752	3rd ray
302	7	142.75384	59.13186	12.51722	2nd gore
305	7	135.84261	78.3083	-.18323	3rd ray
306	7	133.83797	77.27508	12.34206	3rd ray
312	7	128.9281	53.39983	9.91878	2nd gore
313	7	132.99185	76.72299	-7.20591	3rd ray
314	7	115.57539	66.64816	-10.62462	3rd ray
315	7	122.39687	70.57635	-.81481	3rd ray
316	7	120.87519	69.79108	9.75541	3rd ray
317	7	103.44362	59.6961	-56.4628	3rd ray
318	7	56.60966	32.6701	-109.1414	3rd ray
322	7	115.05122	47.64849	7.61174	2nd gore
325	7	109.49229	63.12884	-5.48812	3rd ray
326	7	107.86586	62.27993	7.46484	3rd ray
327	7	67.94277	39.16009	-63.4294	3rd ray
328	7	38.85924	22.40204	-112.6247	3rd ray
332	7	101.11568	41.8779	5.59618	2nd gore
335	7	97.02631	55.91813	-14.23403	3rd ray
336	7	94.80717	54.7324	5.46842	3rd ray
342	7	87.14386	36.0976	3.90871	2nd gore
343	7	80.13374	46.1915	-13.21426	3rd ray
344	7	62.12519	35.8223	-12.08903	3rd ray
345	7	82.66484	47.67777	-6.75386	3rd ray
346	7	81.72147	47.18606	3.7799	3rd ray
352	7	73.14137	30.30009	2.50927	2nd gore
355	7	69.05642	39.84691	-4.03786	3rd ray
356	7	68.59475	39.60629	2.40528	3rd ray
362	7	59.10586	24.48582	1.41959	2nd gore
365	7	55.79727	32.20043	-5.42683	3rd ray
366	7	55.43954	32.00991	1.33949	3rd ray
367	7	31.7302	18.3091	-61.1765	3rd ray
368	7	20.7529	11.9766	-111.4983	3rd ray
372	7	45.02724	18.65363	.64663	2nd gore
375	7	42.7074	24.64167	-10.8548	3rd ray
376	7	42.26082	24.40022	.58295	3rd ray
378	7	3.3775	1.95	4.93987	center ring
391	3	8.48528	-8.48528	210.473	upper ring
392	3	75.69766	64.42471	155.27729	upper cable

Joint Number	Repeats	Global 1 (in.)	Global 2 (in.)	Global 3 (in.)	Location
393	3	142.13856	136.49783	100.85911	upper cable
394	3	202.38241	201.84857	51.64026	upper cable
395	3	208.79339	208.79339	47.01687	4th ray
396	3	200.49454	200.49455	46.82166	4th ray
397	3	142.14964	142.14965	-22.78763	lower cable
398	3	75.44396	75.44396	-92.45934	lower cable
399	3	9.91566	9.91566	-160.70894	lower ring
400	7	239.66909	145.1815	46.17357	3rd gore
401	7	233.88461	148.66553	45.08644	3rd gore
402	7	228.15117	152.20232	44.02648	3rd gore
403	7	231.02302	142.53502	43.06852	3rd gore
404	7	226.67907	149.34014	43.0354	3rd gore
405	7	218.83513	160.45741	42.94971	3rd gore
406	7	211.62863	169.86363	42.89631	3rd gore
407	7	206.08528	181.01008	43.83262	3rd gore
408	7	204.15993	187.47018	44.80356	3rd gore
409	7	202.29715	193.96404	45.79995	3rd gore
410	3	202.11549	202.11549	51.64026	4th ray
411	3	-8.48528	8.48528	210.473	upper ring
412	7	222.48716	155.79184	42.999	3rd gore
413	7	215.21616	165.14772	42.91558	3rd gore
414	7	208.07387	174.60481	42.89219	3rd gore
415	3	192.79945	192.79891	40.3173	4th ray
416	3	192.12181	192.12127	42.89877	4th ray
417	7	203.0278	180.16639	42.83937	3rd gore
418	7	197.55569	186.17918	42.82927	3rd gore
419	3	201.84857	202.38241	51.64026	upper cable
420	3	136.4975	142.13826	100.85935	upper cable
421	3	64.42454	75.6975	155.27742	upper cable
422	7	210.79119	147.60468	38.22959	3rd gore
423	7	203.96494	156.5131	38.14967	3rd gore
424	7	197.12597	165.41092	38.14493	3rd gore
425	3	183.57825	183.57775	31.95918	4th ray
426	3	181.97387	181.97336	38.12955	4th ray
427	7	222.64838	141.85855	40.52211	3rd gore
428	7	216.4031	151.53479	40.51807	3rd gore
429	7	209.39269	160.58562	40.3882	3rd gore
432	7	198.95272	139.31414	33.70956	3rd gore
433	7	192.51177	147.72409	33.62506	3rd gore
434	7	186.06128	156.12605	33.63705	3rd gore
435	3	174.52176	174.52128	22.40011	4th ray
436	3	171.75775	171.75726	33.61543	4th ray
437	7	202.38275	169.82075	40.42318	3rd gore
438	7	194.6782	178.35913	40.34906	3rd gore
439	3	186.85446	186.85153	40.42036	4th ray
442	7	187.03589	130.97044	29.45797	3rd gore
443	7	180.9815	138.87814	29.37529	3rd gore
444	7	174.91946	146.77945	29.3889	3rd gore
445	3	165.31666	165.31666	11.36289	4th ray
446	3	161.47501	161.47459	29.3653	4th ray

Joint Number	Repeats	Global 1 (in.)	Global 2 (in.)	Global 3 (in.)	Location
449	3	194.35959	194.35961	35.1605	4th ray
452	7	175.06598	122.58764	25.45959	3rd gore
453	7	169.39769	129.98802	25.38728	3rd gore
454	7	163.72624	137.38544	25.39614	3rd gore
455	3	153.668	153.66759	11.99103	4th ray
456	3	151.14228	151.14186	25.37345	4th ray
457	3	151.27288	151.27289	6.3358	4th ray
458	3	137.03029	137.0303	1.2795	4th ray
459	3	179.92397	179.92398	23.32287	4th ray
462	7	163.03078	114.15786	21.73906	3rd gore
463	7	157.75241	121.04955	21.67411	3rd gore
464	7	152.47213	127.93933	21.68027	3rd gore
465	3	142.8405	142.8401	9.69302	4th ray
466	3	140.75257	140.75216	21.65987	4th ray
472	7	150.93507	105.68347	18.29622	3rd gore
473	7	146.04974	112.06473	18.23652	3rd gore
474	7	141.16287	118.44435	18.24026	3rd gore
475	3	132.52213	132.52179	4.44151	4th ray
476	3	130.3105	130.31015	18.22242	4th ray
482	7	138.78571	97.1632	15.13349	3rd gore
483	7	134.29715	103.03333	15.07565	3rd gore
484	7	129.80542	108.89955	15.07933	3rd gore
485	3	122.67863	122.67863	-3.77285	4th ray
486	3	119.8193	119.81899	15.06341	4th ray
487	3	112.8717	112.8717	-46.36474	4th ray
488	3	60.4268	60.4268	-104.09237	4th ray
492	7	122.58835	94.07107	12.22519	3rd gore
495	3	110.87286	110.87287	-.07149	4th ray
496	3	109.28275	109.28276	12.18792	4th ray
502	7	110.72059	84.95216	9.65369	3rd gore
503	3	108.56175	108.56175	-7.22575	4th ray
504	3	94.33454	94.33454	-10.64655	4th ray
505	3	99.91557	99.91557	-.85581	4th ray
506	3	98.69797	98.69797	9.6219	4th ray
507	3	84.44636	84.44636	-56.4552	4th ray
508	3	46.21409	46.21409	-109.1376	4th ray
512	7	98.80577	75.80472	7.37376	3rd gore
515	3	89.37971	89.3797	-5.55386	4th ray
516	3	88.0758	88.07579	7.34596	4th ray
517	3	55.4462	55.4462	-63.4244	4th ray
518	3	31.7140	31.7140	-112.6222	4th ray
522	7	86.83676	66.62673	5.3853	3rd gore
525	3	79.17835	79.17835	-14.22661	4th ray
526	3	77.41442	77.40714	5.36185	4th ray
532	7	74.83473	57.42551	3.7298	3rd gore
533	3	65.39399	65.39397	-13.2378	4th ray
534	3	50.70034	50.70034	-12.10961	4th ray
535	3	67.45602	67.45602	-6.79795	4th ray
536	3	66.72917	66.72917	3.69112	4th ray
542	7	62.80926	48.20029	2.35789	3rd gore

Joint Number	Repeats	Global 1 (in.)	Global 2 (in.)	Global 3 (in.)	Location
545	3	56.37551	56.37553	-4.03113	4th ray
546	3	56.01109	56.01111	2.32757	4th ray
552	7	50.75676	38.95099	1.29631	3rd gore
555	3	45.5434	45.54339	-5.40441	4th ray
556	3	45.26958	45.26957	1.2748	4th ray
557	3	25.8990	25.8990	-61.1748	4th ray
558	3	16.9404	16.9404	-111.4974	4th ray
562	7	38.66763	29.67362	.55314	3rd gore
565	3	34.85763	34.85763	-10.85221	4th ray
566	3	34.50876	34.50878	.53551	4th ray
568	3	2.75772	2.75771	4.93987	center ring

TABLE 4. JOINT LOCATIONS ON 15 METER ANTENNA IN CYLINDRICAL COORDINATE SYSTEM (0 to 45 degrees)

Joint Number	Repeats	Radial (in.)	Angular (deg.)	Global 3 (in.)	Location
89	0	5.625	37.5	211.328	mast
99	7	11.288	15.0	-161.82	lower ring
109	3	11.288	0.0	-161.82	lower ring
139	0	6.750	37.5	144.728	mast
149	0	6.750	157.5	144.728	mast
163	0	6.750	277.5	144.728	mast
164	0	7.875	37.5	144.728	mast
179	0	7.875	157.5	144.728	mast
183	0	7.875	277.5	144.728	mast
184	0	5.625	157.5	211.328	mast
194	0	5.625	277.5	211.328	mast
195	0	5.625	37.5	178.028	mast
197	0	5.625	157.5	178.028	mast
198	0	5.625	277.5	178.028	mast
199	0	6.750	37.5	178.028	mast
200	0	6.750	157.5	178.028	mast
220	0	6.750	277.5	178.028	mast
229	0	9.000	37.5	78.128	mast
230	0	9.000	157.5	78.128	mast
231	0	9.000	277.5	78.128	mast
240	0	10.125	37.5	78.128	mast
241	0	10.125	157.5	78.128	mast
250	0	10.125	277.5	78.128	mast
251	0	10.125	37.5	33.222	mast
257	0	10.125	157.5	33.222	mast
258	0	10.125	277.5	33.222	mast
260	0	10.125	37.5	-11.684	mast
261	0	10.125	157.5	-11.684	mast
270	0	10.125	277.5	-11.684	mast
271	0	9.000	37.5	-11.684	mast
277	0	9.000	157.5	-11.684	mast
278	0	9.000	277.5	-11.684	mast

Joint Number	Repeats	Radial (in.)	Angular (deg.)	Global 3 (in.)	Location
279	0	9.000	37.5	-44.984	mast
280	0	9.000	157.5	-44.984	mast
281	0	9.000	277.5	-44.984	mast
287	0	7.875	37.5	-44.984	mast
288	0	7.875	157.5	-44.984	mast
289	7	11.288	30.0	-161.82	lower ring
290	0	7.875	277.5	-44.984	mast
291	0	7.875	37.5	-78.284	mast
299	0	7.875	157.5	-78.284	mast
300	0	7.875	277.5	-78.284	mast
301	0	6.750	37.5	-78.284	mast
303	0	6.750	157.5	-78.284	mast
304	0	6.750	277.5	-78.284	mast
307	0	6.750	37.5	-111.584	mast
308	0	6.750	157.5	-111.584	mast
309	0	6.750	277.5	-111.584	mast
310	0	5.625	37.5	-111.584	mast
311	0	5.625	157.5	-111.584	mast
319	0	5.625	277.5	-111.584	mast
320	0	5.625	37.5	-144.884	mast
321	0	5.625	157.5	-144.884	mast
323	0	5.625	277.5	-144.884	mast
324	0	4.500	37.5	-144.884	mast
329	0	4.500	157.5	-144.884	mast
330	0	4.500	277.5	-144.884	mast
331	0	4.500	37.5	-161.565	mast
333	0	4.500	157.5	-161.565	mast
334	0	4.500	277.5	-161.565	mast
337	0	27.60	37.5	-22.684	tripod support
338	0	27.60	157.5	-22.684	tripod support
339	0	27.60	277.5	-22.684	tripod support
340	0	13.95	37.5	-11.684	tripod support
341	0	13.95	157.5	-11.684	tripod support
347	0	13.95	277.5	-11.684	tripod support
353	0	7.875	37.5	111.428	mast
354	0	7.875	157.5	111.428	mast
373	0	7.875	277.5	111.428	mast
379	0	44.0	37.5	-178.684	tripod support
380	0	44.0	157.5	-178.684	tripod support
381	0	44.0	277.5	-178.684	tripod support
382	0	39.90	37.5	-139.684	tripod support
383	0	39.90	157.5	-139.684	tripod support
384	0	39.90	277.5	-139.684	tripod support
385	0	35.80	37.5	-100.684	tripod support
386	0	35.80	157.5	-100.684	tripod support
387	0	35.80	277.5	-100.684	tripod support

Joint Number	Repeats	Radial (in.)	Angular (deg.)	Global 3 (in.)	Location
388	0	31.70	37.5	-61.684	tripod support
389	0	31.70	157.5	-61.684	tripod support
390	0	31.70	277.5	-61.684	tripod support
479	3	11.288	45.0	-161.82	lower ring
543	0	9.000	37.5	111.428	mast
544	0	9.000	157.5	111.428	mast
563	0	9.000	277.5	111.428	mast
572	0	10.125	37.5	4.940	mast
573	0	10.125	157.5	4.940	mast
574	0	10.125	277.5	4.940	mast
4561	2	3.7528	37.5	217.00	feed mast
4564	2	3.7528	37.5	234.94	feed mast
4567	2	3.7528	37.5	252.88	feed mast
4570	2	3.7528	37.5	270.82	feed mast
4573	2	3.7528	37.5	288.76	feed mast
4576	2	3.7528	37.5	306.70	feed mast
4579	2	3.7528	37.5	324.64	feed mast
4582	2	3.7528	37.5	342.58	feed mast
4585	2	3.7528	37.5	349.23	feed mast

TABLE 5. 1ST RAY CABLE PROPERTIES
SEE FIGURE 16

Grid Point A	Grid Point B	Extensional Stiffness,EA (pound)	Preload (pound)	Unit Weight (pound/in.)
30	31	900.	.0329049	4.25E-6
40	41	900.	.0243736	4.25e-6
50	51	900.	.0275736	4.25E-6
60	61	900.	.0232056	4.25E-6
70	71	900.	.0272396	4.25E-6
80	81	900.	.0268283	4.25E-6
90	91	900.	.0262419	4.25E-6
100	101	900.	.0240300	4.25E-6
110	111	900.	.0347591	4.25E-6
120	121	900.	.0464084	4.25E-6
130	131	900.	.0454264	4.25E-6
140	141	900.	.0431864	4.25E-6
150	151	900.	.0785845	4.25E-6
160	161	900.	.0893691	4.25E-6
170	171	900.	.0878358	4.25E-6
180	181	24000.	.8040719	75.90E-6
147	7	16000.	5.198050	49.20E-6
6	7	32000.	6.797370	98.00E-6
7	30	24000.	2.561188	75.90E-6
30	39	24000.	2.561188	75.90E-6
39	40	24000.	2.539788	75.90E-6
40	50	24000.	2.493788	75.90E-6
50	60	24000.	2.462588	75.90E-6
60	70	24000.	2.493788	75.90E-6
70	80	24000.	2.462588	75.90E-6
80	90	24000.	2.462588	75.90E-6
90	100	24000.	2.462588	75.90E-6
100	110	24000.	2.454588	75.90E-6
110	120	40000.	3.716193	253.00E-6
120	130	40000.	3.689393	253.00E-6
130	140	40000.	3.663993	253.00E-6
140	150	40000.	3.641593	253.00E-6
150	160	56000.	5.946066	354.00E-6
160	170	56000.	5.909042	354.00E-6
170	180	56000.	5.870795	354.00E-6
180	187	33.	5.939994	150.00E-6
6	31	16000.	2.007809	49.20E-6
31	41	16000.	1.912482	49.20E-6
41	51	16000.	1.927322	49.20E-6
51	61	16000.	1.952249	49.20E-6
61	71	16000.	.5269789	49.20E-6
71	81	16000.	.4979550	49.20E-6
81	91	16000.	.4898269	49.20E-6
91	101	16000.	.5025190	49.20E-6
101	111	16000.	.3734870	49.20E-6
111	121	16000.	.3395393	49.20E-6
121	131	16000.	.3317517	49.20E-6

Grid Point A	Grid Point B	Extensional Stiffness,EA (pound)	Preload (pound)	Unit Weight (pound/in.)
131	141	16000.	.3493068	49.20E-6
141	151	16000.	.3134948	49.20E-6
151	161	16000.	.2848810	49.20E-6
161	171	16000.	.2730195	49.20E-6
171	181	16000.	.2848810	49.20E-6
6	67	48000.	11.23090	150.00E-6
67	68	48000.	11.23090	150.00E-6
68	61	48000.	11.23090	150.00E-6
61	87	24000.	2.763387	73.60E-6
87	88	24000.	2.763387	73.60E-6
88	101	24000.	2.763387	73.60E-6
101	113	16000.	2.045809	49.20E-6
113	114	16000.	2.045809	49.20E-6
114	141	16000.	2.045809	49.20E-6
141	143	8000.	1.480757	25.30E-6
143	144	8000.	1.480757	25.30E-6
144	181	8000.	1.480757	25.30E-6
181	187	1.430	1.480004	25.30E-6
61	97	18900.	11.12914	49.20E-6
97	98	18900.	11.12914	49.20E-6
98	109	18900.	11.12914	49.20E-6
101	117	7800.	1.838905	25.30E-6
117	118	7800.	1.838905	25.30E-6
118	109	7800.	1.838905	25.30E-6
141	133	7800.	1.577960	25.30E-6
133	134	7800.	1.577960	25.30E-6
134	109	7800.	1.577960	25.30E-6
181	173	7800.	1.608924	25.30E-6
173	174	7800.	1.608924	25.30E-6
174	109	7800.	1.608924	25.30E-6

TABLE 6. 2ND RAY CABLE PROPERTIES
SEE FIGURE 17

Grid Point A	Grid Point B	Extensional Stiffness,EA (pound)	Preload (pound)	Unit Weight (pound/in.)
36	35	900.	.0528309	4.25E-6
46	45	900.	.0455799	4.25E-6
56	55	900.	.0439334	4.25E-6
66	65	900.	.0381909	4.25E-6
76	75	900.	.0431489	4.25E-6
86	85	900.	.0432224	4.25E-6
96	95	900.	.0428665	4.25E-6
106	105	900.	.0416005	4.25E-6
116	115	900.	.0753073	4.25E-6
126	125	900.	.0657679	4.25E-6
136	135	900.	.0667923	4.25E-6
146	145	900.	.0667923	4.25E-6
156	155	900.	.1289097	4.25E-6
166	165	900.	.1148705	4.25E-6
176	175	900.	.1142690	4.25E-6
186	185	24000.	.8317082	75.90E-6
148	16	16000.	4.127004	49.20E-6
15	16	32000.	7.154029	98.00E-6
16	36	24000.	2.510788	75.90E-6
36	59	24000.	2.523311	75.90E-6
59	46	24000.	2.508511	75.90E-6
46	56	24000.	2.493288	75.90E-6
56	66	24000.	2.473711	75.90E-6
66	76	24000.	2.473711	75.90E-6
76	86	24000.	2.460265	75.90E-6
86	96	24000.	2.446888	75.90E-6
96	106	24000.	2.433111	75.90E-6
106	116	24000.	2.419589	75.90E-6
116	126	40000.	3.676140	253.00E-6
126	136	40000.	3.653127	253.00E-6
136	146	40000.	3.632139	253.00E-6
146	156	40000.	3.614039	253.00E-6
156	166	56000.	5.942829	354.00E-6
166	176	56000.	5.905695	354.00E-6
176	186	56000.	5.868361	354.00E-6
186	188	33.	5.939994	150.00E-6
15	35	16000.	2.411008	49.20E-6
35	45	16000.	2.308608	49.20E-6
45	55	16000.	2.325870	49.20E-6
55	65	16000.	2.359195	49.20E-6
65	75	16000.	.6555153	49.20E-6
75	85	16000.	.6237188	49.20E-6
85	95	16000.	.6179265	49.20E-6
95	105	16000.	.6384331	49.20E-6
105	115	16000.	.4797090	49.20E-6
115	125	16000.	.4403957	49.20E-6
125	135	16000.	.4349736	49.20E-6

Grid Point A	Grid Point B	Extensional Stiffness,EA (pound)	Preload (pound)	Unit Weight (pound/in.)
135	145	16000.	.4611303	49.20E-6
145	155	16000.	.4747674	49.20E-6
155	165	16000.	.4260380	49.20E-6
165	175	16000.	.4119598	49.20E-6
175	185	16000.	.4287091	49.20E-6
15	69	48000.	12.68233	150.00E-6
69	79	48000.	12.68233	150.00E-6
79	65	48000.	12.68233	150.00E-6
65	77	24000.	2.954486	73.60E-6
77	78	24000.	2.954486	73.60E-6
78	105	24000.	2.954486	73.60E-6
105	123	16000.	2.063296	49.20E-6
123	124	16000.	2.063296	49.20E-6
124	145	16000.	2.063296	49.20E-6
145	153	8000.	1.366297	25.30E-6
153	154	8000.	1.366297	25.30E-6
154	185	8000.	1.366297	25.30E-6
185	188	1.430	1.480004	25.30E-6
65	107	18900.	11.12914	49.20E-6
107	108	18900.	11.12914	49.20E-6
108	99	18900.	11.12914	49.20E-6
105	127	7800.	1.838905	25.30E-6
127	128	7800.	1.838905	25.30E-6
128	99	7800.	1.838905	25.30E-6
145	137	7800.	1.577960	25.30E-6
137	138	7800.	1.577960	25.30E-6
138	99	7800.	1.577960	25.30E-6
185	177	7800.	1.608924	25.30E-6
177	178	7800.	1.608924	25.30E-6
178	99	7800.	1.608924	25.30E-6

TABLE 7. 3RD RAY CABLE PROPERTIES
SEE FIGURE 18

Grid Point A	Grid Point B	Extensional Stiffness, EA (pound)	Preload (pound)	Unit Weight (pound/in.)
226	225	900.	.0451639	4.25E-6
236	235	900.	.0496884	4.25E-6
246	245	900.	.0459044	4.25E-6
256	255	900.	.0411845	4.25E-6
266	265	900.	.0458109	4.25E-6
276	275	900.	.0456834	4.25E-6
286	285	900.	.0453464	4.25E-6
296	295	900.	.0446764	4.25E-6
306	305	900.	.0737654	4.25E-6
316	315	900.	.0686555	4.25E-6
326	325	900.	.0675069	4.25E-6
336	335	900.	.0675069	4.25E-6
346	345	900.	.1289497	4.25E-6
356	355	900.	.1148805	4.25E-6
366	365	900.	.1136205	4.25E-6
376	375	24000.	.8332355	75.90E-6
190	206	16000.	3.539493	49.20E-6
205	206	32000.	7.420214	98.00E-6
206	226	24000.	2.673311	75.90E-6
226	249	24000.	2.684687	75.90E-6
249	236	24000.	2.673311	75.90E-6
236	246	24000.	2.665887	75.90E-6
246	256	24000.	2.642287	75.90E-6
256	266	24000.	2.618864	75.90E-6
266	276	24000.	2.596811	75.90E-6
276	286	24000.	2.575311	75.90E-6
286	296	24000.	2.554111	75.90E-6
296	306	24000.	2.531611	75.90E-6
306	316	40000.	3.734593	253.00E-6
316	326	40000.	3.712793	253.00E-6
326	336	40000.	3.690993	253.00E-6
336	346	40000.	3.667893	253.00E-6
346	356	56000.	5.932729	354.00E-6
356	366	56000.	5.898795	354.00E-6
366	376	56000.	5.864061	354.00E-6
376	378	33.	5.939994	150.00E-6
205	225	16000.	2.190008	49.20E-6
225	235	16000.	2.067196	49.20E-6
235	245	16000.	2.090696	49.20E-6
245	255	16000.	2.190008	49.20E-6
255	265	16000.	.6617722	49.20E-6
265	275	16000.	.6297898	49.20E-6
275	285	16000.	.6240177	49.20E-6
285	295	16000.	.6447976	49.20E-6
295	305	16000.	.4901390	49.20E-6
305	315	16000.	.4506254	49.20E-6
315	325	16000.	.4450372	49.20E-6

Grid Point A	Grid Point B	Extensional Stiffness,EA (pound)	Preload (pound)	Unit Weight (pound/in.)
325	335	16000.	.4720536	49.20E-6
335	345	16000.	.4747638	49.20E-6
345	355	16000.	.4259344	49.20E-6
355	365	16000.	.4121539	49.20E-6
365	375	16000.	.4289232	49.20E-6
205	259	48000.	13.04972	150.00E-6
259	269	48000.	13.04972	150.00E-6
269	255	48000.	13.04972	150.00E-6
255	267	24000.	3.005821	73.60E-6
267	268	24000.	3.005821	73.60E-6
268	295	24000.	3.005821	73.60E-6
295	313	16000.	2.093382	49.20E-6
313	314	16000.	2.093382	49.20E-6
314	335	16000.	2.093382	49.20E-6
335	343	8000.	1.366713	25.30E-6
343	344	8000.	1.366713	25.30E-6
344	375	8000.	1.366713	25.30E-6
375	378	1.430	1.480004	25.30E-6
255	297	18900.	11.12857	49.20E-6
297	298	18900.	11.12857	49.20E-6
298	289	18900.	11.12857	49.20E-6
295	317	7800.	1.838905	25.30E-6
317	318	7800.	1.838905	25.30E-6
318	289	7800.	1.838905	25.30E-6
335	327	7800.	1.577960	25.30E-6
327	328	7800.	1.577960	25.30E-6
328	289	7800.	1.577960	25.30E-6
375	367	7800.	1.608924	25.30E-6
367	368	7800.	1.608924	25.30E-6
368	289	7800.	1.608924	25.30E-6

TABLE 8. 4TH RAY CABLE PROPERTIES
SEE FIGURE 19

Grid Point A	Grid Point B	Extensional Stiffness,EA (pound)	Preload (pound)	Unit Weight (pound/in.)
416	415	900.	-.0057440	4.25E-6
426	425	900.	.0456559	4.25E-6
436	435	900.	.0444194	4.25E-6
446	445	900.	.0386863	4.25E-6
456	455	900.	.0432714	4.25E-6
466	465	900.	.0402424	4.25E-6
476	475	900.	.0421964	4.25E-6
486	485	900.	.0402424	4.25E-6
496	495	900.	.0709999	4.25E-6
506	505	900.	.0611584	4.25E-6
516	515	900.	.0602739	4.25E-6
526	525	900.	.0610073	4.25E-6
536	535	900.	.1184885	4.25E-6
546	545	900.	.1087325	4.25E-6
556	555	900.	.1085358	4.25E-6
566	565	24000.	.8206537	75.90E-6
410	396	16000.	3.014794	49.20E-6
395	396	32000.	7.758510	98.00E-6
396	416	24000.	2.766987	75.90E-6
416	439	24000.	2.783187	75.90E-6
439	426	24000.	2.766987	75.90E-6
426	436	24000.	2.714587	75.90E-6
436	446	24000.	2.714587	75.90E-6
446	456	24000.	2.691787	75.90E-6
456	466	24000.	2.667987	75.90E-6
466	476	24000.	2.642187	75.90E-6
476	486	24000.	2.616188	75.90E-6
486	496	24000.	2.588588	75.90E-6
496	506	40000.	3.724993	253.00E-6
506	516	40000.	3.724993	253.00E-6
516	526	40000.	3.701393	253.00E-6
526	536	40000.	3.672193	253.00E-6
536	546	56000.	5.929066	354.00E-6
546	556	56000.	5.898019	354.00E-6
556	566	56000.	5.864195	354.00E-6
566	568	33.	5.939994	150.00E-6
395	415	16000.	1.940976	49.20E-6
415	425	16000.	1.799636	49.20E-6
425	435	16000.	1.817096	49.20E-6
435	445	16000.	1.846696	49.20E-6
445	455	16000.	.6073959	49.20E-6
455	465	16000.	.5764273	49.20E-6
465	475	16000.	.5694104	49.20E-6
475	485	16000.	.5864788	49.20E-6
485	495	16000.	.4475509	49.20E-6
495	505	16000.	.4072955	49.20E-6
505	515	16000.	.4010192	49.20E-6

Grid Point A	Grid Point B	Extensional Stiffness,EA (pound)	Preload (pound)	Unit Weight (pound/in.)
515	525	16000.	.4228072	49.20E-6
525	535	16000.	.4248567	49.20E-6
535	545	16000.	.3819505	49.20E-6
545	555	16000.	.3688306	49.20E-6
555	565	16000.	.3838279	49.20E-6
395	449	48000.	12.23814	150.00E-6
449	459	48000.	12.23814	150.00E-6
459	445	48000.	12.23814	150.00E-6
445	457	24000.	2.886586	73.60E-6
457	458	24000.	2.886586	73.60E-6
458	485	24000.	2.886586	73.60E-6
485	503	16000.	2.051183	49.20E-6
503	504	16000.	2.051183	49.20E-6
504	525	16000.	2.051183	49.20E-6
525	533	8000.	1.397917	25.30E-6
533	534	8000.	1.397917	25.30E-6
534	565	8000.	1.397917	25.30E-6
565	568	1.430	1.480004	25.30E-6
445	487	18900.	11.12914	49.20E-6
487	488	18900.	11.12914	49.20E-6
488	479	18900.	11.12914	49.20E-6
485	507	7800.	1.838905	25.30E-6
507	508	7800.	1.838905	25.30E-6
508	479	7800.	1.838905	25.30E-6
525	517	7800.	1.577960	25.30E-6
517	518	7800.	1.577960	25.30E-6
518	479	7800.	1.577960	25.30E-6
565	557	7800.	1.608924	25.30E-6
557	558	7800.	1.608924	25.30E-6
558	479	7800.	1.608924	25.30E-6

TABLE 9. 1ST GORE CABLE PROPERTIES
SEE FIGURE 20

Grid Point A	Grid Point B	Extensional Stiffness,EA (pound)	Preload (pound)	Unit Weight (pound/in.)
35	34	24000.	1.412435	75.90E-6
45	44	900.	.1806386	4.25E-6
55	54	900.	.0848197	4.25E-6
65	64	900.	.0573694	4.25E-6
75	74	900.	.0706058	4.25E-6
85	84	900.	.0710298	4.25E-6
95	94	900.	.0622559	4.25E-6
105	104	900.	.0547428	4.25E-6
115	112	900.	.0459499	4.25E-6
125	122	900.	.0511769	4.25E-6
135	132	900.	.0405439	4.25E-6
145	142	90.	.0296130	4.25E-6
16	29	48000.	6.697762	147.00E-6
29	28	48000.	6.726414	147.00E-6
28	27	48000.	6.756966	147.00E-6
27	34	48000.	6.770114	147.00E-6
34	26	32000.	7.652729	98.00E-6
26	33	32000.	7.652729	98.00E-6
44	43	900.	.1628978	4.25E-6
54	53	900.	.0790181	4.25E-6
64	63	900.	.0447182	4.25E-6
74	73	900.	.0583490	4.25E-6
84	83	900.	.0575360	4.25E-6
94	93	900.	.0481820	4.25E-6
104	103	.901	.0149661	4.25E-6
34	57	16000.	2.247412	49.20E-6
57	44	16000.	2.247412	49.20E-6
44	54	16000.	2.227429	49.20E-6
54	64	16000.	2.216179	49.20E-6
64	74	16000.	2.193912	49.20E-6
74	84	16000.	2.171679	49.20E-6
84	94	16000.	2.149013	49.20E-6
94	104	16000.	2.136229	49.20E-6
104	116	8000.	.9220001	25.30E-6
104	112	8000.	1.545697	25.30E-6
112	122	16000.	2.710311	49.20E-6
122	132	16000.	2.686778	49.20E-6
132	142	16000.	2.662629	49.20E-6
142	156	8000.	1.668197	25.30E-6
31	32	24000.	1.464508	75.90E-6
41	42	900.	.1338588	4.25E-6
51	52	900.	.0768427	4.25E-6
61	62	900.	.0538007	4.25E-6
71	72	900.	.0664949	4.25E-6
81	82	900.	.0656909	4.25E-6
91	92	900.	.0578338	4.25E-6
101	102	900.	.0525730	4.25E-6

Grid Point A	Grid Point B	Extensional Stiffness,EA (pound)	Preload (pound)	Unit Weight (pound/in.)
111	112	900.	.0619829	4.25E-6
121	122	900.	.0513552	4.25E-6
131	132	900.	.0418729	4.25E-6
141	142	90.	.0511668	4.25E-6
7	20	48000.	6.721914	147.00E-6
20	21	48000.	6.740163	147.00E-6
21	22	48000.	6.764314	147.00E-6
22	32	48000.	6.771563	147.00E-6
32	25	32000.	7.658340	98.00E-6
25	33	32000.	7.656429	98.00E-6
42	43	900.	.1570387	4.25E-6
52	53	900.	.0779460	4.25E-6
62	63	900.	.0452262	4.25E-6
72	73	900.	.0583909	4.25E-6
82	83	900.	.0572920	4.25E-6
92	93	900.	.0478440	4.25E-6
102	103	.901	.0156860	4.25E-6
32	48	16000.	2.220196	49.20E-6
48	42	16000.	2.220196	49.20E-6
42	52	16000.	2.197429	49.20E-6
52	62	16000.	2.174996	49.20E-6
62	72	16000.	2.160945	49.20E-6
72	82	16000.	2.138479	49.20E-6
82	92	16000.	2.116531	49.20E-6
92	102	16000.	2.105430	49.20E-6
110	102	8000.	.9161882	25.30E-6
102	112	8000.	1.510597	25.30E-6
150	142	8000.	1.648597	25.30E-6
180	182	90.	.2631978	4.25E-6
186	182	90.	.2631815	4.25E-6

TABLE 10. 2ND GORE CABLE PROPERTIES
SEE FIGURE 21

Grid Point A	Grid Point B	Extensional Stiffness,EA (pound)	Preload (pound)	Unit Weight (pound/in.)
225	224	24000.	1.863198	75.90E-6
235	234	900.	.1635205	4.25E-6
245	244	900.	.0866180	4.25E-6
255	254	900.	.0548598	4.25E-6
265	264	900.	.0699808	4.25E-6
275	274	900.	.0708129	4.25E-6
285	284	900.	.0615148	4.25E-6
295	294	900.	.0542770	4.25E-6
305	302	900.	.0550299	4.25E-6
315	312	900.	.0534289	4.25E-6
325	322	900.	.0423149	4.25E-6
335	332	90.	.0552169	4.25E-6
206	219	48000.	6.559214	147.00E-6
219	218	48000.	6.584366	147.00E-6
218	217	48000.	6.613618	147.00E-6
217	224	48000.	6.625066	147.00E-6
224	216	32000.	7.960108	98.00E-6
216	223	32000.	7.965792	98.00E-6
234	233	900.	.1377374	4.25E-6
244	243	900.	.0733170	4.25E-6
254	253	900.	.0363521	4.25E-6
264	263	900.	.0568210	4.25E-6
274	273	900.	.0570130	4.25E-6
284	283	900.	.0464489	4.25E-6
294	293	.901	.0049872	4.25E-6
224	247	16000.	2.164279	49.20E-6
247	234	16000.	2.164279	49.20E-6
234	244	16000.	2.155696	49.20E-6
244	254	16000.	2.141112	49.20E-6
254	264	16000.	2.118279	49.20E-6
264	274	16000.	2.105196	49.20E-6
274	284	16000.	2.082829	49.20E-6
284	294	16000.	2.060996	49.20E-6
294	306	8000.	.8727983	25.30E-6
294	302	8000.	1.513297	25.30E-6
302	312	16000.	2.694028	49.20E-6
312	322	16000.	2.658312	49.20E-6
322	332	16000.	2.630795	49.20E-6
332	346	8000.	1.624797	25.30E-6
35	222	24000.	1.792653	75.90E-6
45	232	900.	.1085998	4.25E-6
55	242	900.	.0800088	4.25E-6
65	252	900.	.0535108	4.25E-6
75	262	900.	.0683949	4.25E-6
85	272	900.	.0687739	4.25E-6
95	282	900.	.0600148	4.25E-6
105	292	900.	.0527739	4.25E-6

Grid Point A	Grid Point B	Extensional Stiffness,EA (pound)	Preload (pound)	Unit Weight (pound/in.)
115	302	900.	.0540300	4.25E-6
125	312	900.	.0511259	4.25E-6
135	322	900.	.0411419	4.25E-6
145	332	90.	.0267656	4.25E-6
16	210	48000.	6.723218	147.00E-6
210	211	48000.	6.735666	147.00E-6
211	212	48000.	6.761218	147.00E-6
212	222	48000.	6.761218	147.00E-6
222	215	32000.	7.971092	98.00E-6
215	223	32000.	7.971092	98.00E-6
232	233	900.	.1296975	4.25E-6
242	243	900.	.0723879	4.25E-6
252	253	900.	.0365649	4.25E-6
262	263	900.	.0542891	4.25E-6
272	273	900.	.0562069	4.25E-6
282	283	900.	.0466259	4.25E-6
292	293	.901	.0054185	4.25E-6
222	238	16000.	2.214796	49.20E-6
238	232	16000.	2.219379	49.20E-6
232	242	16000.	2.198012	49.20E-6
242	252	16000.	2.182979	49.20E-6
252	262	16000.	2.157413	49.20E-6
262	272	16000.	2.140729	49.20E-6
272	282	16000.	2.115613	49.20E-6
282	292	16000.	2.101330	49.20E-6
292	116	8000.	.9008854	25.30E-6
292	302	8000.	1.520314	25.30E-6
332	156	8000.	1.664197	25.30E-6
186	372	90.	.2631406	4.25E-6
376	372	90.	.2632006	4.25E-6

TABLE 11. 3RD GORE CABLE PROPERTIES
SEE FIGURE 22

Grid Point A	Grid Point B	Extensional Stiffness,EA (pound)	Preload (pound)	Unit Weight (pound/in.)
415	414	24000.	2.013525	75.90E-6
425	424	900.	.1552205	4.25E-6
435	434	900.	.0833347	4.25E-6
445	444	900.	.0545279	4.25E-6
455	454	900.	.0683079	4.25E-6
465	464	900.	.0688009	4.25E-6
475	474	900.	.0597519	4.25E-6
485	484	900.	.0524177	4.25E-6
495	492	900.	.0577257	4.25E-6
505	502	900.	.0519600	4.25E-6
515	512	900.	.0413409	4.25E-6
525	522	90.	.0372194	4.25E-6
396	409	48000.	6.470663	147.00E-6
409	408	48000.	6.497214	147.00E-6
408	407	48000.	6.525865	147.00E-6
407	414	48000.	6.534814	147.00E-6
414	406	32000.	8.017923	98.00E-6
406	413	32000.	8.017923	98.00E-6
424	423	900.	.1506473	4.25E-6
434	433	900.	.0712270	4.25E-6
444	443	900.	.0396811	4.25E-6
454	453	900.	.0554210	4.25E-6
464	463	900.	.0565450	4.25E-6
474	473	900.	.0487899	4.25E-6
484	483	.901	.0547146	4.25E-6
414	437	16000.	2.108979	49.20E-6
437	424	16000.	2.119330	49.20E-6
424	434	16000.	2.094913	49.20E-6
434	444	16000.	2.069279	49.20E-6
444	454	16000.	2.041413	49.20E-6
454	464	16000.	2.041413	49.20E-6
464	474	16000.	2.019479	49.20E-6
474	484	16000.	2.006213	49.20E-6
484	496	8000.	.8472594	25.30E-6
484	492	8000.	1.471114	25.30E-6
492	502	16000.	2.630612	49.20E-6
502	512	16000.	2.608778	49.20E-6
512	522	16000.	2.578429	49.20E-6
522	536	8000.	1.616414	25.30E-6
225	412	24000.	1.935271	75.90E-6
235	422	900.	.1584089	4.25E-6
245	432	900.	.0848689	4.25E-6
255	442	900.	.0546167	4.25E-6
265	452	900.	.0694299	4.25E-6
275	462	900.	.0701679	4.25E-6
285	472	900.	.0607019	4.25E-6
295	482	900.	.0523238	4.25E-6

Grid Point A	Grid Point B	Extensional Stiffness,EA (pound)	Preload (pound)	Unit Weight (pound/in.)
305	492	900.	.0504938	4.25E-6
315	502	900.	.0531969	4.25E-6
325	512	900.	.0418739	4.25E-6
335	522	90.	.0447495	4.25E-6
206	400	48000.	6.571762	147.00E-6
400	401	48000.	6.592866	147.00E-6
401	402	48000.	6.619918	147.00E-6
402	412	48000.	6.627866	147.00E-6
412	405	32000.	8.017823	98.00E-6
405	413	32000.	8.017823	98.00E-6
422	423	900.	.1514081	4.25E-6
432	433	900.	.0716861	4.25E-6
442	443	900.	.0392261	4.25E-6
452	453	900.	.0553549	4.25E-6
462	463	900.	.0563259	4.25E-6
472	473	900.	.0490229	4.25E-6
482	483	.901	.0050677	4.25E-6
412	428	16000.	2.168629	49.20E-6
428	422	16000.	2.168629	49.20E-6
422	432	16000.	2.147596	49.20E-6
432	442	16000.	2.126129	49.20E-6
442	452	16000.	2.105196	49.20E-6
452	462	16000.	2.090813	49.20E-6
462	472	16000.	2.066979	49.20E-6
472	482	16000.	2.052496	49.20E-6
482	306	8000.	.8757654	25.30E-6
482	492	8000.	1.496414	25.30E-6
522	346	8000.	1.617014	25.30E-6
376	562	90.	.2635469	4.25E-6
566	562	90.	.2632878	4.25E-6

TABLE 12. HOOP SUPPORT CABLE PROPERTIES
SEE FIGURE 23

Grid Point A	Grid Point B	Extensional Stiffness, EA (pound)	Preload (pound)	Unit Weight (pound/in.)
15	14	13200.	28.19997	172.00E-6
14	13	13200.	28.19997	172.00E-6
13	12	13200.	28.19997	172.00E-6
12	11	13200.	28.19997	172.00E-6
15	167	13200.	28.19997	172.00E-6
167	168	13200.	28.19997	172.00E-6
168	169	13200.	28.19997	172.00E-6
169	129	13200.	28.19997	172.00E-6
6	157	13200.	28.19997	172.00E-6
157	158	13200.	28.19997	172.00E-6
158	159	13200.	28.19997	172.00E-6
159	119	13200.	28.19997	172.00E-6
5	4	13200.	28.19997	172.00E-6
4	3	13200.	28.19997	172.00E-6
3	2	13200.	28.19997	172.00E-6
6	5	13200.	28.19997	172.00E-6
15	17	39900.	5.878630	98.00E-6
17	18	39900.	5.878630	98.00E-6
18	19	39900.	5.878630	98.00E-6
6	8	39900.	5.878630	98.00E-6
8	9	39900.	5.878630	98.00E-6
9	10	39900.	5.878630	98.00E-6
205	204	13200.	28.19997	172.00E-6
204	203	13200.	28.19997	172.00E-6
203	202	13200.	28.19997	172.00E-6
202	201	13200.	28.19997	172.00E-6
205	191	13200.	28.19997	172.00E-6
191	192	13200.	28.19997	172.00E-6
192	193	13200.	28.19997	172.00E-6
193	189	13200.	28.19997	172.00E-6
205	207	39900.	5.878630	98.00E-6
207	208	39900.	5.878630	98.00E-6
208	209	39900.	5.878630	98.00E-6
395	394	13200.	28.19997	172.00E-6
394	393	13200.	28.19997	172.00E-6
393	392	13200.	28.19997	172.00E-6
392	391	13200.	28.19997	172.00E-6
395	419	13200.	28.19997	172.00E-6
419	420	13200	28.19997	172.00E-6
420	421	13200.	28.19997	172.00E-6
421	411	13200.	28.19997	172.00E-6
395	397	39900.	5.878630	98.00E-6
397	398	39900.	5.878630	98.00E-6
398	399	39900.	5.878630	98.00E-6

TABLE 13. 1ST, 2ND AND 3RD GORE TRIANGULAR WEB PROPERTIES SEE FIGURE 24, 25 and 26

Shear stiffness = 0.41 pound/in.
Weight = .345E-04 pound/sq. in.

Grid Point A	Grid Point B	Grid Point C	Extensional Stiff. (pound/in.)		Preload (pound/in.)	
			A-B	90 deg.	A-B	90 deg.
16	29	36	.70	2.50	.02044	.01238
29	28	38	.70	2.50	.02044	.01238
28	27	37	.70	2.50	.02044	.01238
27	34	37	.70	2.50	.02044	.01238
7	20	30	.70	2.50	.02044	.01238
20	21	23	.70	2.50	.02044	.01238
21	22	24	.70	2.50	.02044	.01238
22	32	24	.70	2.50	.02044	.01238
30	23	39	.70	2.50	.02044	.01238
23	24	47	.70	2.50	.02044	.01238
24	32	48	.70	2.50	.02044	.01238
32	25	48	.70	2.50	.02044	.01238
25	33	49	.70	2.50	.02044	.01238
33	26	49	.70	2.50	.02044	.01238
26	34	57	.70	2.50	.02044	.01238
34	37	57	.70	2.50	.02044	.01238
37	38	58	.70	2.50	.02044	.01238
38	36	59	.70	2.50	.02044	.01238
48	49	42	.70	2.50	.02044	.01238
42	43	49	.70	2.50	.02044	.01238
49	57	43	.70	2.50	.02044	.01238
43	44	57	.70	2.50	.02044	.01238
57	49	26	.70	2.50	.02044	.01238
49	48	25	.70	2.50	.02044	.01238
58	59	38	.70	2.50	.02044	.01238
57	58	37	.70	2.50	.02044	.01238
48	47	24	.70	2.50	.02044	.01238
47	39	23	.70	2.50	.02044	.01238
39	47	40	.70	2.50	.02044	.01238
42	40	47	.70	2.50	.02044	.01238
47	48	42	.70	2.50	.02044	.01238
44	46	58	.70	2.50	.02044	.01238
58	57	44	.70	2.50	.02044	.01238
59	58	46	.70	2.50	.02044	.01238
30	23	20	.70	2.50	.02044	.01238
23	24	21	.70	2.50	.02044	.01238
36	38	29	.70	2.50	.02044	.01238
38	37	28	.70	2.50	.02044	.01238
44	46	56	.70	2.50	.02044	.01238
54	56	66	.70	2.50	.02044	.01238
64	66	76	.70	2.50	.02044	.01238
74	76	86	.70	2.50	.02044	.01238
84	86	96	.70	2.50	.02044	.01238
94	96	106	.70	2.50	.02044	.01238

Grid Point A	Grid Point B	Grid Point C	Extensional Stiff. (pound/in.) A-B	Extensional Stiff. (pound/in.) 90 deg.	Preload (pound/in.) A-B	Preload (pound/in.) 90 deg.
104	106	116	.70	2.50	.02044	.01238
56	54	44	.70	2.50	.02044	.01238
66	64	54	.70	2.50	.02044	.01238
76	74	64	.70	2.50	.02044	.01238
86	84	74	.70	2.50	.02044	.01238
96	94	84	.70	2.50	.02044	.01238
106	104	94	.70	2.50	.02044	.01238
43	44	54	.70	2.50	.02044	.01238
53	54	64	.70	2.50	.02044	.01238
63	64	74	.70	2.50	.02044	.01238
73	74	84	.70	2.50	.02044	.01238
83	84	94	.70	2.50	.02044	.01238
93	94	104	.70	2.50	.02044	.01238
54	53	43	.70	2.50	.02044	.01238
64	63	53	.70	2.50	.02044	.01238
74	73	63	.70	2.50	.02044	.01238
84	83	73	.70	2.50	.02044	.01238
94	93	83	.70	2.50	.02044	.01238
104	103	93	.70	2.50	.02044	.01238
103	104	112	.70	2.50	.02044	.01238
116	112	104	.70	2.50	.02044	.01238
112	116	126	.70	2.50	.02044	.01238
122	126	136	.70	2.50	.02044	.01238
132	136	146	.70	2.50	.02044	.01238
126	122	112	.70	2.50	.02044	.01238
136	132	122	.70	2.50	.02044	.01238
146	142	132	.70	2.50	.02044	.01238
142	146	156	.70	2.50	.02044	.01238
156	152	142	.70	2.50	.02044	.01238
152	156	166	.70	2.50	.02044	.01238
162	166	176	.70	2.50	.02044	.01238
172	176	186	.70	2.50	.02044	.01238
166	162	152	.70	2.50	.02044	.01238
176	172	162	.70	2.50	.02044	.01238
186	182	172	.70	2.50	.02044	.01238
42	40	50	.70	2.50	.02044	.01238
52	50	60	.70	2.50	.02044	.01238
62	60	70	.70	2.50	.02044	.01238
72	70	80	.70	2.50	.02044	.01238
82	80	90	.70	2.50	.02044	.01238
92	90	100	.70	2.50	.02044	.01238
102	100	110	.70	2.50	.02044	.01238
50	52	42	.70	2.50	.02044	.01238
60	62	52	.70	2.50	.02044	.01238
70	72	62	.70	2.50	.02044	.01238
80	82	72	.70	2.50	.02044	.01238
90	92	82	.70	2.50	.02044	.01238
100	102	92	.70	2.50	.02044	.01238
43	42	52	.70	2.50	.02044	.01238
53	52	62	.70	2.50	.02044	.01238

Grid Point A	Grid Point B	Grid Point C	Extensional Stiff. (pound/in.) A-B	Extensional Stiff. (pound/in.) 90 deg.	Preload (pound/in.) A-B	Preload (pound/in.) 90 deg.
63	62	72	.70	2.50	.02044	.01238
73	72	82	.70	2.50	.02044	.01238
83	82	92	.70	2.50	.02044	.01238
93	92	102	.70	2.50	.02044	.01238
52	53	43	.70	2.50	.02044	.01238
62	63	53	.70	2.50	.02044	.01238
72	73	63	.70	2.50	.02044	.01238
82	83	73	.70	2.50	.02044	.01238
92	93	83	.70	2.50	.02044	.01238
102	103	93	.70	2.50	.02044	.01238
103	102	112	.70	2.50	.02044	.01238
110	112	102	.70	2.50	.02044	.01238
112	110	120	.70	2.50	.02044	.01238
122	120	130	.70	2.50	.02044	.01238
132	130	140	.70	2.50	.02044	.01238
120	122	112	.70	2.50	.02044	.01238
130	132	122	.70	2.50	.02044	.01238
140	142	132	.70	2.50	.02044	.01238
142	140	150	.70	2.50	.02044	.01238
150	152	142	.70	2.50	.02044	.01238
152	150	160	.70	2.50	.02044	.01238
162	160	170	.70	2.50	.02044	.01238
172	170	180	.70	2.50	.02044	.01238
160	162	152	.70	2.50	.02044	.01238
170	172	162	.70	2.50	.02044	.01238
180	182	172	.70	2.50	.02044	.01238

TABLE 14. 15 METER ANTENNA TRUSS MAST BEAM PROPERTIES
SEE FIGURE 27

E = 16.72E+06 psi
Density = 0
Preload = 0.0 in all mast elements

Grid Point A	Grid Point B	I1 & I2 (in.**4)	Alpha (in.**4)	Area (sq.in.)	J (in.**4)	Type
331	333	.05969	0.0	.04665	.0012294	batten
333	334	.05969	0.0	.04665	.0012294	batten
334	331	.05969	0.0	.04665	.0012294	batten
324	329	.05969	0.0	.04665	.0012294	batten
329	330	.05969	0.0	.04665	.0012294	batten
330	324	.05969	0.0	.04665	.0012294	batten
320	321	.05969	0.0	.04665	.0012294	batten
321	323	.05969	0.0	.04665	.0012294	batten
323	320	.05969	0.0	.04665	.0012294	batten
310	311	.05969	0.0	.04665	.0012294	batten
311	319	.05969	0.0	.04665	.0012294	batten
319	310	.05969	0.0	.04665	.0012294	batten
307	308	.05969	0.0	.04665	.0012294	batten
308	309	.05969	0.0	.04665	.0012294	batten
309	307	.05969	0.0	.04665	.0012294	batten
301	303	.05969	0.0	.04665	.0012294	batten
303	304	.05969	0.0	.04665	.0012294	batten
304	301	.05969	0.0	.04665	.0012294	batten
291	299	.05969	0.0	.04665	.0012294	batten
299	300	.05969	0.0	.04665	.0012294	batten
300	291	.05969	0.0	.04665	.0012294	batten
287	288	.05969	0.0	.04665	.0012294	batten
288	290	.05969	0.0	.04665	.0012294	batten
290	287	.05969	0.0	.04665	.0012294	batten
279	280	.05969	0.0	.04665	.0012294	batten
280	281	.05969	0.0	.04665	.0012294	batten
281	279	.05969	0.0	.04665	.0012294	batten
271	277	.05969	0.0	.04665	.0012294	batten
277	278	.05969	0.0	.04665	.0012294	batten
278	271	.05969	0.0	.04665	.0012294	batten
260	261	.05969	0.0	.04665	.0012294	batten
261	270	.05969	0.0	.04665	.0012294	batten
270	260	.05969	0.0	.04665	.0012294	batten
251	257	900.00	0.0	900.00	900.00	batten
257	258	900.00	0.0	900.00	900.00	batten
258	251	900.00	0.0	900.00	900.00	batten
240	241	.05969	0.0	.04665	.0012294	batten
241	250	.05969	0.0	.04665	.0012294	batten
250	240	.05969	0.0	.04665	.0012294	batten
229	230	.05969	0.0	.04665	.0012294	batten
230	231	.05969	0.0	.04665	.0012294	batten
231	229	.05969	0.0	.04665	.0012294	batten
543	544	.05969	0.0	.04665	.0012294	batten

Grid Point A	Grid Point B	I1 & I2 (in.**4)	Alpha (in.**4)	Area (sq.in.)	J (in.**4)	Type
544	563	.05969	0.0	.04665	.0012294	batten
563	543	.05969	0.0	.04665	.0012294	batten
353	354	.05969	0.0	.04665	.0012294	batten
354	373	.05969	0.0	.04665	.0012294	batten
373	353	.05969	0.0	.04665	.0012294	batten
164	179	.05969	0.0	.04665	.0012294	batten
179	183	.05969	0.0	.04665	.0012294	batten
183	164	.05969	0.0	.04665	.0012294	batten
139	149	.05969	0.0	.04665	.0012294	batten
149	163	.05969	0.0	.04665	.0012294	batten
163	139	.05969	0.0	.04665	.0012294	batten
199	200	.05969	0.0	.04665	.0012294	batten
200	220	.05969	0.0	.04665	.0012294	batten
220	199	.05969	0.0	.04665	.0012294	batten
195	197	.05969	0.0	.04665	.0012294	batten
197	198	.05969	0.0	.04665	.0012294	batten
198	195	.05969	0.0	.04665	.0012294	batten
89	184	.05969	0.0	.04665	.0012294	batten
184	194	.05969	0.0	.04665	.0012294	batten
194	89	.05969	0.0	.04665	.0012294	batten
331	324	.04089	0.0	.1290	.03085	longeron
333	329	.04089	0.0	.1290	.03085	longeron
334	330	.04089	0.0	.1290	.03085	longeron
320	310	.04089	0.0	.1290	.03085	longeron
321	311	.04089	0.0	.1290	.03085	longeron
323	319	.04089	0.0	.1290	.03085	longeron
307	301	.04089	0.0	.1290	.03085	longeron
308	303	.04089	0.0	.1290	.03085	longeron
309	304	.04089	0.0	.1290	.03085	longeron
291	287	.04089	0.0	.1290	.03085	longeron
299	288	.04089	0.0	.1290	.03085	longeron
300	290	.04089	0.0	.1290	.03085	longeron
279	271	.04089	0.0	.1290	.03085	longeron
280	277	.04089	0.0	.1290	.03085	longeron
281	278	.04089	0.0	.1290	.03085	longeron
260	572	.04089	0.0	.1290	.03085	longeron
261	573	.04089	0.0	.1290	.03085	longeron
270	574	.04089	0.0	.1290	.03085	longeron
572	251	.04089	0.0	.1290	.03085	longeron
573	257	.04089	0.0	.1290	.03085	longeron
574	258	.04089	0.0	.1290	.03085	longeron
251	240	.04089	0.0	.1290	.03085	longeron
257	241	.04089	0.0	.1290	.03085	longeron
258	250	.04089	0.0	.1290	.03085	longeron
229	543	.04089	0.0	.1290	.03085	longeron
230	544	.04089	0.0	.1290	.03085	longeron
231	563	.04089	0.0	.1290	.03085	longeron
353	164	.04089	0.0	.1290	.03085	longeron
354	179	.04089	0.0	.1290	.03085	longeron
373	183	.04089	0.0	.1290	.03085	longeron

Grid Point A	Grid Point B	I1 & I2 (in.**4)	Alpha (in.**4)	Area (sq.in.)	J (in.**4)	Type
139	199	.04089	0.0	.1290	.03085	longeron
149	200	.04089	0.0	.1290	.03085	longeron
163	220	.04089	0.0	.1290	.03085	longeron
195	89	.04089	0.0	.1290	.03085	longeron
197	184	.04089	0.0	.1290	.03085	longeron
198	194	.04089	0.0	.1290	.03085	longeron
324	320	900.00	0.0	900.00	900.00	radial
329	321	900.00	0.0	900.00	900.00	radial
330	323	900.00	0.0	900.00	900.00	radial
310	307	900.00	0.0	900.00	900.00	radial
311	308	900.00	0.0	900.00	900.00	radial
319	309	900.00	0.0	900.00	900.00	radial
301	291	900.00	0.0	900.00	900.00	radial
303	299	900.00	0.0	900.00	900.00	radial
304	300	900.00	0.0	900.00	900.00	radial
287	279	900.00	0.0	900.00	900.00	radial
288	280	900.00	0.0	900.00	900.00	radial
290	281	900.00	0.0	900.00	900.00	radial
271	260	900.00	0.0	900.00	900.00	radial
277	261	900.00	0.0	900.00	900.00	radial
278	270	900.00	0.0	900.00	900.00	radial
240	229	900.00	0.0	900.00	900.00	radial
241	230	900.00	0.0	900.00	900.00	radial
250	231	900.00	0.0	900.00	900.00	radial
543	353	900.00	0.0	900.00	900.00	radial
544	354	900.00	0.0	900.00	900.00	radial
563	373	900.00	0.0	900.00	900.00	radial
164	139	900.00	0.0	900.00	900.00	radial
179	149	900.00	0.0	900.00	900.00	radial
183	163	900.00	0.0	900.00	900.00	radial
199	195	900.00	0.0	900.00	900.00	radial
200	197	900.00	0.0	900.00	900.00	radial
220	198	900.00	0.0	900.00	900.00	radial
331	329	.05969	0.0	.01350	.001294	diagonal
333	330	.05969	0.0	.01350	.001294	diagonal
334	324	.05969	0.0	.01350	.001294	diagonal
320	319	.05969	0.0	.01350	.001294	diagonal
321	310	.05969	0.0	.01350	.001294	diagonal
323	311	.05969	0.0	.01350	.001294	diagonal
307	303	.05969	0.0	.01350	.001294	diagonal
308	304	.05969	0.0	.01350	.001294	diagonal
309	301	.05969	0.0	.01350	.001294	diagonal
291	290	.05969	0.0	.01350	.001294	diagonal
299	287	.05969	0.0	.01350	.001294	diagonal
300	288	.05969	0.0	.01350	.001294	diagonal
279	277	.05969	0.0	.01350	.001294	diagonal
280	278	.05969	0.0	.01350	.001294	diagonal
281	271	.05969	0.0	.01350	.001294	diagonal
260	258	.05969	0.0	.01350	.001294	diagonal
261	251	.05969	0.0	.01350	.001294	diagonal

Grid Point A	Grid Point B	I1 & I2 (in.**4)	Alpha (in.**4)	Area (sq.in.)	J (in.**4)	Type
270	257	.05969	0.0	.01350	.001294	diagonal
251	241	.05969	0.0	.01350	.001294	diagonal
257	250	.05969	0.0	.01350	.001294	diagonal
258	240	.05969	0.0	.01350	.001294	diagonal
229	563	.05969	0.0	.01350	.001294	diagonal
230	543	.05969	0.0	.01350	.001294	diagonal
231	544	.05969	0.0	.01350	.001294	diagonal
353	179	.05969	0.0	.01350	.001294	diagonal
354	183	.05969	0.0	.01350	.001294	diagonal
373	164	.05969	0.0	.01350	.001294	diagonal
139	220	.05969	0.0	.01350	.001294	diagonal
149	199	.05969	0.0	.01350	.001294	diagonal
163	200	.05969	0.0	.01350	.001294	diagonal
195	184	.05969	0.0	.01350	.001294	diagonal
197	194	.05969	0.0	.01350	.001294	diagonal
198	89	.05969	0.0	.01350	.001294	diagonal
89	221	900.00	0.0	900.00	900.00	radial
184	221	900.00	0.0	900.00	900.00	radial
194	221	900.00	0.0	900.00	900.00	radial
331	1	900.00	0.0	900.00	900.00	radial
333	1	900.00	0.0	900.00	900.00	radial
334	1	900.00	0.0	900.00	900.00	radial
572	196	900.00	0.0	900.00	900.00	radial
573	196	900.00	0.0	900.00	900.00	radial
574	196	900.00	0.0	900.00	900.00	radial

TABLE 15. SEMI-RIGID, SPREADER BAR AND HOOP BEAM PROPERTIES
SEE FIGURE 23, 28, 29 and 30

YOUNG'S MODULUS:
Hoop Elements = 16.72E+06 psi
Mast to cable elements = 10.6E+06 psi
Spreader bar elements = 10.4E+06 psi

Grid Point A	Grid Point B	I1 & I2 (in.**4)	Density (lb/in**3)	Area (sq.in.)	J (in.**4)	Preload Stress (psi)	Type
6	15	.26156	0.0	.34707	.52312	-925.21	hoop
15	205	.26156	0.0	.34707	.52312	-925.21	hoop
205	395	.26156	0.0	.34707	.52312	-925.21	hoop
196	187	900.00	0.0	900.00	900.00	3.51	mast
196	188	900.00	0.0	900.00	900.00	3.51	mast
196	378	900.00	0.0	900.00	900.00	3.51	mast
196	568	900.00	0.0	900.00	900.00	3.51	mast
221	2	900.00	0.0	900.00	900.00	3.51	mast
221	11	900.00	0.0	900.00	900.00	3.51	mast
221	201	900.00	0.0	900.00	900.00	3.51	mast
221	391	900.00	0.0	900.00	900.00	3.51	mast
221	119	900.00	0.0	900.00	900.00	3.51	mast
221	129	900.00	0.0	900.00	900.00	3.51	mast
221	189	900.00	0.0	900.00	900.00	3.51	mast
221	411	900.00	0.0	900.00	900.00	3.51	mast
1	10	900.00	0.0	900.00	900.00	3.51	mast
1	19	900.00	0.0	900.00	900.00	3.51	mast
1	209	900.00	0.0	900.00	900.00	3.51	mast
1	309	900.00	0.0	900.00	900.00	3.51	mast
5	147	.20000	0.1154	.00149	.40000	-13.23	bar
147	157	.20000	0.1154	.00149	.40000	-13.23	bar
14	148	.20000	0.1154	.00149	.40000	-8.77	bar
148	167	.20000	0.1154	.00149	.40000	-8.77	bar
191	190	.20000	0.1154	.00149	.40000	-5.76	bar
190	204	.20000	0.1154	.00149	.40000	-5.20	bar
394	410	.20000	0.1154	.00149	.40000	-9.58	bar
410	419	.20000	0.1154	.00149	.40000	-9.59	bar

TABLE 16. 15 METER ANTENNA TRIPOD SUPPORT STRUCTURE BEAM PROPERTIES
SEE FIGURE 31

PRELOADS:

All support structure preload stress = 0.0 psi

YOUNG'S MODULUS:

E = 10.0E+06 psi

DENSITY = 0

Grid Point A	Grid Point B	I1 & I2 (in.**4)	Alpha (in.**4)	Area (sq.in.)	J (in.**4)	Type
379	382	18.7	0.0	4.52	37.4	leg
380	383	18.7	0.0	4.52	37.4	leg
381	384	18.7	0.0	4.52	37.4	leg
382	385	18.7	0.0	4.52	37.4	leg
383	386	18.7	0.0	4.52	37.4	leg
384	387	18.7	0.0	4.52	37.4	leg
385	388	18.7	0.0	4.52	37.4	leg
386	389	18.7	0.0	4.52	37.4	leg
387	390	18.7	0.0	4.52	37.4	leg
388	337	18.7	0.0	4.52	37.4	leg
389	338	18.7	0.0	4.52	37.4	leg
390	339	18.7	0.0	4.52	37.4	leg
337	340	2.813	0.0	3.75	1.44	leg
338	341	2.813	0.0	3.75	1.44	leg
339	347	2.813	0.0	3.75	1.44	leg
340	341	.1276	0.0	.589	.2573	batten
341	347	.1276	0.0	.589	.2573	batten
347	340	.1276	0.0	.589	.2573	batten
340	260	.133	0.0	2.00	.0240	radial
341	261	.133	0.0	2.00	.0240	radial
347	270	.133	0.0	2.00	.0240	radial

TABLE 17. 15 METER ANTENNA FEED MAST BEAM PROPERTIES
SEE FIGURE 32

PRELOADS:
All feed mast preload stress = 0.0 psi
YOUNG'S MODULUS = 30.0E+06 psi
WEIGHT DENSITY = .282 lb/in**3

Grid Point A	Grid Point B	I1 & I2 (in.**4)	Alpha (in.**4)	Area (sq.in.)	J (in.**4)	Type
4561	4564	.005036	1.0	.078618	.010072	longeron
4564	4567	.005036	1.0	.078618	.010072	longeron
4567	4570	.005036	1.0	.078618	.010072	longeron
4570	4573	.005036	1.0	.078618	.010072	longeron
4573	4576	.005036	1.0	.078618	.010072	longeron
4576	4579	.005036	1.0	.078618	.010072	longeron
4579	4582	.005036	1.0	.078618	.010072	longeron
4562	4565	.005036	1.0	.078618	.010072	longeron
4565	4568	.005036	1.0	.078618	.010072	longeron
4568	4571	.005036	1.0	.078618	.010072	longeron
4571	4574	.005036	1.0	.078618	.010072	longeron
4574	4577	.005036	1.0	.078618	.010072	longeron
4577	4580	.005036	1.0	.078618	.010072	longeron
4580	4583	.005036	1.0	.078618	.010072	longeron
4563	4566	.005036	1.0	.078618	.010072	longeron
4566	4569	.005036	1.0	.078618	.010072	longeron
4569	4572	.005036	1.0	.078618	.010072	longeron
4572	4575	.005036	1.0	.078618	.010072	longeron
4575	4578	.005036	1.0	.078618	.010072	longeron
4578	4581	.005036	1.0	.078618	.010072	longeron
4581	4584	.005036	1.0	.078618	.010072	longeron
4561	4562	.0004826	1.0	.030964	.0009652	batten
4562	4563	.0004826	1.0	.030964	.0009652	batten
4563	4561	.0004826	1.0	.030964	.0009652	batten
4564	4565	.0004826	1.0	.030964	.0009652	batten
4565	4566	.0004826	1.0	.030964	.0009652	batten
4566	4564	.0004826	1.0	.030964	.0009652	batten
4567	4568	.0004826	1.0	.030964	.0009652	batten
4568	4569	.0004826	1.0	.030964	.0009652	batten
4569	4567	.0004826	1.0	.030964	.0009652	batten
4570	4571	.0004826	1.0	.030964	.0009652	batten
4571	4572	.0004826	1.0	.030964	.0009652	batten
4572	4570	.0004826	1.0	.030964	.0009652	batten
4573	4574	.0004826	1.0	.030964	.0009652	batten
4574	4575	.0004826	1.0	.030964	.0009652	batten
4575	4573	.0004826	1.0	.030964	.0009652	batten
4576	4577	.0004826	1.0	.030964	.0009652	batten
4577	4578	.0004826	1.0	.030964	.0009652	batten
4578	4576	.0004826	1.0	.030964	.0009652	batten
4579	4580	.0004826	1.0	.030964	.0009652	batten
4580	4581	.0004826	1.0	.030964	.0009652	batten
4581	4579	.0004826	1.0	.030964	.0009652	batten
4582	4583	.0004826	1.0	.030964	.0009652	batten

Grid Point A	Grid Point B	I1 & I2 (in.**4)	Alpha (in.**4)	Area (sq.in.)	J (in.**4)	Type
4583	4584	.0004826	1.0	.030964	.0009652	batten
4584	4582	.0004826	1.0	.030964	.0009652	batten
4561	4565	.0004826	1.0	.030964	.0009652	diagonal
4567	4571	.0004826	1.0	.030964	.0009652	diagonal
4573	4577	.0004826	1.0	.030964	.0009652	diagonal
4579	4583	.0004826	1.0	.030964	.0009652	diagonal
4562	4566	.0004826	1.0	.030964	.0009652	diagonal
4568	4572	.0004826	1.0	.030964	.0009652	diagonal
4574	4578	.0004826	1.0	.030964	.0009652	diagonal
4580	4584	.0004826	1.0	.030964	.0009652	diagonal
4563	4564	.0004826	1.0	.030964	.0009652	diagonal
4569	4570	.0004826	1.0	.030964	.0009652	diagonal
4575	4576	.0004826	1.0	.030964	.0009652	diagonal
4581	4582	.0004826	1.0	.030964	.0009652	diagonal
4564	4569	.0004826	1.0	.030964	.0009652	diagonal
4570	4575	.0004826	1.0	.030964	.0009652	diagonal
4576	4581	.0004826	1.0	.030964	.0009652	diagonal
4565	4567	.0004826	1.0	.030964	.0009652	diagonal
4571	4573	.0004826	1.0	.030964	.0009652	diagonal
4577	4579	.0004826	1.0	.030964	.0009652	diagonal
4566	4568	.0004826	1.0	.030964	.0009652	diagonal
4572	4574	.0004826	1.0	.030964	.0009652	diagonal
4578	4580	.0004826	1.0	.030964	.0009652	diagonal
221	4561	900.	1.0	900.	900.	rigid
4582	4585	900.	1.0	900.	900.	rigid
4585	4586	900.	1.0	900.	900.	rigid
221	4562	900.	1.0	900.	900.	rigid
4583	4586	900.	1.0	900.	900.	rigid
4586	4587	900.	1.0	900.	900.	rigid
221	4563	900.	1.0	900.	900.	rigid
4584	4587	900.	1.0	900.	900.	rigid
4587	4585	900.	1.0	900.	900.	rigid

TABLE 18. 15 METER ANTENNA LUMPED MASSES AT GRID POINTS

Grid Point	Mass (lb-sec**2/in)	No. of Repeats	Grid Point Increment
6	35750.000000E-06	3	1140
7	18.134720E-06	3	1140
15	30880.000000E-06	7	570
16	31.787560E-06	7	570
30	5.440414E-06	3	1140
31	16.010362E-06	3	1140
32	26.424870E-06	7	570
34	26.424870E-06	7	570
35	7.772021E-06	7	570
36	2.694301E-06	7	570
40	10.000000E-06	3	1140
41	21.295340E-06	3	1140
42	1.243523E-06	7	570
44	1.243523E-06	7	570
45	10.310880E-06	7	570
46	4.689119E-06	7	570
50	16.113990E-06	3	1140
51	26.424880E-06	3	1140
52	1.243523E-06	7	570
54	1.243523E-06	7	570
55	13.031093E-06	7	570
56	7.564767E-06	7	570
60	23.834200E-06	3	1140
61	142.797920E-06	3	1140
62	1.243523E-06	7	570
64	1.243523E-06	7	570
65	132.590700E-06	7	570
66	11.424870E-06	7	570
67	8.756476E-06	3	1140
68	5.647668E-06	3	1140
69	4.378238E-06	7	570
70	21.191700E-06	3	1140
71	27.305700E-06	3	1140
72	1.243523E-06	7	570
74	1.243523E-06	7	570
75	13.393780E-06	7	570
76	10.103630E-06	7	570
77	3.652850E-06	7	570
78	3.678756E-06	7	570
79	2.953368E-06	7	570
80	17.875648E-06	3	1140
81	27.927460E-06	3	1140
82	1.243523E-06	7	570
84	1.243523E-06	7	570
85	13.678760E-06	7	570
86	8.471503E-06	7	570
87	7.253886E-06	3	1140
88	7.305700E-06	3	1140
90	18.911918E-06	3	1140

C-2

Grid Point	Mass (lb-sec**2/in)	No. of Repeats	Grid Point Increment
91	30.155440E-06	3	1140
92	1.243523E-06	7	570
94	1.243523E-06	7	570
95	14.818650E-06	7	570
96	9.067358E-06	7	570
100	24.145080E-06	3	1140
101	145.544040E-06	3	1140
102	15.284970E-06	7	570
104	15.284970E-06	7	570
105	134.844600E-06	7	570
106	11.683940E-06	7	570
110	44.818660E-06	3	1140
111	27.461140E-06	3	1140
112	17.150260E-06	7	570
113	10.051814E-06	3	1140
114	10.466322E-06	3	1140
115	13.678760E-06	7	570
116	34.481870E-06	7	570
120	15.284974E-06	3	1140
121	27.720200E-06	3	1140
122	1.424870E-06	7	570
123	5.077720E-06	7	570
124	5.207254E-06	7	570
125	13.730570E-06	7	570
126	7.331606E-06	7	570
130	16.787564E-06	3	1140
131	31.658040E-06	3	1140
132	1.424870E-06	7	570
135	15.699480E-06	7	570
136	8.212435E-06	7	570
140	23.782380E-06	3	1140
141	144.196900E-06	3	1140
142	16.554400E-06	7	570
143	10.000000E-06	3	1140
144	11.139896E-06	3	1140
145	134.326400E-06	7	570
146	11.683940E-06	7	570
147	30.051820E-06	3	1140
148	30.051810E-06	7	570
150	42.849740E-06	3	1140
151	23.937820E-06	3	1140
153	5.155440E-06	7	570
154	1.891192E-06	7	570
155	12.020730E-06	7	570
156	33.549220E-06	7	570
160	9.948186E-06	3	1140
161	20.984460E-06	3	1140
165	10.207250E-06	7	570
166	4.818653E-06	7	570
170	8.808290E-06	3	1140

Grid Point	Mass (lb-sec**2/in)	No. of Repeats	Grid Point Increment
171	21.347160E-06	3	1140
175	12.979270E-06	7	570
176	4.455959E-06	7	570
180	93.212440E-06	3	1140
181	150.880820E-06	3	1140
182	3.238342E-06	7	570
185	141.554400E-06	7	570
186	77.979270E-06	7	570
187	1943.000000E-06	3	1140
188	1943.000000E-06	7	570
190	30.051810E-06	7	570
205	30880.000000E-06	7	570
206	31.139900E-06	7	570
222	26.424870E-06	7	570
224	26.424870E-06	7	570
225	6.891192E-06	7	570
226	1.891192E-06	7	570
232	1.243523E-06	7	570
234	1.243523E-06	7	570
235	9.740933E-06	7	570
236	4.067358E-06	7	570
242	1.243523E-06	7	570
244	1.243523E-06	7	570
245	12.564770E-06	7	570
246	7.072539E-06	7	570
252	1.243523E-06	7	570
254	1.243523E-06	7	570
255	132.202100E-06	7	570
256	10.958550E-06	7	570
259	4.430052E-06	7	570
262	1.243523E-06	7	570
264	1.243523E-06	7	570
265	13.056990E-06	7	570
266	9.715026E-06	7	570
267	3.626943E-06	7	570
268	3.678756E-06	7	570
269	3.108808E-06	7	570
272	1.243523E-06	7	570
274	1.243523E-06	7	570
275	1.331606E-06	7	570
276	8.108808E-06	7	570
282	1.243523E-06	7	570
284	1.243523E-06	7	570
285	14.455960E-06	7	570
286	8.756477E-06	7	570
292	15.284970E-06	7	570
294	15.284970E-06	7	570
295	134.611400E-06	7	570
296	11.398960E-06	7	570
302	17.150260E-06	7	570

Grid Point	Mass (lb-sec**2/in)	No. of Repeats	Grid Point Increment
305	13.393780E-06	7	570
306	34.196890E-06	7	570
312	1.424870E-06	7	570
313	5.077720E-06	7	570
314	5.207254E-06	7	570
315	13.445600E-06	7	570
316	7.072539E-06	7	570
322	1.424870E-06	7	570
325	15.440410E-06	7	570
326	7.979275E-06	7	570
332	16.554400E-06	7	570
335	134.196900E-06	7	570
336	11.502590E-06	7	570
343	5.155440E-06	7	570
344	1.891192E-06	7	570
345	11.865280E-06	7	570
346	33.341970E-06	7	570
355	10.025910E-06	7	570
356	4.663212E-06	7	570
365	12.746110E-06	7	570
366	4.352332E-06	7	570
372	3.186528E-06	7	570
375	141.373100E-06	7	570
376	77.823830E-06	7	570
378	1943.000000E-06	7	570
395	35750.000000E-06	3	1140
396	33.937820E-06	3	1140
410	30.051820E-06	3	1140
412	26.424870E-06	7	570
414	26.424870E-06	7	570
415	12.797928E-06	3	1140
416	3.264248E-06	3	1140
422	1.243523E-06	7	570
424	1.243523E-06	7	570
425	18.549222E-06	3	1140
426	7.668394E-06	3	1140
432	1.243523E-06	7	570
434	1.243523E-06	7	570
435	24.196900E-06	3	1140
436	13.678756E-06	3	1140
442	1.243523E-06	7	570
444	1.243523E-06	7	570
445	141.036260E-06	3	1140
446	21.606220E-06	3	1140
449	8.860104E-06	3	1140
452	1.243523E-06	7	570
454	1.243523E-06	7	570
455	25.284980E-06	3	1140
456	18.963730E-06	3	1140
457	7.253886E-06	3	1140

Grid Point	Mass (lb-sec**2/in)	No. of Repeats	Grid Point Increment
458	7.305700E-06	3	1140
459	6.062176E-06	3	1140
462	1.243523E-06	7	570
464	1.243523E-06	7	570
465	25.751300E-06	3	1140
466	15.751296E-06	3	1140
472	1.243523E-06	7	570
474	1.243523E-06	7	570
475	28.031080E-06	3	1140
476	17.098446E-06	3	1140
482	15.284970E-06	7	570
484	15.284970E-06	7	570
485	144.196900E-06	3	1140
486	22.383420E-06	3	1140
492	17.150260E-06	7	570
495	26.010360E-06	3	1140
496	42.953360E-06	3	1140
502	1.424870E-06	7	570
503	10.207254E-06	3	1140
504	10.310880E-06	3	1140
505	26.165800E-06	3	1140
506	13.730570E-06	3	1140
512	1.424870E-06	7	570
515	30.103620E-06	3	1140
516	15.699482E-06	3	1140
522	16.554400E-06	7	570
525	143.419680E-06	3	1140
526	22.694300E-06	3	1140
533	10.259068E-06	3	1140
534	3.782384E-06	3	1140
535	23.005180E-06	3	1140
536	41.502600E-06	3	1140
545	19.326424E-06	3	1140
546	9.015544E-06	3	1140
555	24.715020E-06	3	1140
556	8.393782E-06	3	1140
562	3.186528E-06	7	570
565	155.699480E-06	3	1140
566	92.331600E-06	3	1140
568	1943.000000E-06	3	1140
331	5304.000000E-06	0	
333	5304.000000E-06	0	
334	5304.000000E-06	0	
320	7154.000000E-06	0	
321	7154.000000E-06	0	
323	7154.000000E-06	0	
307	3700.000000E-06	0	
308	3700.000000E-06	0	
309	3700.000000E-06	0	
291	3700.000000E-06	0	

Grid Point	Mass (lb-sec**2/in)	No. of Repeats	Grid Point Increment	
299	3700.000000E-06	0		
300	3700.000000E-06	0		
279	3700.000000E-06	0		
280	3700.000000E-06	0		
281	3700.000000E-06	0		
260	3700.000000E-06	0		
261	3700.000000E-06	0		
270	3700.000000E-06	0		
251	73700.000000E-06	0		
257	73700.000000E-06	0		
258	73700.000000E-06	0		
240	3700.000000E-06	0		
241	3700.000000E-06	0		
250	3700.000000E-06	0		
543	3700.000000E-06	0		
544	3700.000000E-06	0		
563	3700.000000E-06	0		
164	3700.000000E-06	0		
179	3700.000000E-06	0		
183	3700.000000E-06	0		
199	3700.000000E-06	0		
200	3700.000000E-06	0		
220	3700.000000E-06	0		
89	1850.000000E-06	0		
184	1850.000000E-06	0		
194	1850.000000E-06	0		
2	6910.000000E-06	3	1140	
11	6910.000000E-06	7	570	
201	6910.000000E-06	7	570	
391	6910.000000E-06	3	1140	
10	10813.000000E-06	3	1140	
19	10813.000000E-06	7	570	
209	10813.000000E-06	7	570	
399	10813.000000E-06	3	1140	
4585	205500.000000E-06	0		feed mast
4586	205500.000000E-06	0		feed mast
4587	205500.000000E-06	0		feed mast
4561	3519.000000E-06	0		feed mast
4562	3519.000000E-06	0		feed mast
4563	3519.000000E-06	0		feed mast
4582	6973.300000E-06	0		feed mast
4583	6973.300000E-06	0		feed mast
4584	6973.300000E-06	0		feed mast

TABLE 19. REDUCED MODEL JOINT LOCATIONS IN GLOBAL CARTESIAN COORDINATE SYSTEM

Joint Number	Repeats	Global 1 (in.)	Global 2 (in.)	Global 3 (in.)	Location
241	0	0.0	0.0	211.328	mast
242	0	0.0	0.0	178.028	mast
243	0	0.0	0.0	144.728	mast
244	0	0.0	0.0	111.428	mast
245	0	0.0	0.0	78.128	mast
246	0	0.0	0.0	33.222	mast
247	0	0.0	0.0	4.940	mast
248	0	0.0	0.0	-11.684	mast
249	0	0.0	0.0	-44.984	mast
250	0	0.0	0.0	-78.284	mast
251	0	0.0	0.0	-111.584	mast
252	0	0.0	0.0	-144.884	mast
253	0	0.0	0.0	-161.565	mast
279	0	0.0	0.0	531.000	cable attach
280	0	0.0	0.0	281.000	cable slide
270	0	0.0	0.0	281.000	mast slide
266	0	0.0	0.0	217.00	feed mast
267	0	0.0	0.0	234.94	feed mast
268	0	0.0	0.0	252.88	feed mast
269	0	0.0	0.0	270.82	feed mast
271	0	0.0	0.0	288.76	feed mast
272	0	0.0	0.0	306.70	feed mast
273	0	0.0	0.0	324.64	feed mast
274	0	0.0	0.0	342.58	feed mast
275	0	0.0	0.0	349.23	feed mast
276	0	0.0	0.0	349.23	feed mast

TABLE 20. REDUCED MODEL JOINT LOCATIONS IN CYLINDRICAL COORDINATE SYSTEM

Joint Number	Repeats/ Increment	Radial (in.)	Angular (deg.)	Global 3 (in.)	Location
1	3/60	48.761	0.0	.93791	1st ray
11	3/60	48.761	15.0	.71836	2nd ray
21	3/60	48.761	30.0	.58035	3rd ray
31	3/60	48.761	45.0	.53372	4th ray
41	3/60	48.761	60.0	.58035	5th ray
51	3/60	48.761	75.0	.71836	6th ray
2	3/60	109.445	0.0	6.26474	1st ray
12	3/60	109.445	15.0	5.77196	2nd ray
22	3/60	109.445	30.0	5.46219	3rd ray
32	3/60	109.445	45.0	5.35653	4th ray
42	3/60	109.445	60.0	5.46219	5th ray
52	3/60	109.445	75.0	5.77196	6th ray
3	3/60	169.409	0.0	16.45860	1st ray
13	3/60	169.409	15.0	15.69580	2nd ray
23	3/60	169.409	30.0	15.21630	3rd ray
33	3/60	169.409	45.0	15.05270	4th ray
43	3/60	169.409	60.0	15.21630	5th ray
53	3/60	169.409	75.0	15.69580	6th ray
4	3/60	228.320	0.0	31.24580	1st ray
14	3/60	228.320	15.0	30.21770	2nd ray
24	3/60	228.320	30.0	29.57150	3rd ray
34	3/60	228.320	45.0	29.35110	4th ray
44	3/60	228.320	60.0	29.57150	5th ray
54	3/60	228.320	75.0	30.21770	6th ray
5	23/10	295.27274	0.0	53.79430	1st ray
6	23/10	49.2911	0.0	-10.85100	1st ray
7	23/10	111.9706	0.0	-14.22400	1st ray
8	23/10	173.4886	0.0	-3.76855	1st ray
9	23/10	233.7864	0.0	11.37090	1st ray
10	23/10	12.000	0.0	210.47300	upper ring
254	2/1	10.125	37.5	-11.684	tripod support
257	2/1	13.950	37.5	-11.684	tripod support
260	2/1	27.600	37.5	-22.684	tripod support
263	2/1	44.000	37.5	-178.684	tripod support

TABLE 21. REDUCED MODEL RAY CABLE PROPERTIES
SEE FIGURE 33

Grid Point A	Grid Point B	Extensional Stiffness,EA (pound)	Preload (pound)	Unit Weight (pound/in.)
4	9	900.	.0381909	4.25E-6
3	8	900.	.0416005	4.25E-6
2	7	900.	.0667923	4.25E-6
1	6	24000.	.8317074	75.90E-6
4	5	24000.	2.510788	75.90E-6
3	4	24000.	2.460265	75.90E-6
2	3	40000.	3.676140	253.00E-6
1	2	56000.	5.942829	354.00E-6
1	247	33.	5.939994	150.00E-6
5	9	48000.	12.68233	150.00E-6
8	9	24000.	2.954486	73.60E-6
7	8	16000.	2.063296	49.20E-6
6	7	8000.	1.366297	25.30E-6
6	247	1.430	1.479994	25.30E-6
9	253	18900.	11.12914	49.20E-6
8	253	7800.	1.838905	25.30E-6
7	253	7800.	1.577960	25.30E-6
6	253	7800.	1.608924	25.30E-6

TABLE 22. REDUCED MODEL 1ST CORE CABLE PROPERTIES
SEE FIGURE 34

Grid Point A	Grid Point B	Extensional Stiffness,EA (pound)	Preload (pound)	Unit Weight (pound/in.)
4	14	900.	.0447171	4.25E-6
9	19	900.	.0447171	4.25E-6
3	13	900.	.0447171	4.25E-6
8	18	900.	.0447171	4.25E-6
2	12	90.	.0296130	4.25E-6
7	17	90.	.0296130	4.25E-6
1	11	90.	.2631978	4.25E-6
6	16	90.	.2631978	4.25E-6

TABLE 23. REDUCED MODEL HOOP SUPPORT CABLE PROPERTIES SEE FIGURE 35

Grid Point A	Grid Point B	Extensional Stiffness,EA (pound)	Preload (pound)	Unit Weight (pound/in.)
5	190	13200.	28.19997	172.00E-6
5	70	13200.	28.19997	172.00E-6
15	200	13200.	28.19997	172.00E-6
15	80	13200.	28.19997	172.00E-6
25	210	13200.	28.19997	172.00E-6
25	90	13200.	28.19997	172.00E-6
35	220	13200.	28.19997	172.00E-6
35	100	13200.	28.19997	172.00E-6
5	253	39900.	5.878630	98.00E-6
15	253	39900.	5.878630	98.00E-6
25	253	39900.	5.878630	98.00E-6
35	253	39900.	5.878630	98.00E-6

TABLE 24. REDUCED MODEL TRAPIZOIDAL WEB PROPERTIES
SEE FIGURE 34

Shear stiffness = 0.41 pound/in.
Weight = .345e-4 pound/sq. in.

Grid Point A	Grid Point B	Grid Point C	Grid Point D	Extensional Stiff. (pound/in.) A-B	Extensional Stiff. (pound/in.) 90 deg.	Preload (pound/in.) A-B	Preload (pound/in.) 90 deg.
15	5	4	14	.70	2.50	.01999	.00999
14	4	3	13	.70	2.50	.01999	.00999
13	3	2	12	.70	2.50	.01999	.00999
12	2	1	11	.70	2.50	.01999	.00999

TABLE 25. REDUCED MODEL MAST BEAM PROPERTIES
SEE FIGURE 36

Preload = 0.0 in all mast elements

Grid Point A	Grid Point B	I1 & I2 (in.**4)	Alpha (in.**4)	Area (sq.in.)	J (in.**4)	Type
253	252	2.978	14.43	.387	.4018	longeron
252	251	4.653	31.06	.387	.2888	longeron
251	250	6.700	22.68	.387	.5712	longeron
250	249	9.120	17.64	.387	1.0028	longeron
249	248	11.912	14.39	.387	1.6115	longeron
248	247	15.076	19.03	.387	1.5346	longeron
247	246	15.076	19.03	.387	1.5346	longeron
246	245	15.076	19.03	.387	1.5346	longeron
245	244	11.912	14.39	.387	1.6115	longeron
244	243	9.120	17.64	.387	1.0028	longeron
243	242	6.700	22.68	.387	.5712	longeron
242	241	4.653	31.06	.387	.2888	longeron

TABLE 26. REDUCED MODEL CABLE/MAST ATTACHMENT AND HOOP BEAM PROPERTIES
SEE FIGURE 35and 36

PRELOADS:

Hoop elements, compression stress = 937.03 psi
Mast to cable elements, tensile stress = 3.51 psi

Grid Point A	Grid Point B	I1 & I2 (in.**4)	Alpha (in.**4)	Area (sq.in.)	J (in.**4)	Type
5	15	.26156	0.0	.34707	.52312	hoop
15	25	.26156	0.0	.34707	.52312	hoop
25	35	.26156	0.0	.34707	.52312	hoop
241	10	900.00	0.0	900.00	900.00	mast
241	20	900.00	0.0	900.00	900.00	mast
241	30	900.00	0.0	900.00	900.00	mast
241	40	900.00	0.0	900.00	900.00	mast

TABLE 27. REDUCED MODEL TRIPOD SUPPORT BEAM PROPERTIES
SEE FIGURE 37

PRELOADS:

All support structure preload stress = 0.0 psi

Grid Point A	Grid Point B	I1 & I2 (in.**4)	Alpha (in.**4)	Area (sq.in.)	J (in.**4)	Type
263	260	18.7	0.0	4.52	37.4	leg
264	261	18.7	0.0	4.52	37.4	leg
265	262	18.7	0.0	4.52	37.4	leg
260	257	2.813	0.0	3.75	1.44	leg
261	258	2.813	0.0	3.75	1.44	leg
262	259	2.813	0.0	3.75	1.44	leg
257	258	.1276	0.0	.589	.2573	batten
258	259	.1276	0.0	.589	.2573	batten
259	257	.1276	0.0	.589	.2573	batten
257	254	.133	0.0	2.00	.0240	radial
258	255	.133	0.0	2.00	.0240	radial
259	256	.133	0.0	2.00	.0240	radial

TABLE 28. REDUCED MODEL FEED MAST BEAM PROPERTIES
SEE FIGURE 38

PRELOADS:

All feed mast preload stress = 0.0 psi

Weight Density = .282 lb/in**3

E = 30.0e+06 psi

Grid Point A	Grid Point B	I1 & I2 (in.**4)	Alpha (in.**4)	Area (sq.in.)	J (in.**4)	Type
241	266	1.6608	19.366	.23585	.10183	rigid
266	267	1.6608	19.366	.23585	.10183	longeron
267	268	1.6608	19.366	.23585	.10183	longeron
268	269	1.6608	19.366	.23585	.10183	longeron
269	270	1.6608	19.366	.23585	.10183	longeron
270	271	1.6608	19.366	.23585	.10103	longeron
271	272	1.6608	19.366	.23585	.10183	longeron
272	273	1.6608	19.366	.23585	.10183	longeron
273	274	1.6608	19.366	.23585	.10183	longeron
274	275	1.6608	19.366	.23585	.10183	longeron
275	276	1.6608	19.366	.23585	.10183	longeron
275	277	1.6608	19.366	.23585	.10183	longeron
275	278	1.6608	19.366	.23585	.10183	longeron

TABLE 29. REDUCED MODEL LUMPED MASSES AT GRID POINTS

Grid Point	Mass (lb-sec**2/in)	I1	I2 (lb-sec**2-in)	I3	No. of Repeats	Grid Point Incrament
5	.03575000	0	0	0	7	30
5	.00182001	0	0	0	23	10
247	.00755480	0	0	0	0	
247	.00613916	0	0	0	0	
15	.03088000	0	0	0	7	30
25	.03088000	0	0	0	7	30
247	.04663200	.3546	.3546	.70927	0	
253	.01591200	.1611	.1611	.3222	0	
252	.02146200	.3395	.3395	.6791	0	
251	.01110000	.2529	.2529	.5057	0	
250	.01110000	.3442	.3442	.6884	0	
249	.01110000	.4496	.4496	.8991	0	
248	.01110000	.5690	.5690	1.1379	0	
246	.22110000	11.3331	11.3331	11.3331	0	
245	.01110000	.5690	.5690	1.1379	0	
244	.01110000	.4496	.4496	.8991	0	
243	.01110000	.3442	.3442	.6884	0	
242	.01110000	.2529	.2529	.5057	0	
241	.00555000	.0878	.0878	.1756	0	
10	.00691000	0	0	0	23	10
253	.24360000	23.951	23.951	47.9017	0	
276	.20550000	0	0	0	0	
277	.20550000	0	0	0	0	
278	.20550000	0	0	0	0	
266	.01055700	0	0	0	0	
274	.02092000	0	0	0	0	

Table 30. MEASURED AND PREDICTED HOOP COLUMN WEIGHTS

Substructure		Analysis (lbs.)	Measured (lbs.)
Cables and Mesh			
web		8.190	
upper hoop	2.788		
lower hoop	.822		
G04	.333		
G03	.141		
G02	.109		
G01	.095		
others	2.832		
total cables	7.120	7.120	
lumped mass		11.937	
Total		27.247	28.3
Hoop			
beams		290.071	
motors		11.040	
Total		301.111	301.1
Mast			
upper cable stow		64.014	
center cable stow		81.060	
mesh attachment		18.000	
lower cable stow		94.030	
preload segment		7.999	
distributed mass		47.131	
Total		312.234	312.1
Subtotal (no tripod support)		640.591	641.5
Tripod Support			
total distributed		237.340	237.3
Total with tripod support		877.931	878.8
Feed Mast			
distributed mass		13.214	
ballast		238.000	
base mass		4.075	
top mass		8.075	
total		263.364	263.4
Total, tripod and feed mast		1141.295	1142.2
Total with feed mast only		903.955	904.9

Table 31. CENTER OF GRAVITY AND MASS INERTIA PROPERTIES

Full Model with Hoop Column and Feed Mast

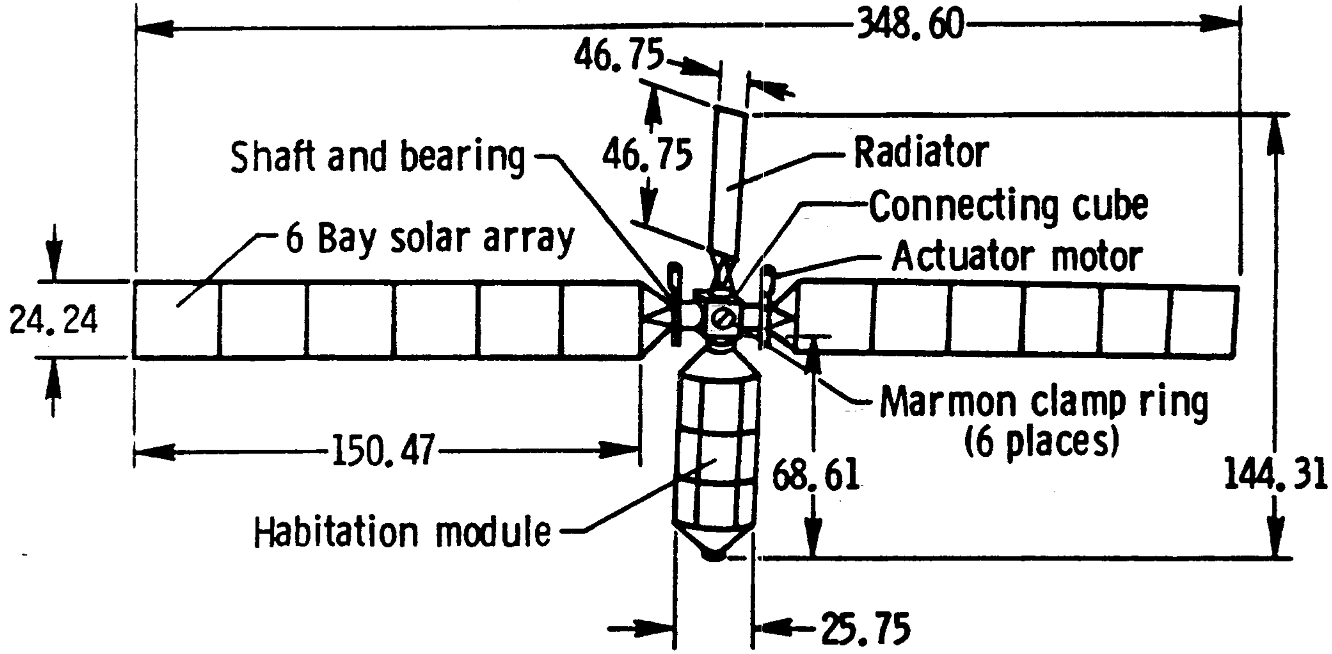
Total Mass = 2.34172 lb-sec^2/in(903.90#)

Model	Global Coordinate (in.)			Mass Inertia (lb-sec^2-in)		
	X	Y	Z	Ix	Iy	Iz
Assemblage	0.0	0.0	117.120	101910.	101910.	70445.

Full Model with Hoop Column, Feed Mast and Tripod

Total Mass = 2.96094 lb-sec^2/in(1142.92#)

Model	Global Coordinate (in.)			Mass Inertia (lb-sec^2-in)		
	X	Y	Z	Ix	Iy	Iz
Assemblage	0.0	0.0	73.520	125120.	125120.	71193.



Dimensions in inches

Figure 1. Experimental Generic Model Dimensions

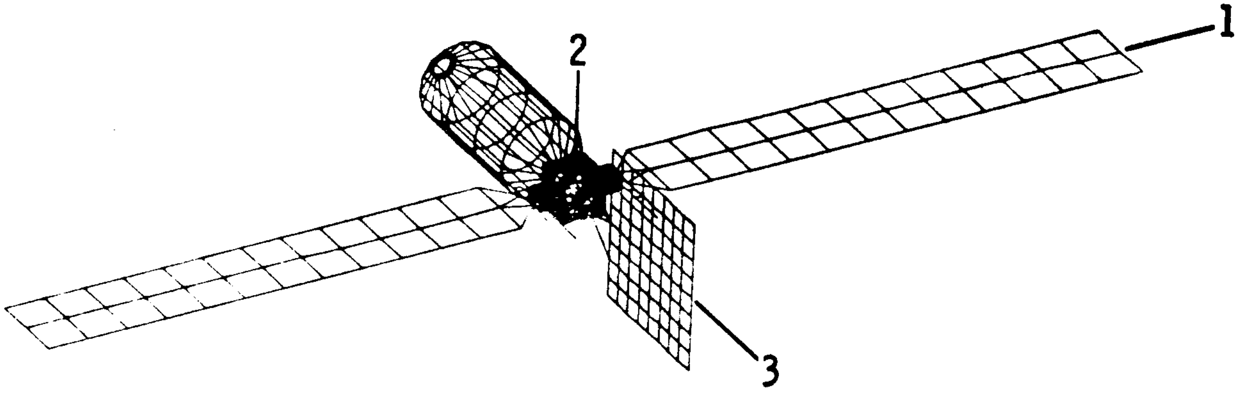
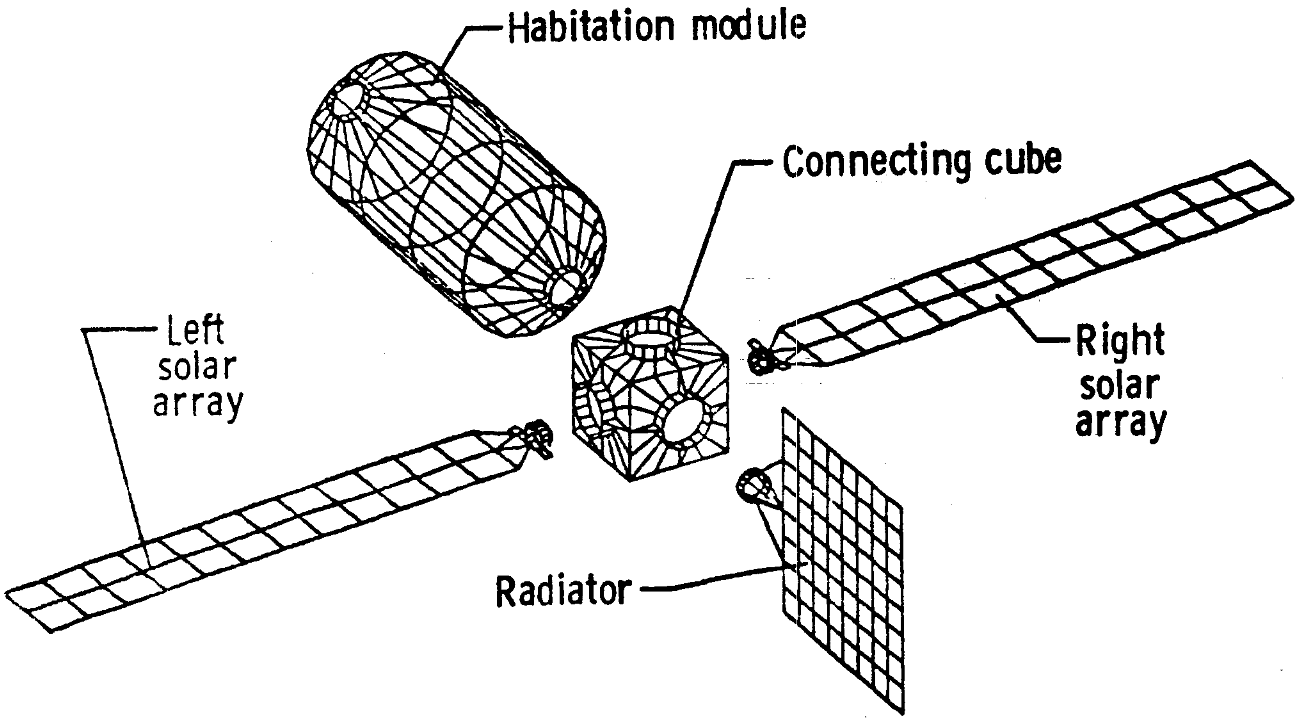


Figure 2. Analytical Model of the Generic Dynamic Model Without Cables



Substructures not to scale

Figure 3. Analytical Substructure Models

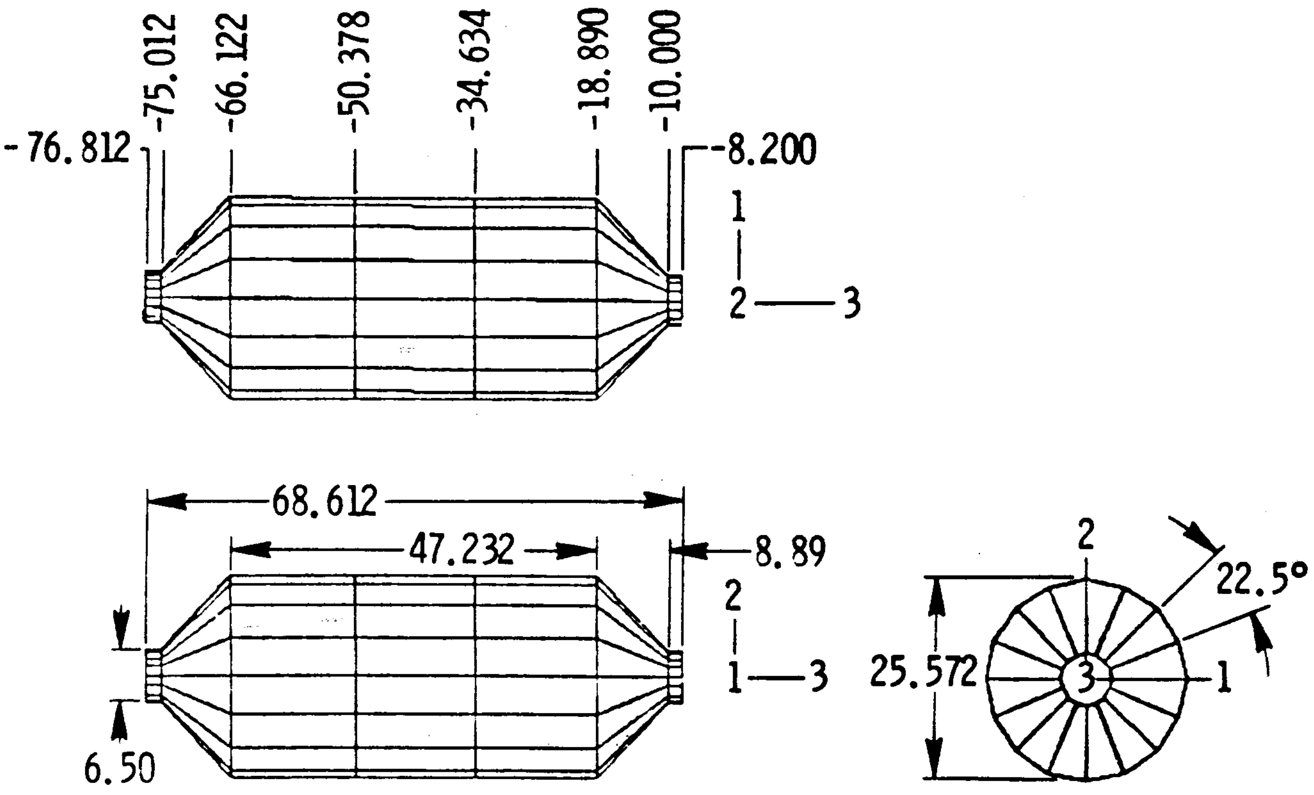


Figure 4. Analytical Habitation Module

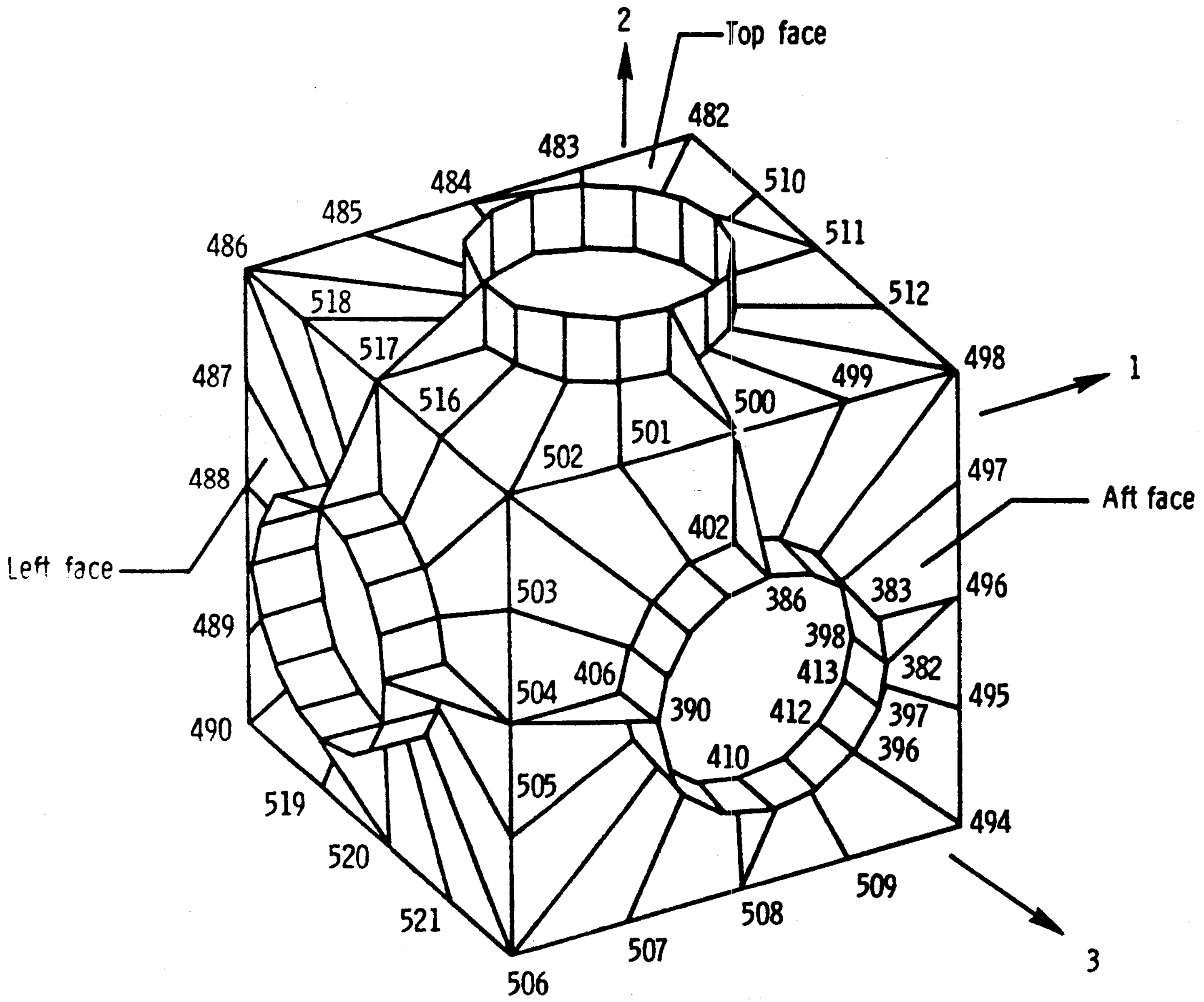


Figure 5. Connecting Cube Analytical Model

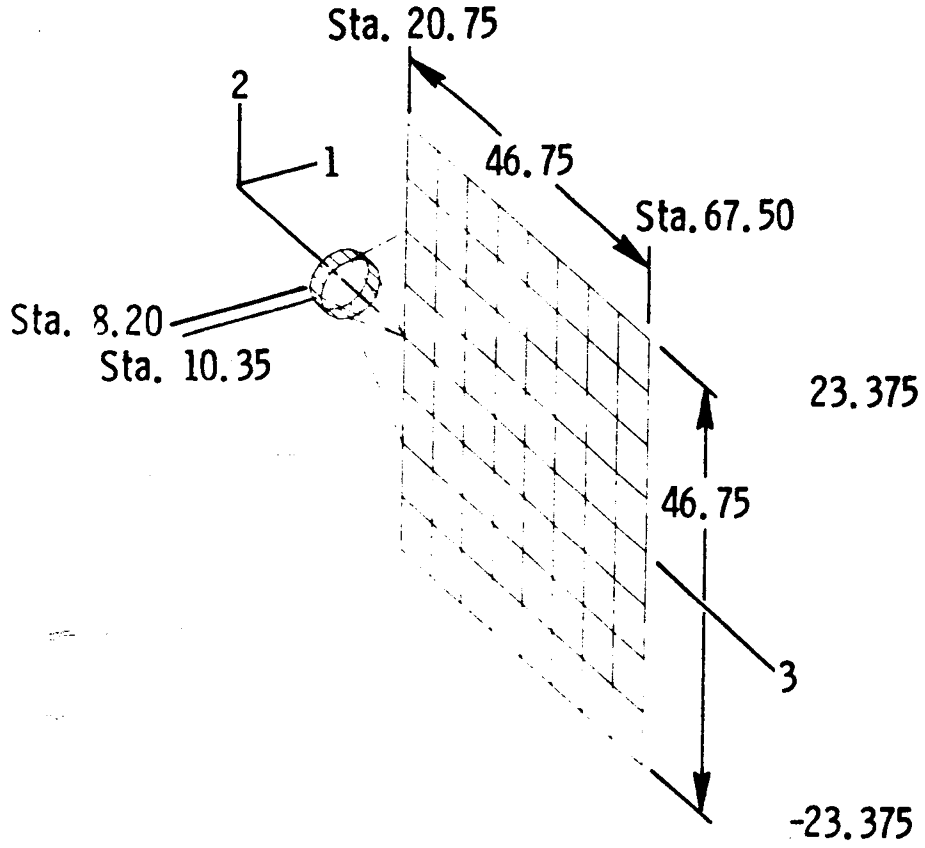


Figure 6. Radiator Analytical Model

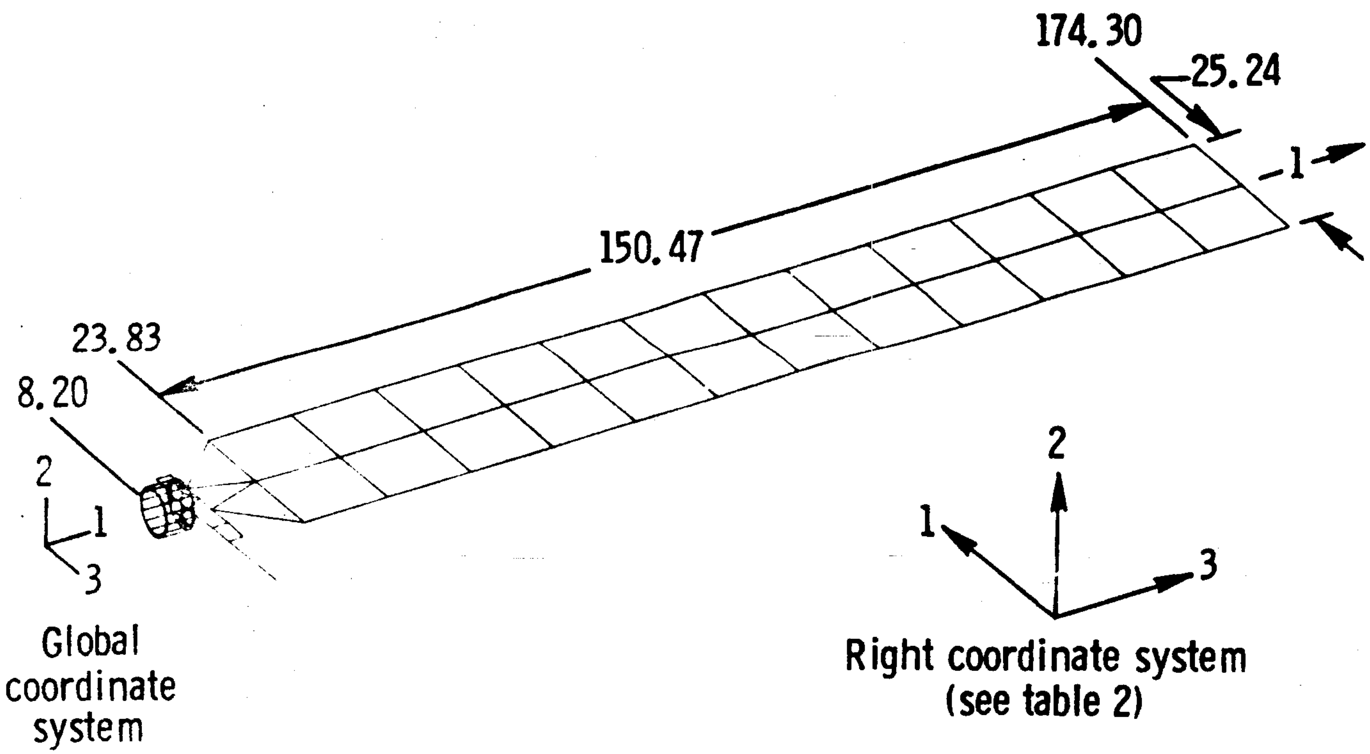


Figure 7. Right Solar Array Analytical Model

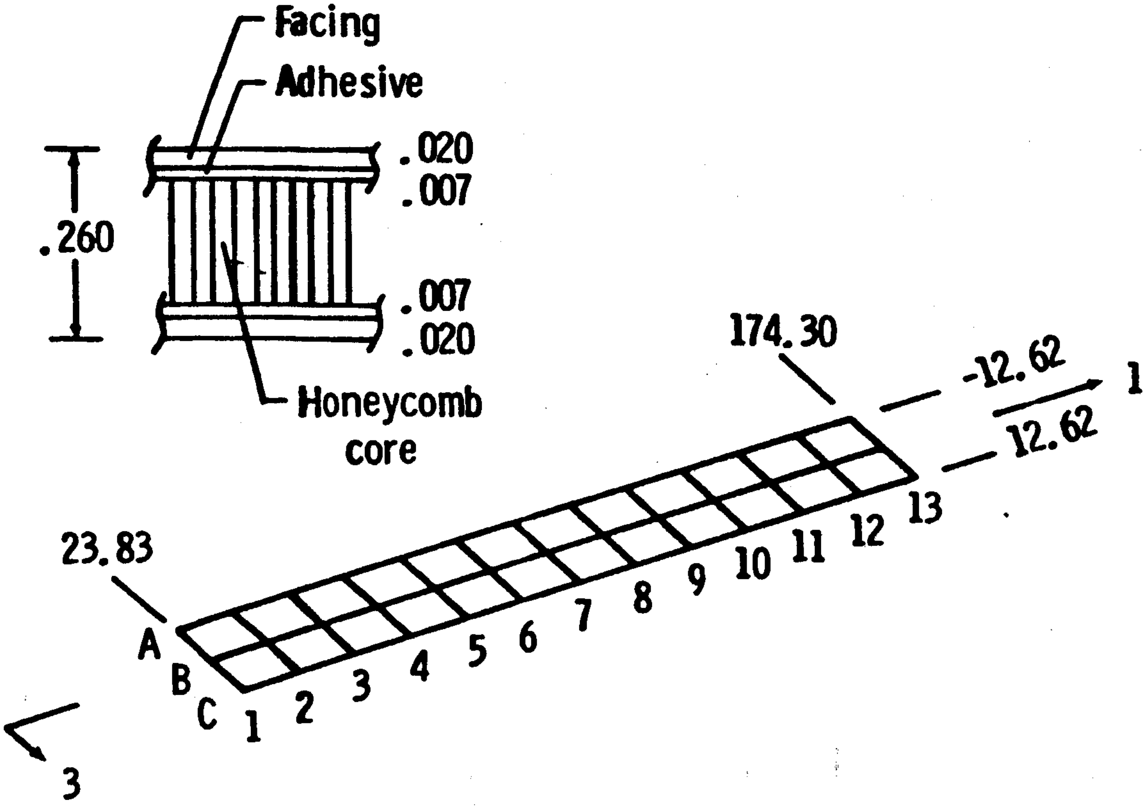


Figure 8. Right Solar Array Sandwich Honeycomb Plate Elements

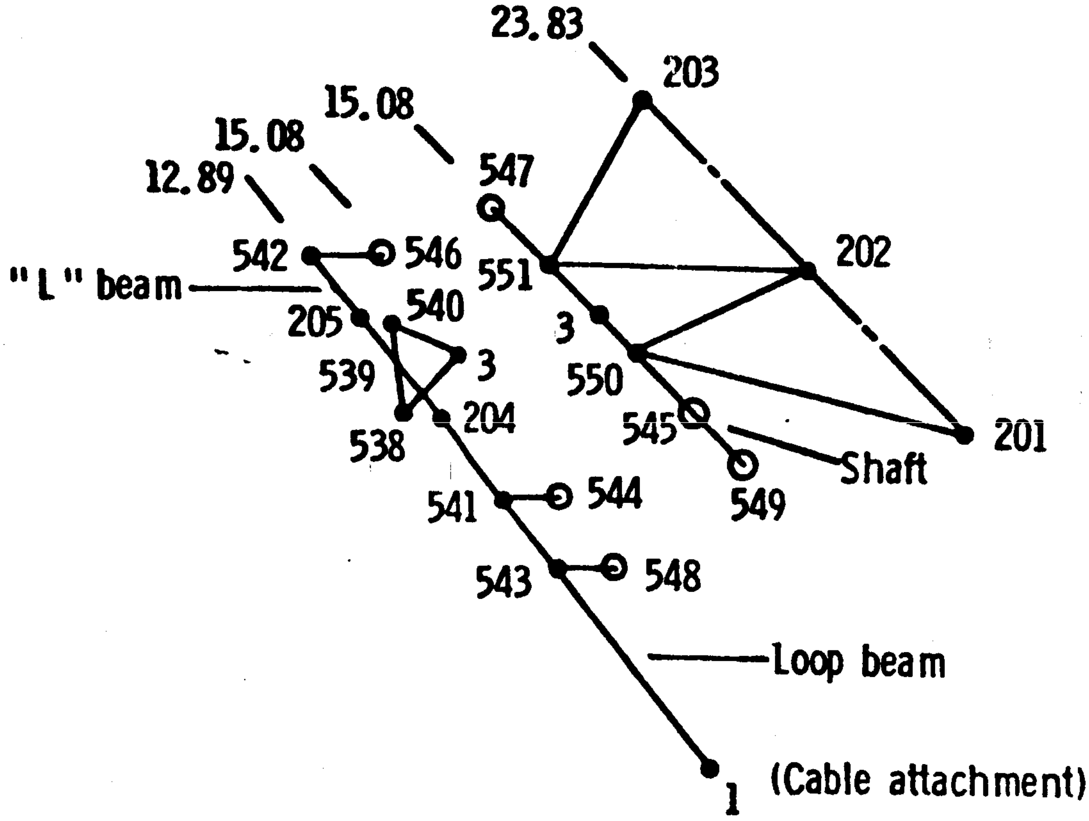


Figure 9. Right Solar Array Truss, Shaft and L Support Beam

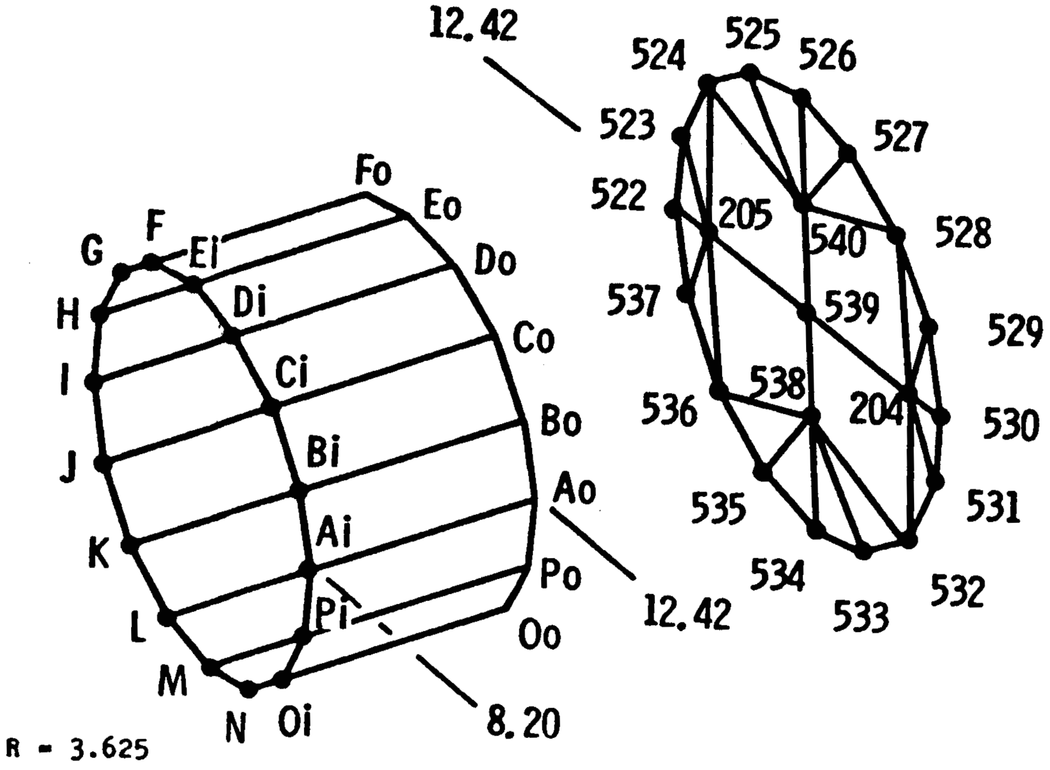


Figure 10. Right Solar Array Support Bulkhead and Cylinder Plate Elements

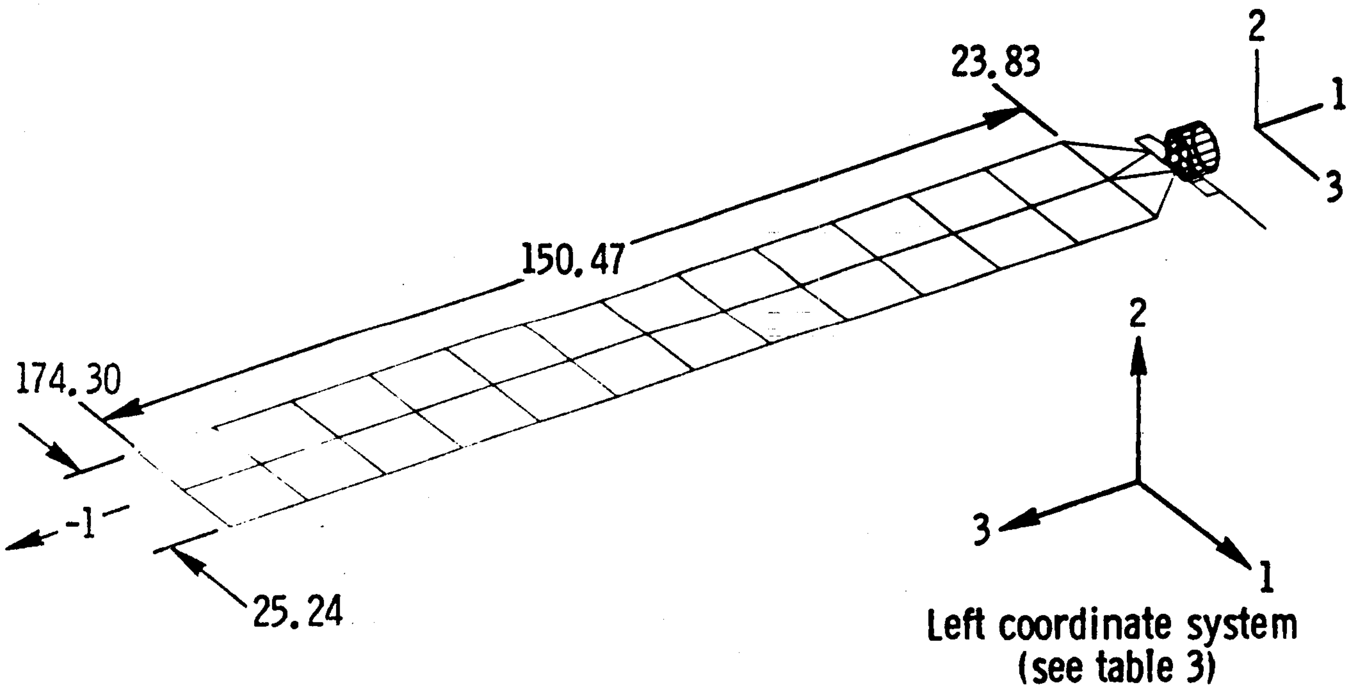


Figure 11. Left Solar Array Anelytical Model

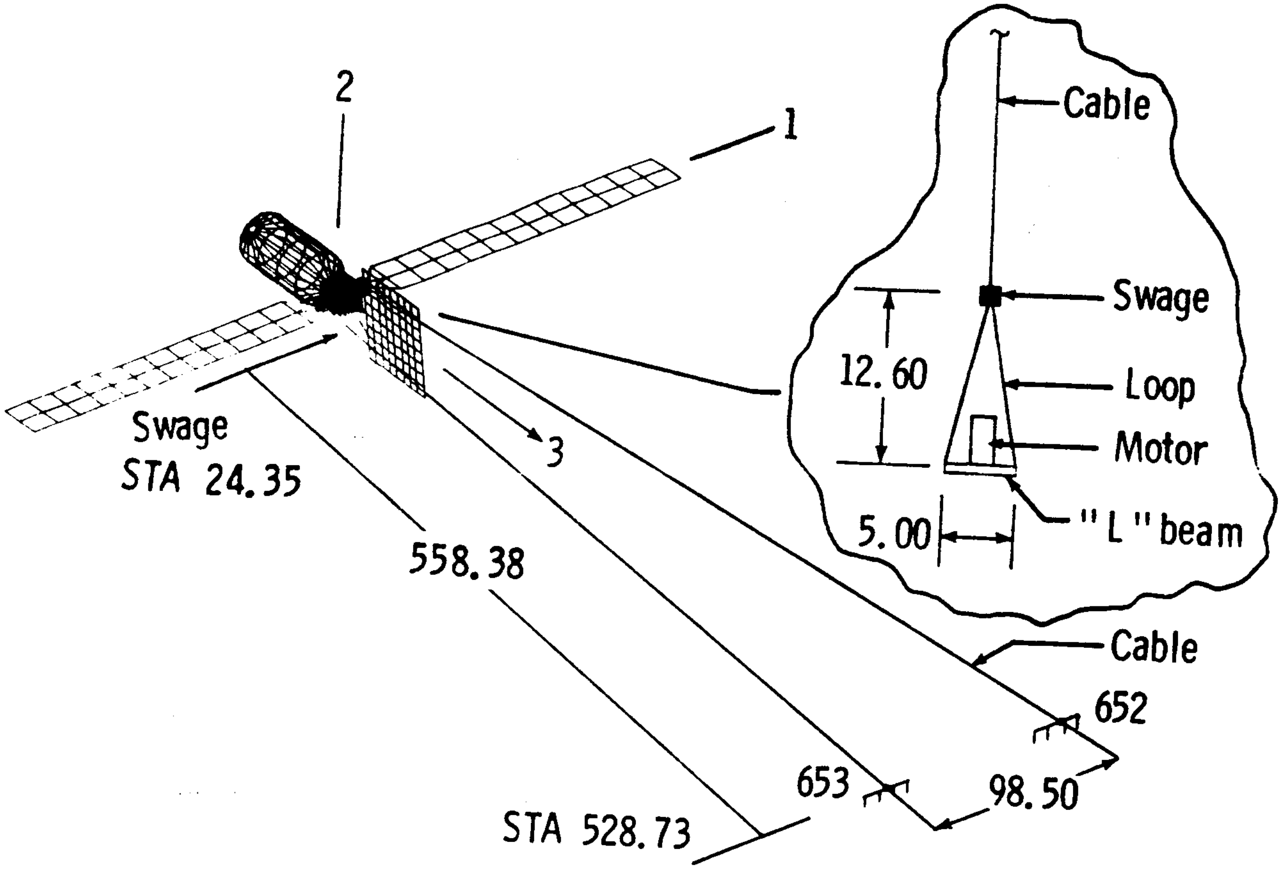


Figure 12. Analytical Model of the Generic Dynamic Model With Cables

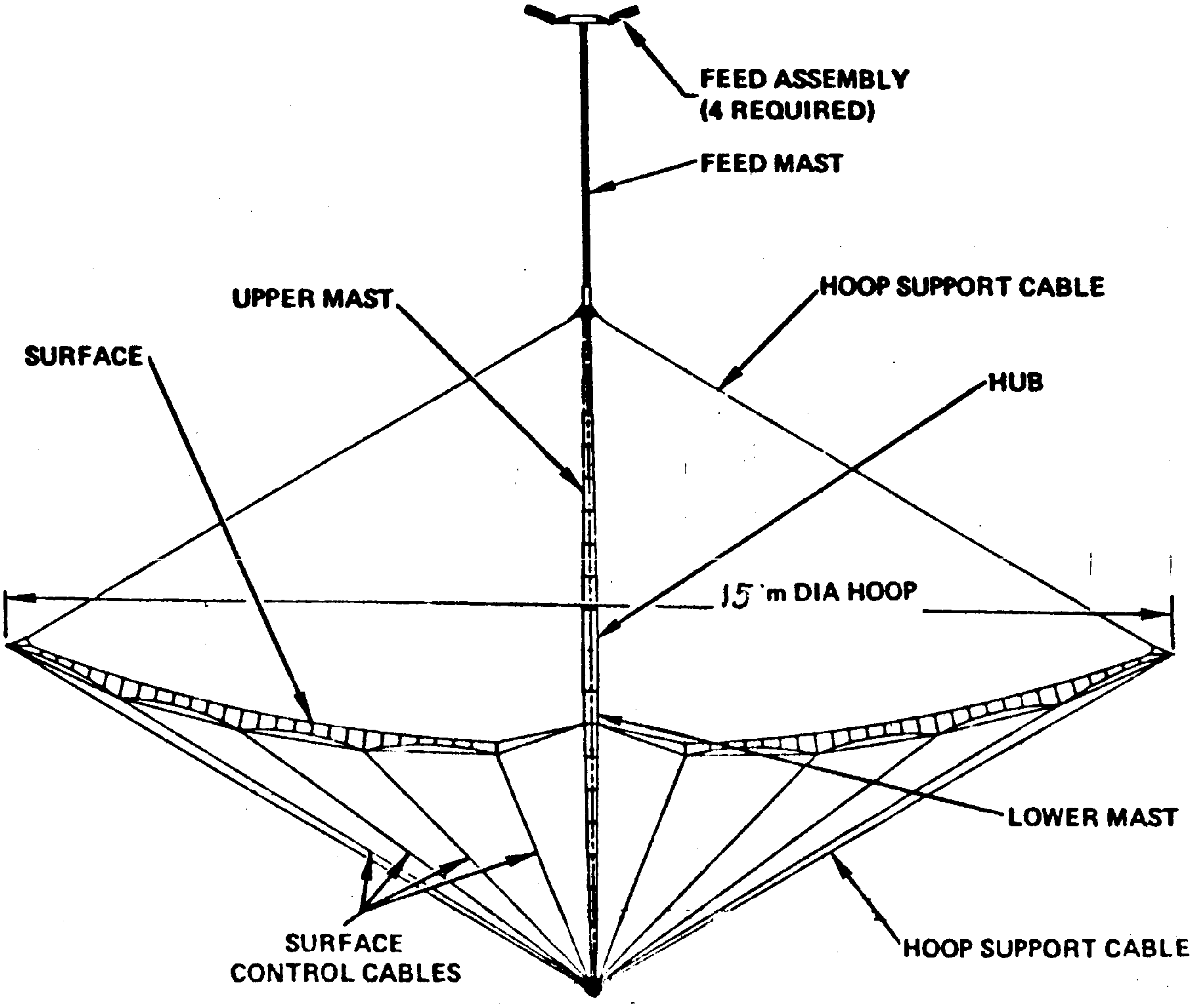


Figure 13. 15 Meter Hoop Column Configuration

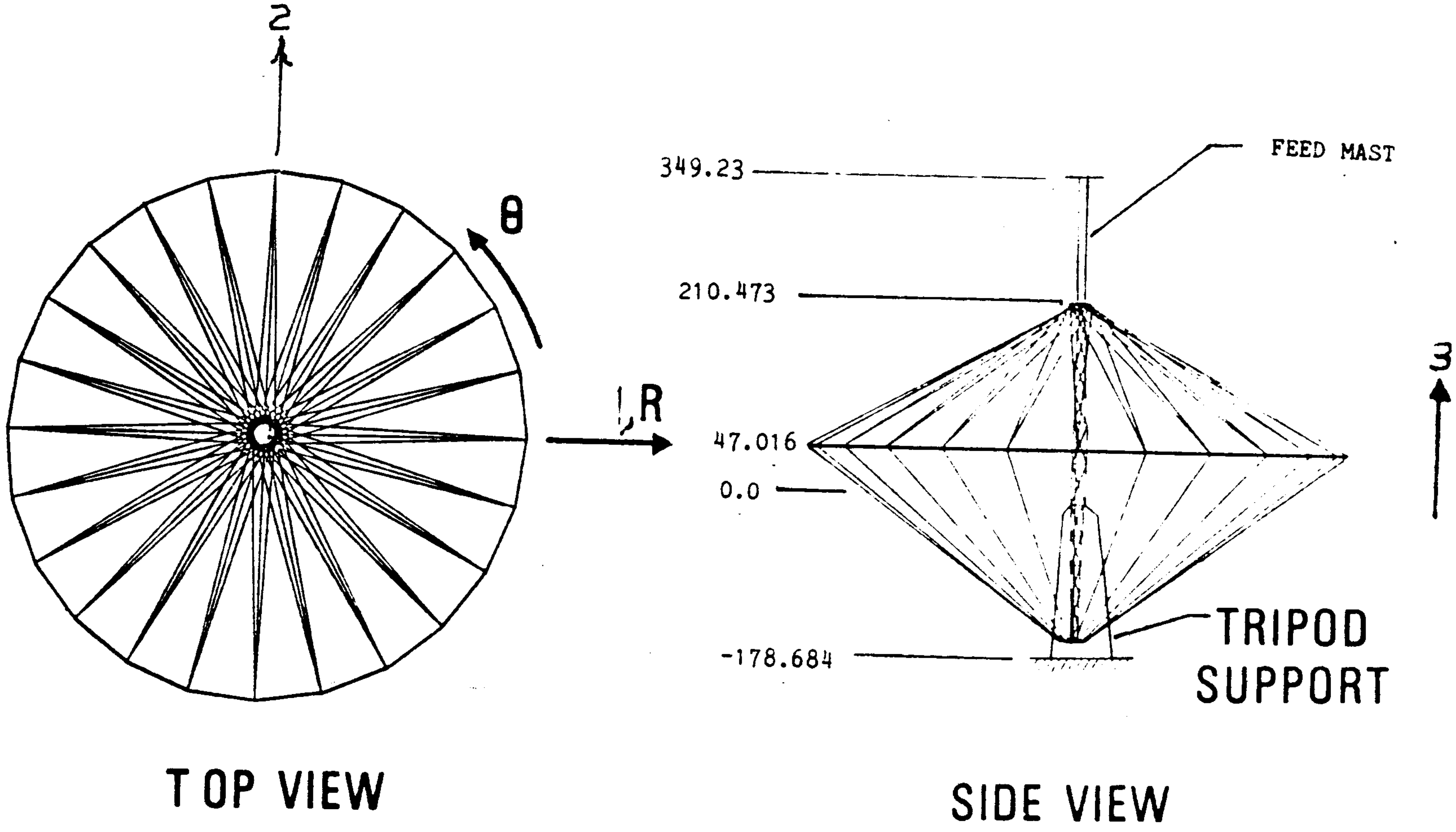
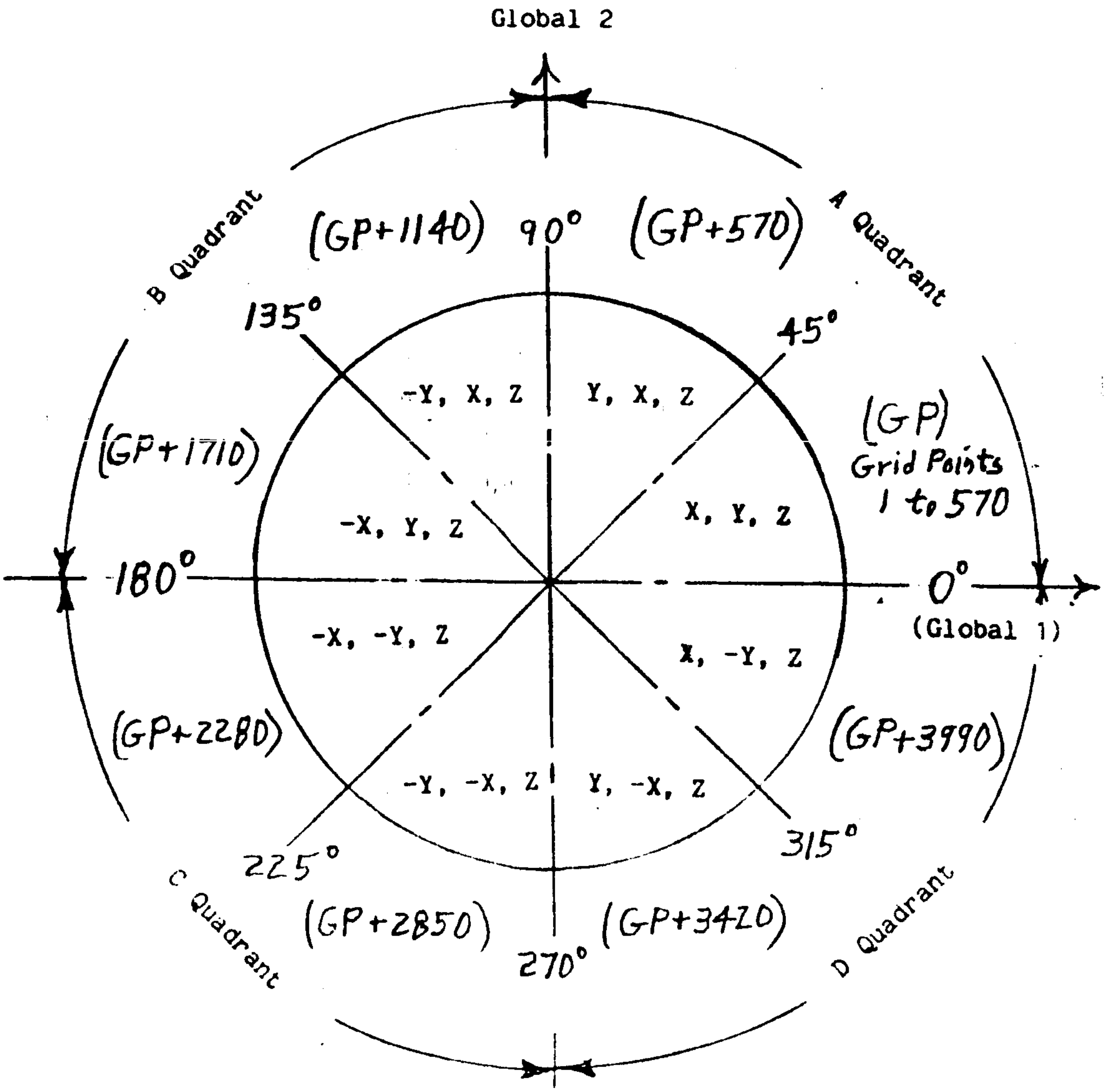
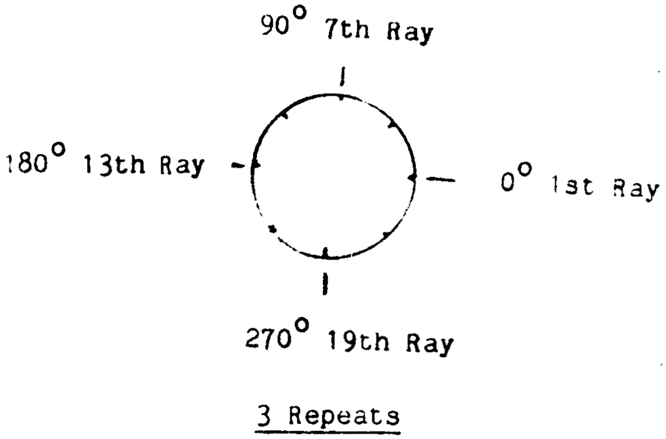


Figure 14. 15 Meter Hoop Column Model on Tripod Support



X = Global 1 dimension in 0 to 45 degree model
Y = Global 2 dimension in 0 to 45 degree model
Z = Global 3 dimension in 0 to 45 degree model

Figure 15. Grid Point Numbering and Global Dimensions



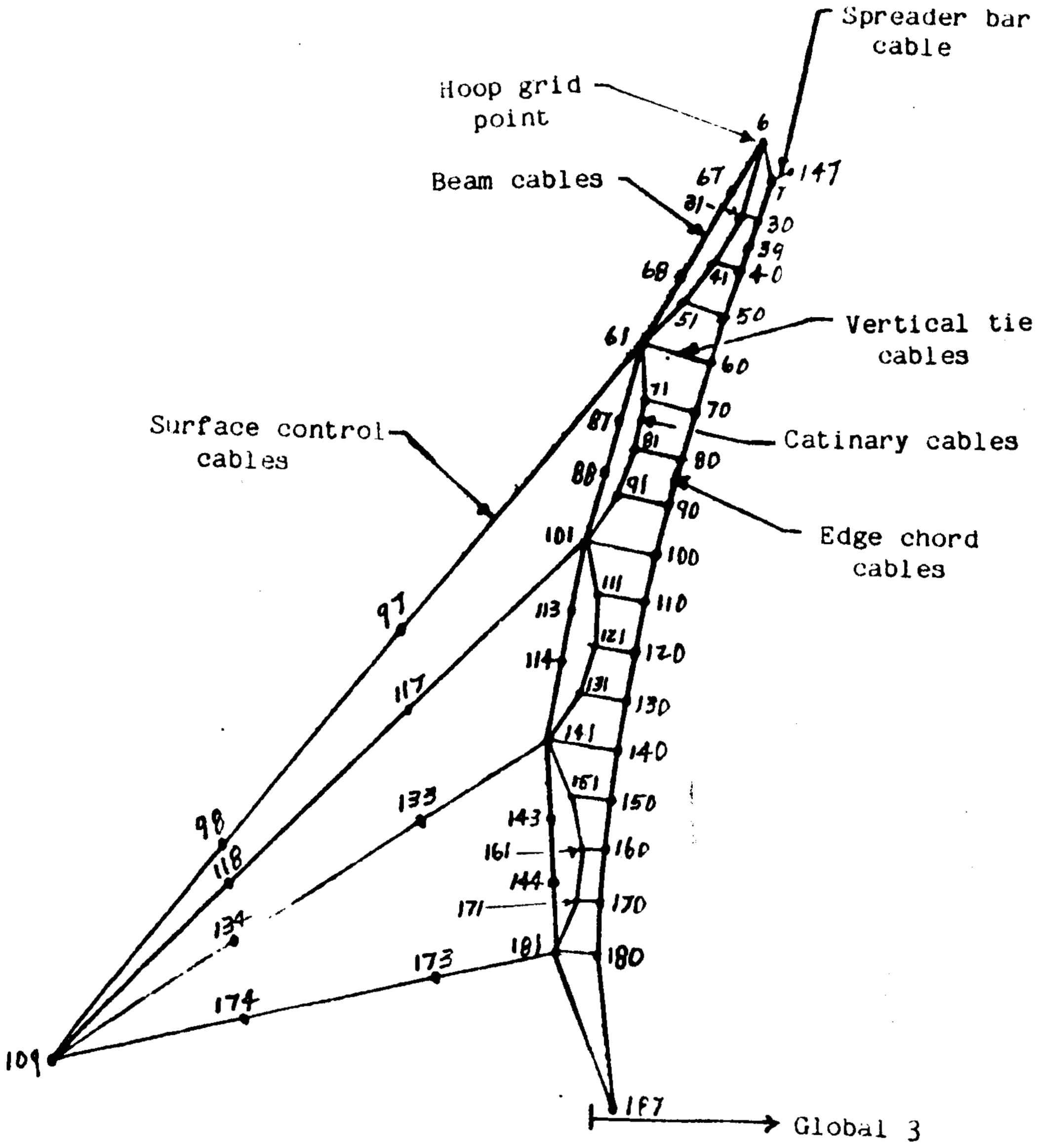
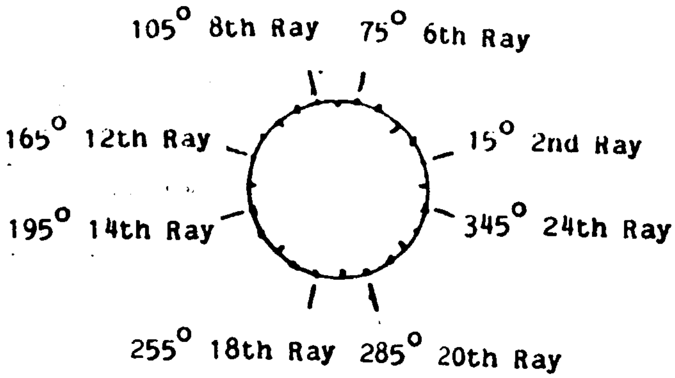


Figure 16. 1st Ray Cables and Grid Point Locations (0 degrees)



7 Repeats

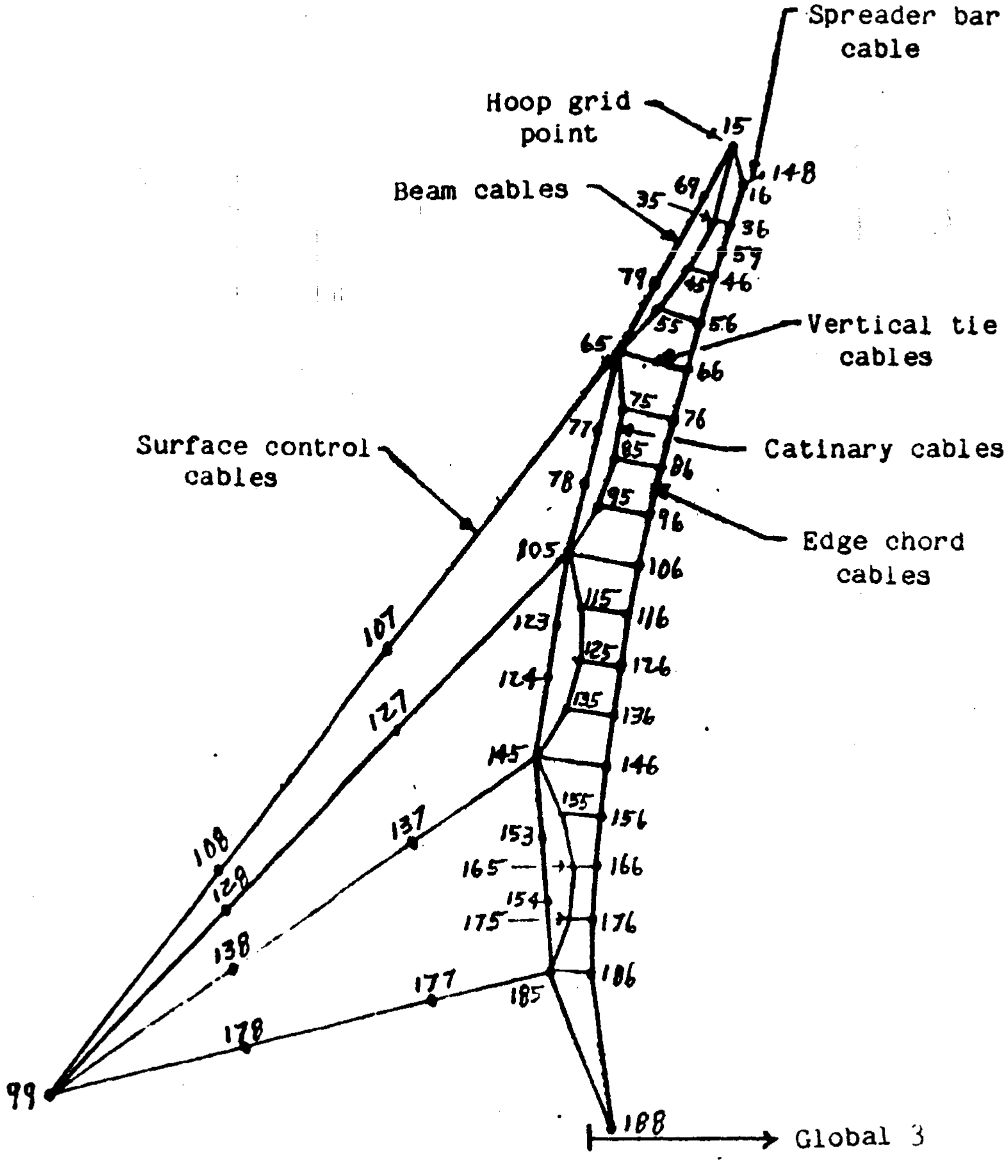


Figure 17. 2nd Ray Cables and Grid Point Locations (15 degrees)

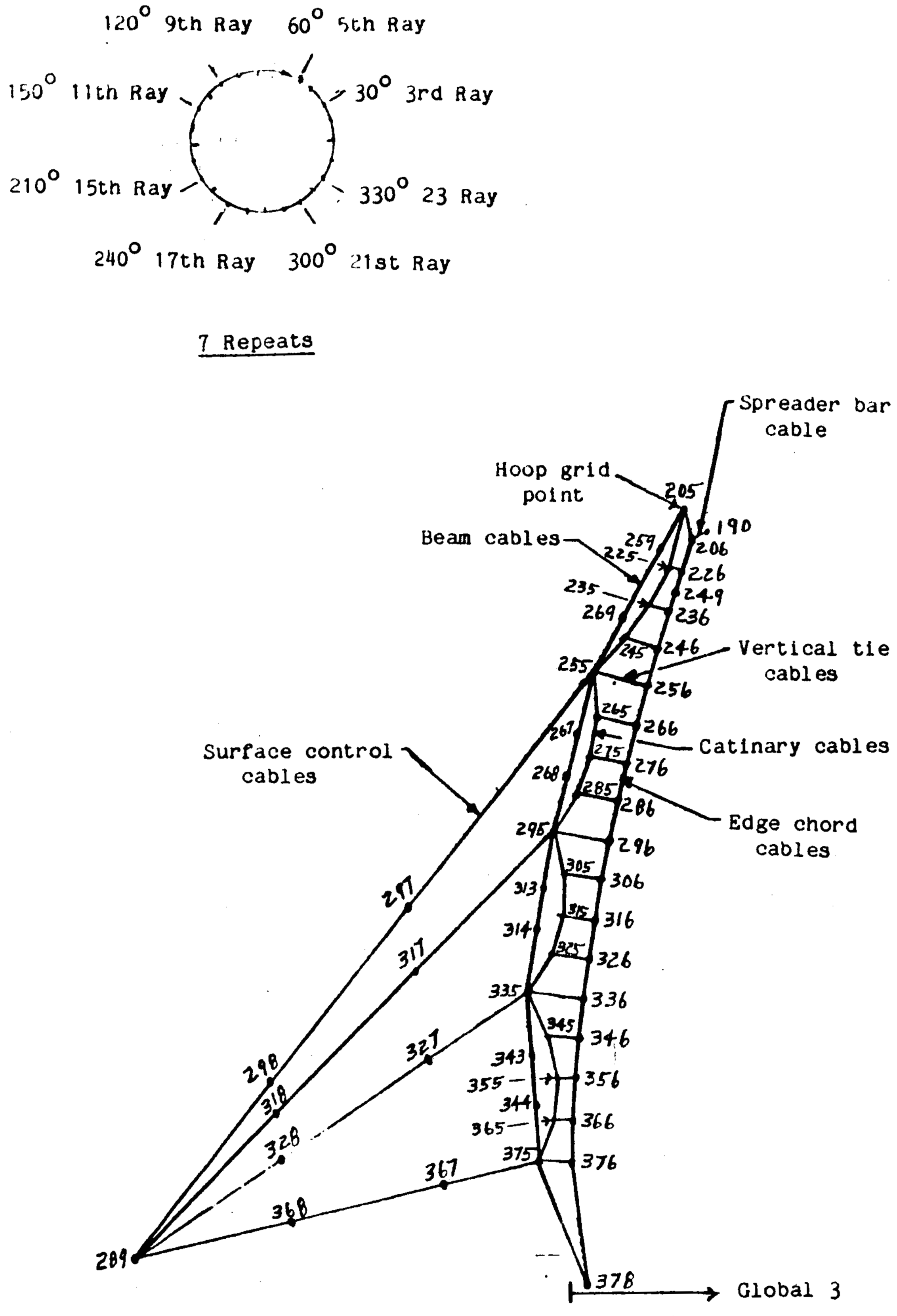
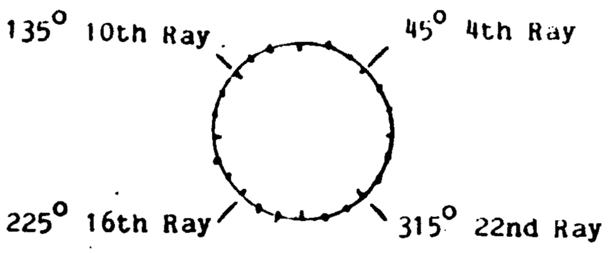


Figure 18. 3rd Ray Cables and Grid Point Locations (30 degrees)



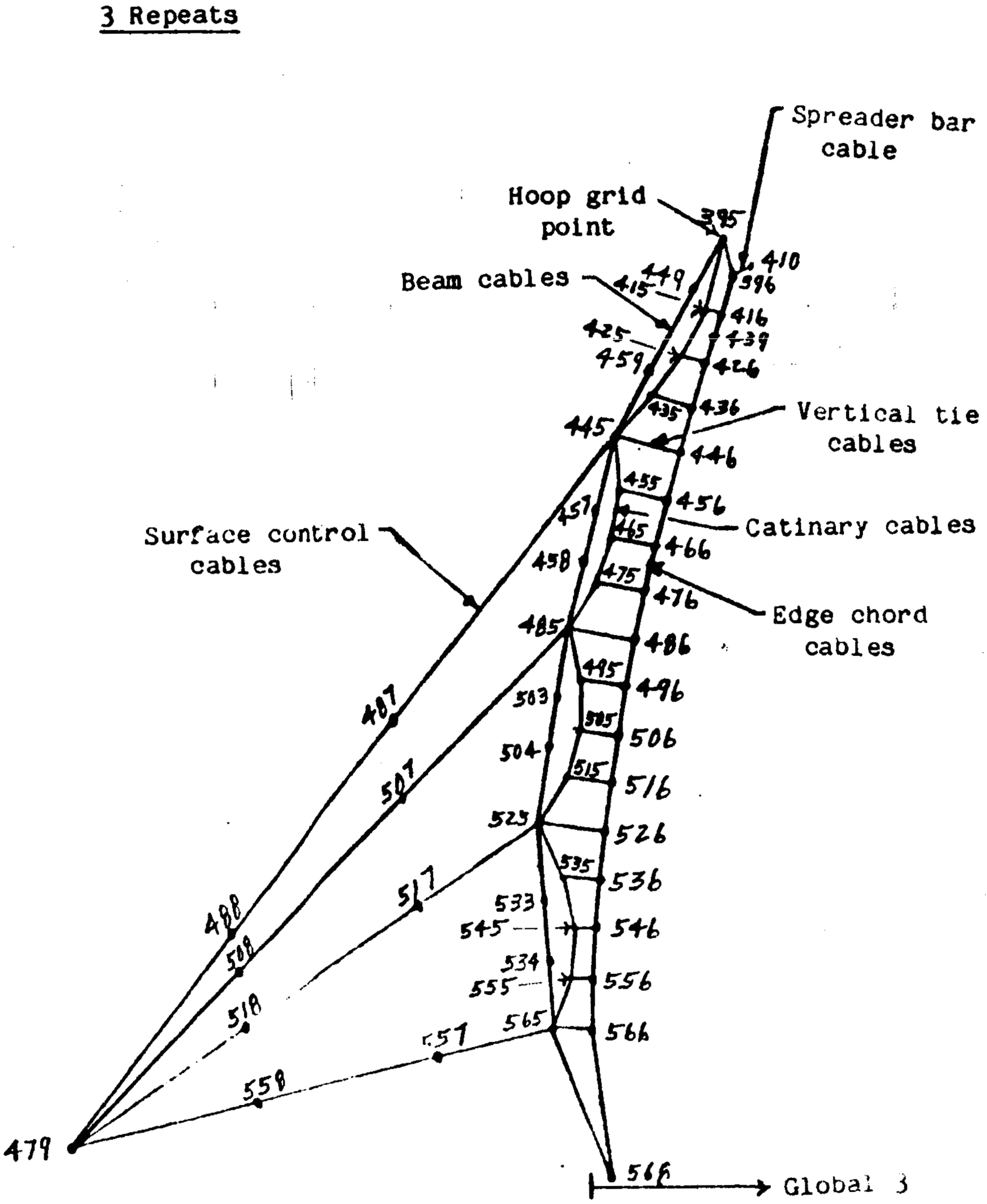


Figure 1[illegible]. 4th Ray Cables and Grid Point Locations (45 degrees)

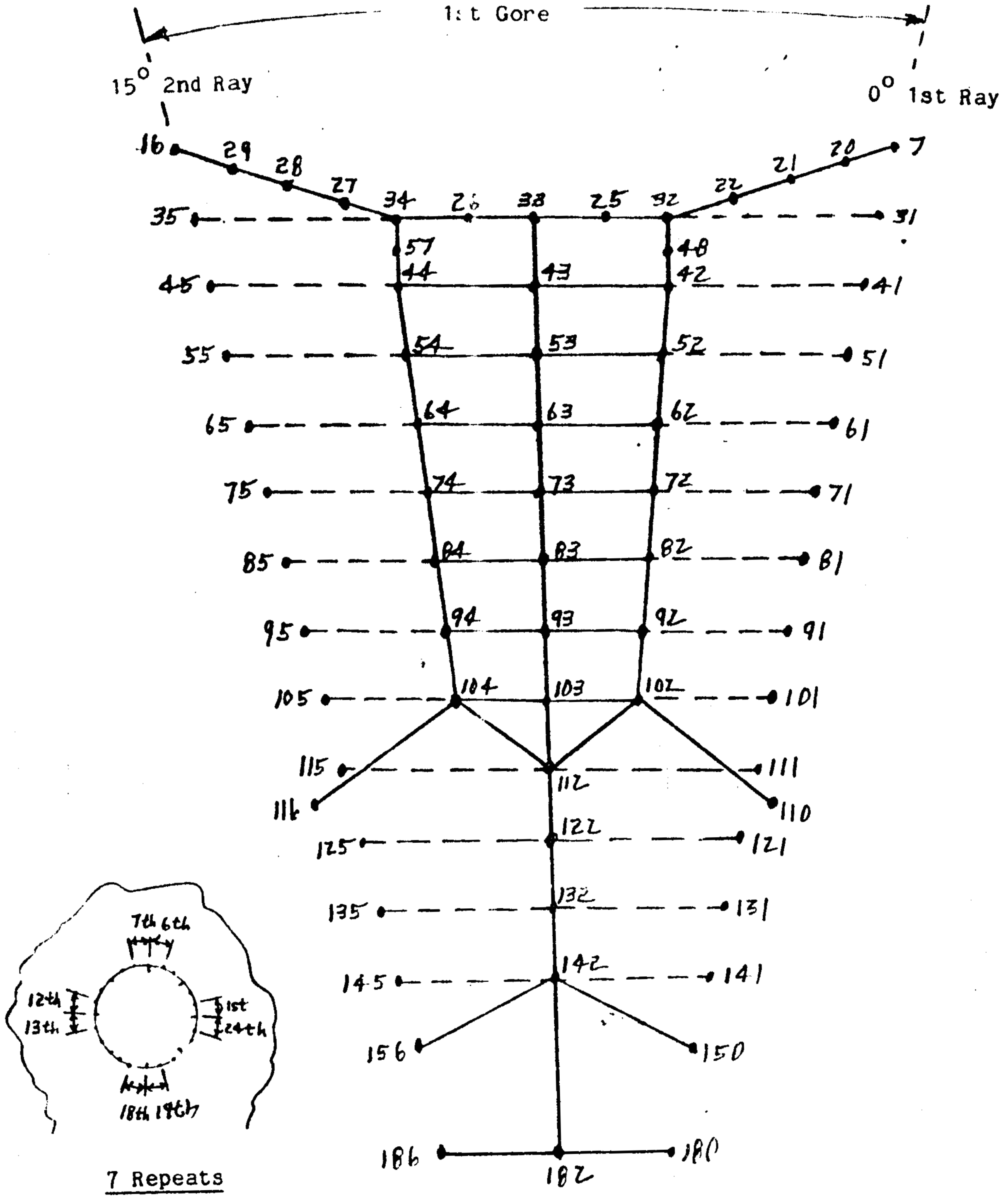


Figure 20. 1st Gore Cable Grid Point Locations (0 to 15 degrees)

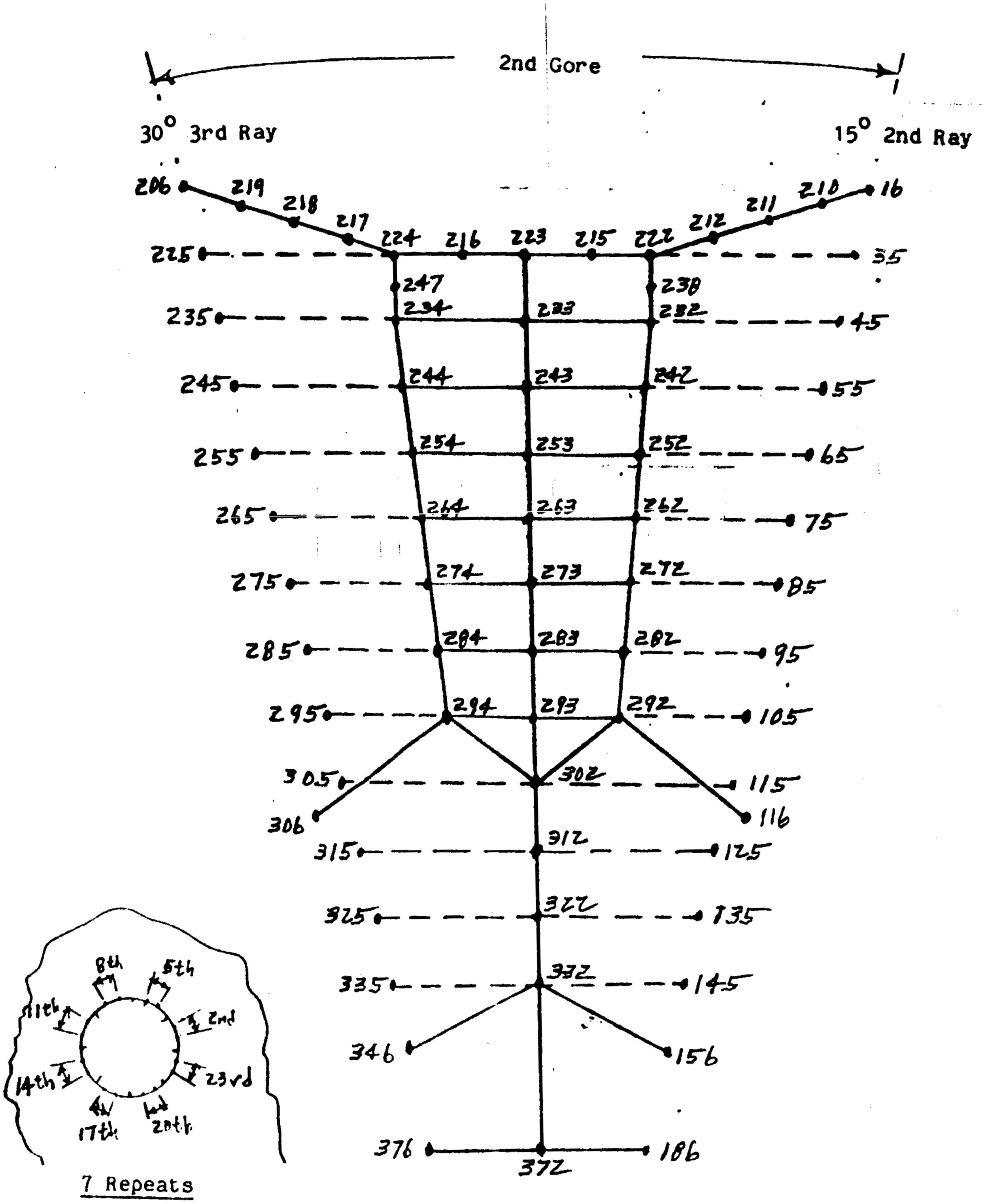


Figure 21. 2nd Gore Cable Grid Point Locations (15 to 30 degrees)

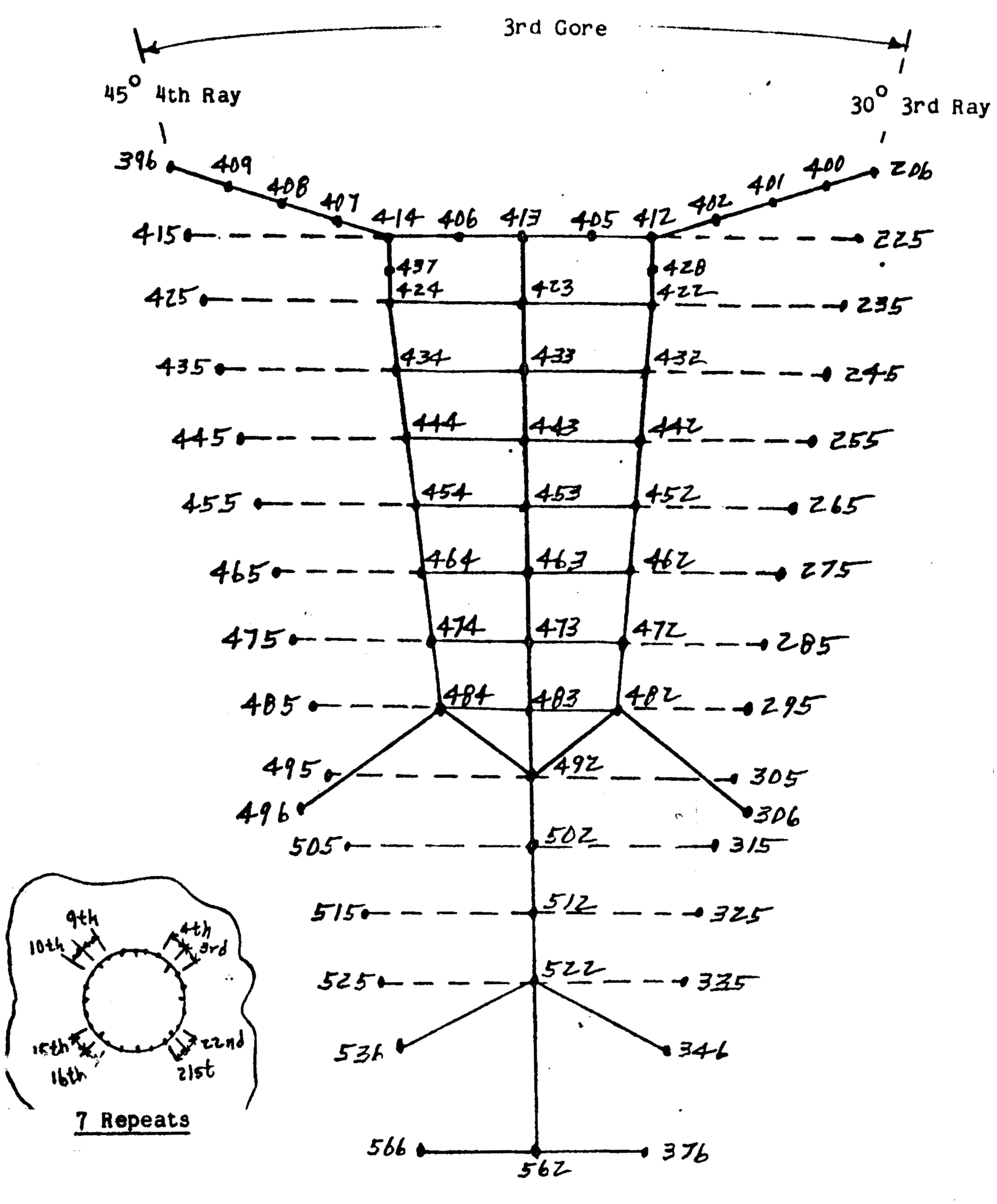
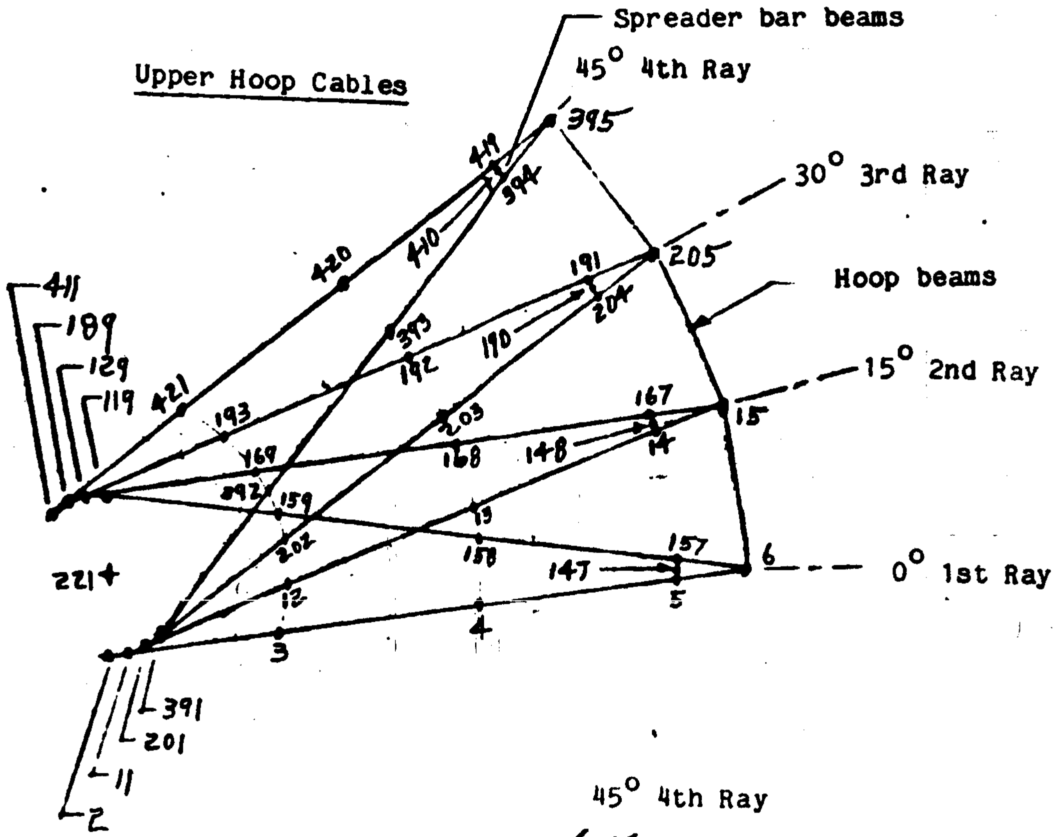


Figure 22. 3rd Gore Cable Grid Point Locations (30 to 45 degrees)



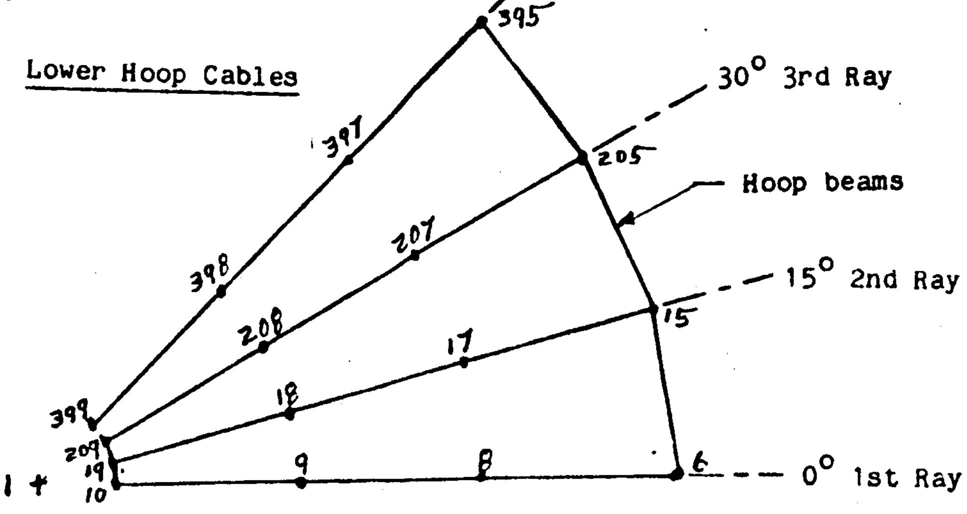


Figure 23. Hoop Support Cables (0 to 45 degrees)

0° to 15°

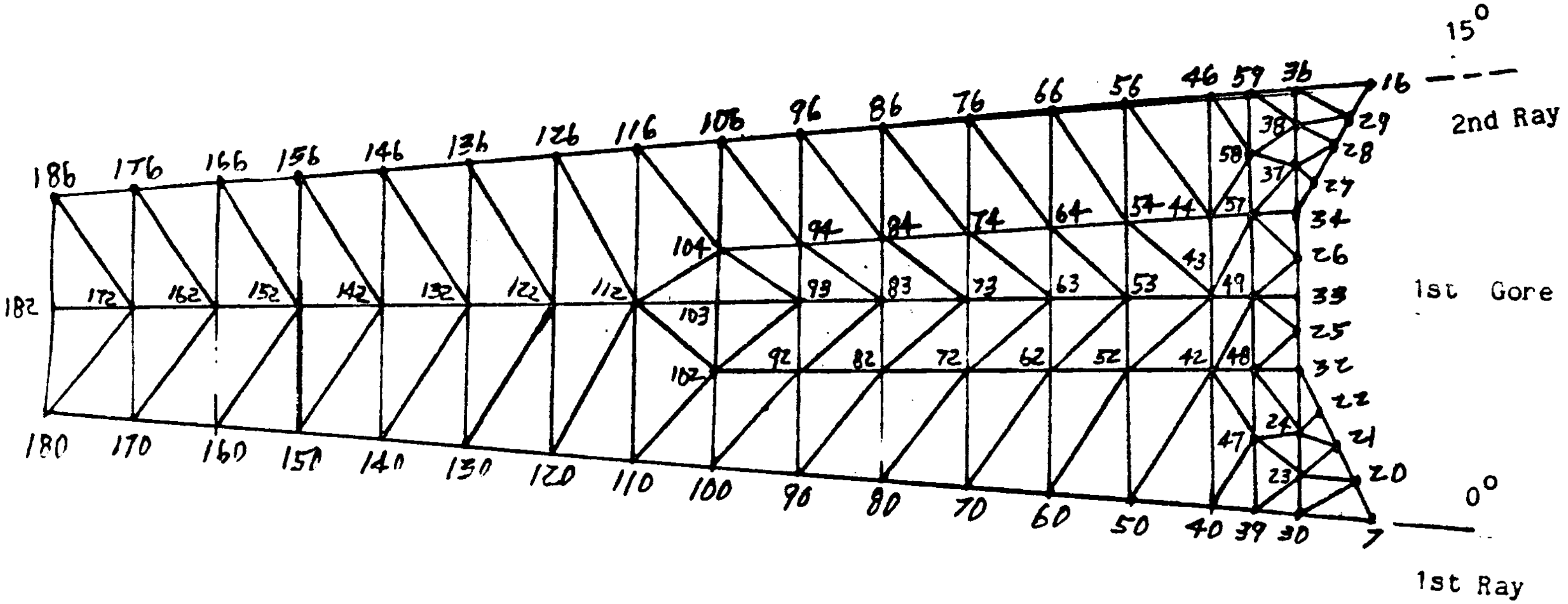


Figure 24. 1st Gore Triangular Web Elements and Grid Point Locations

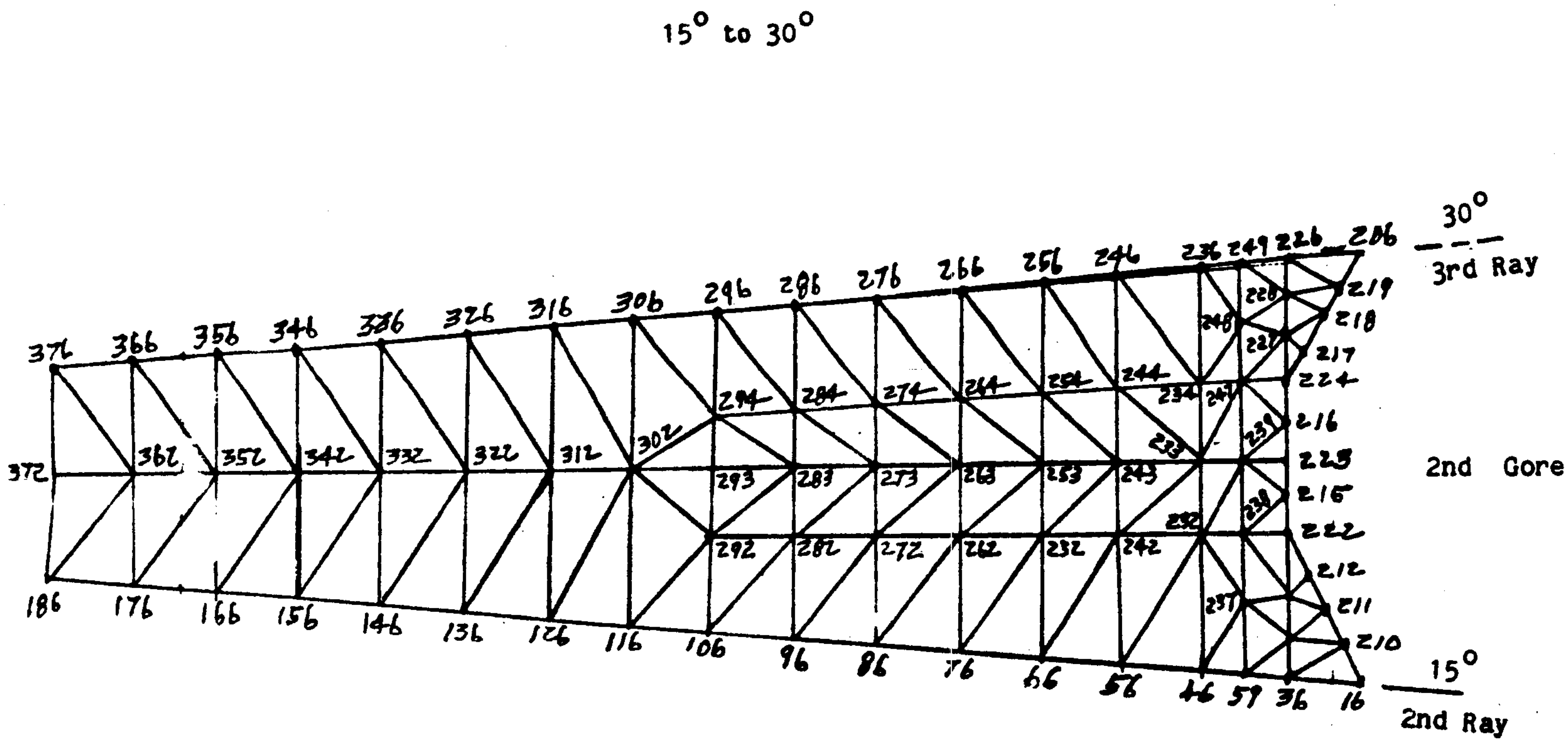


Figure 25. 2nd Gore Triangular Web Elements and Grid Point Locations

30° to 45°

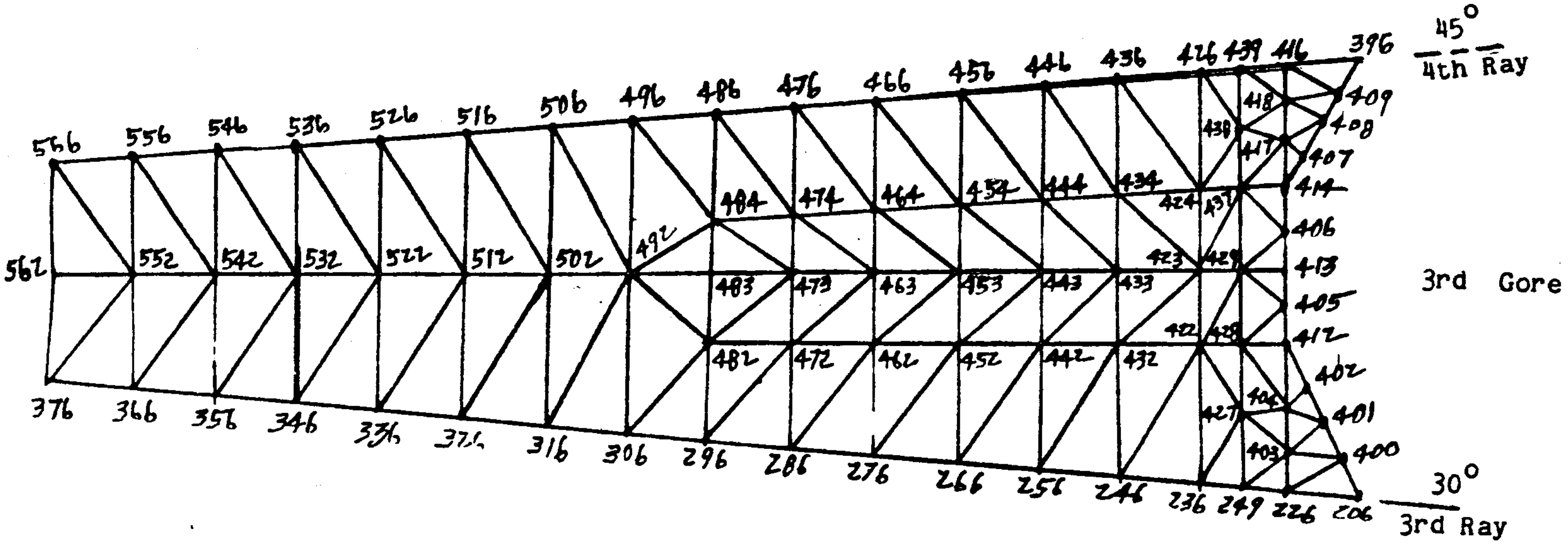


Figure 26. 3rd Gore Triangular Web Elements and Grid Point Locations

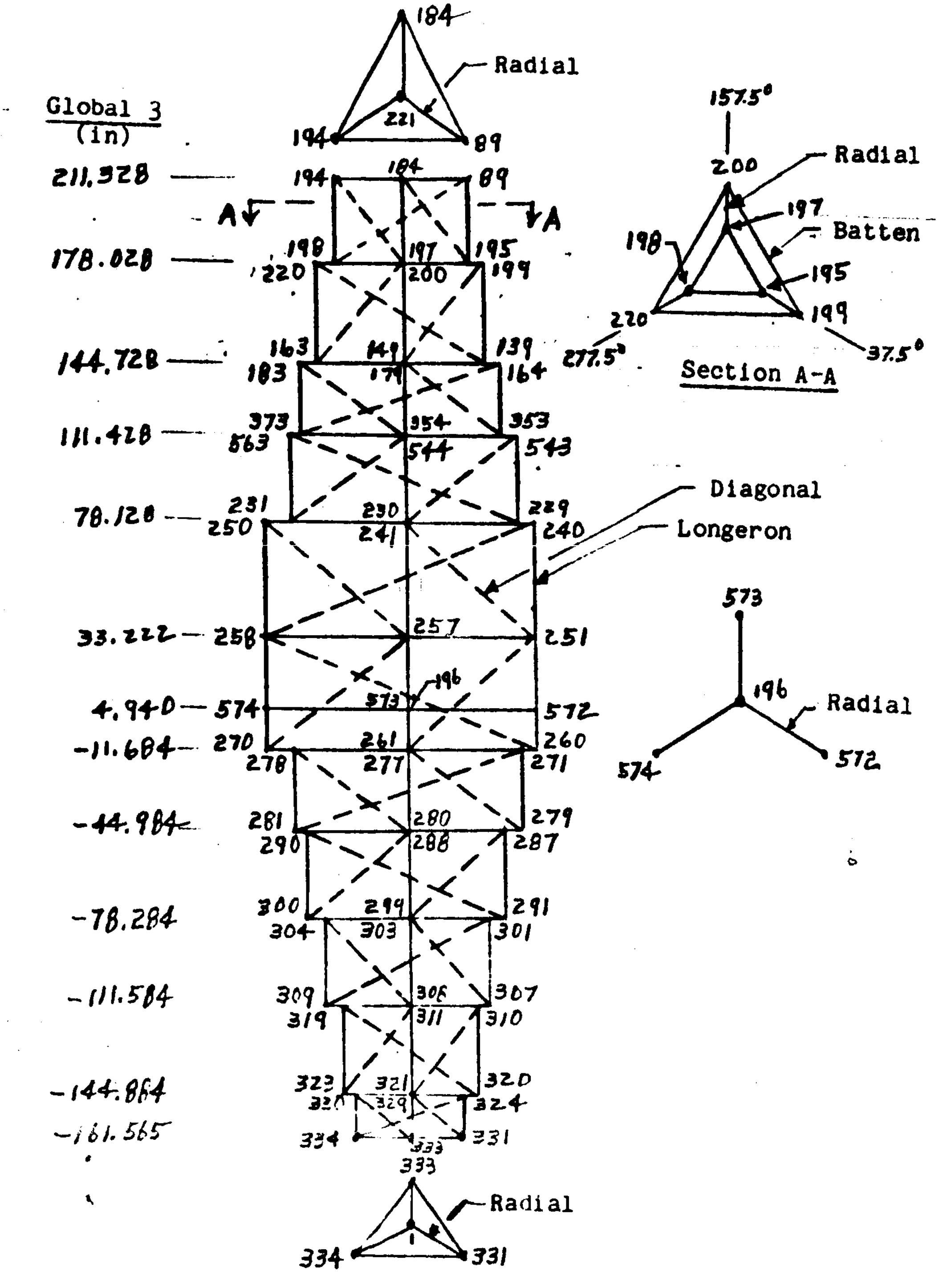
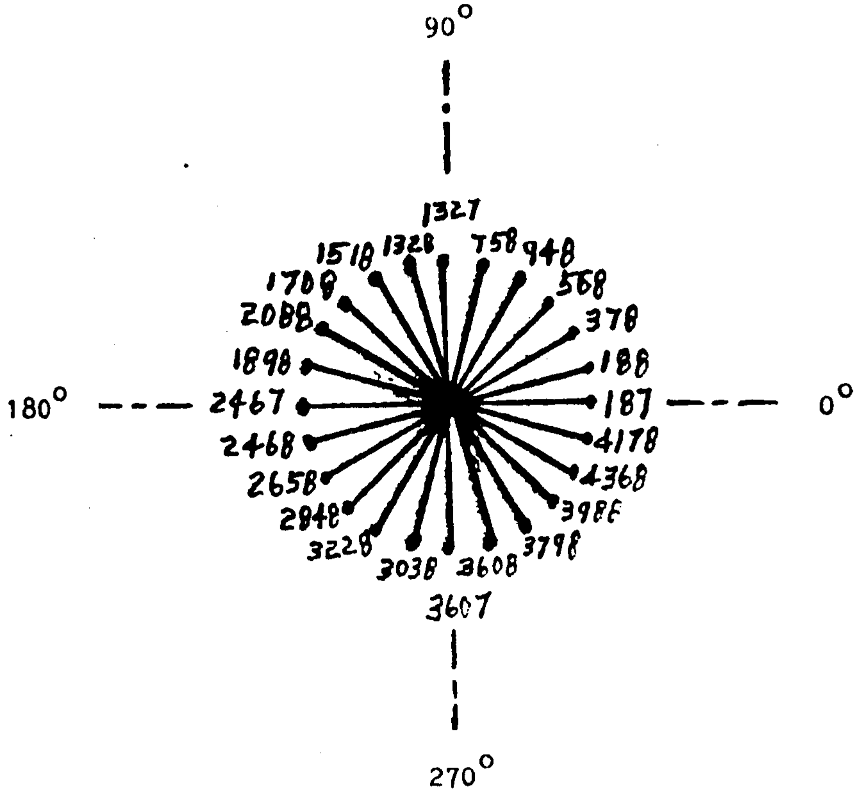


Figure 27. Mast Truss Beams and Grid Point Locations

Center grid point = 196
Located on Mast
(see Fig. 27)



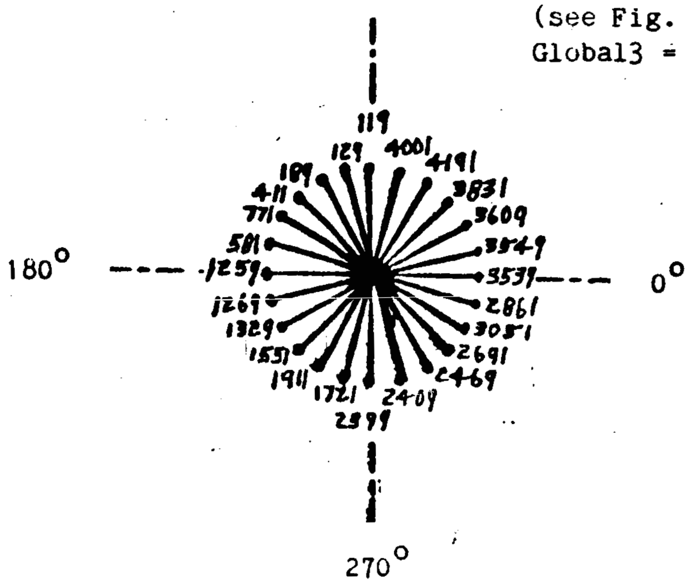
	Radius (in.)	Global3 (in.)
Ring grid points	3.90	4.94
grid point 196	0	4.93987

Figure 28. Mast Center Cable Attachment, Semi-Rigid Beams

Plus 90 Degree Hoop Cable Attachments

Radius = 12.0 in.
Global3 = 210.473 in.

Center grid point = 221
Located on mast
(see Fig. 27)
Global3 = 211.328 in.



Minus 90 Degree Hoop Cable Attachments

Radius = 12.0 in.
Global3 = 210. in.

Center grid point = 221
Located on mast
(see Fig. 27)
Global3 = 211.328 in.

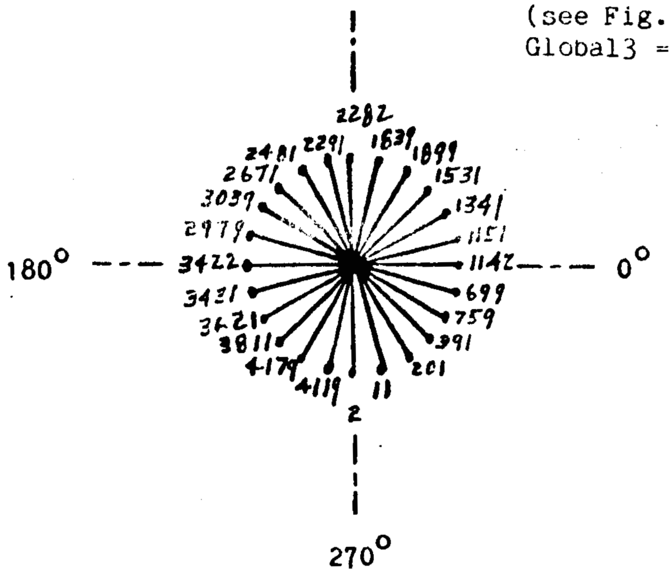
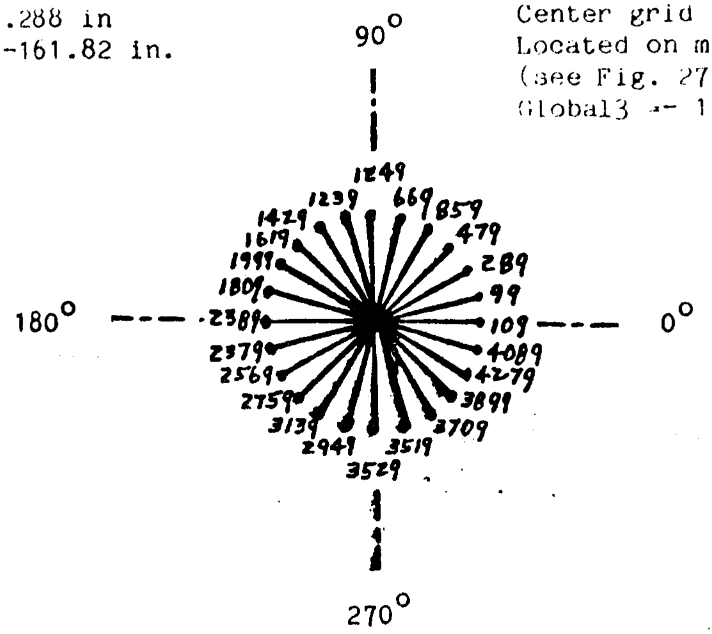


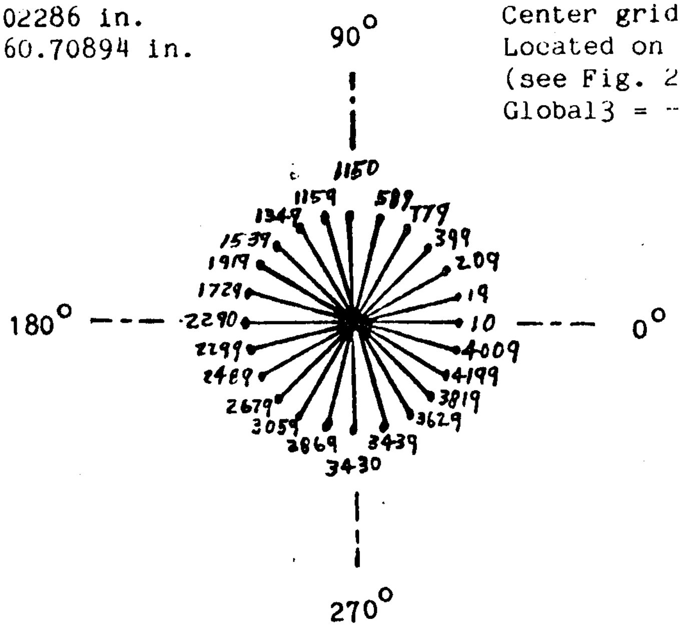
Figure 29. Mast Upper Cable Attachments, Semi-Rigid Beams



Lower Ray Cable Attachments

Radius = 11.288 in
Global3 = -161.82 in.

Center grid point = 1
Located on mast
(see Fig. 27)
Global3 = - 161.565 in.



Lower Hoop Cable Attachments

Radius = 14.02286 in.
Global3 = -160.70894 in.

Center grid point = 1
Located on mast
(see Fig. 27)
Global3 = -161.565 in.

Figure 30. Mast Lower Cable Attachments, Semi-Rigid Beams

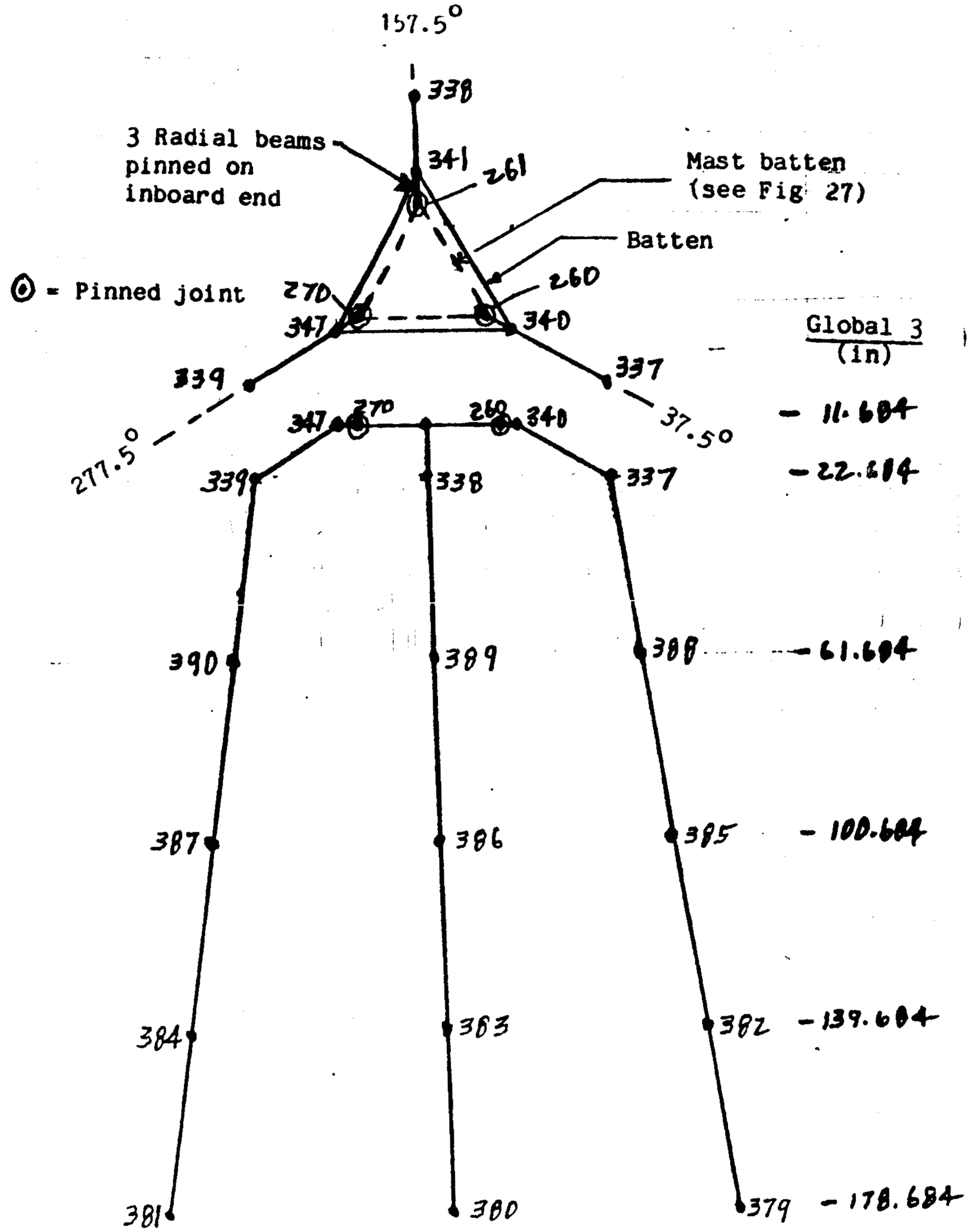


Figure 31. Tripod Support Beams and Grid Point Locations

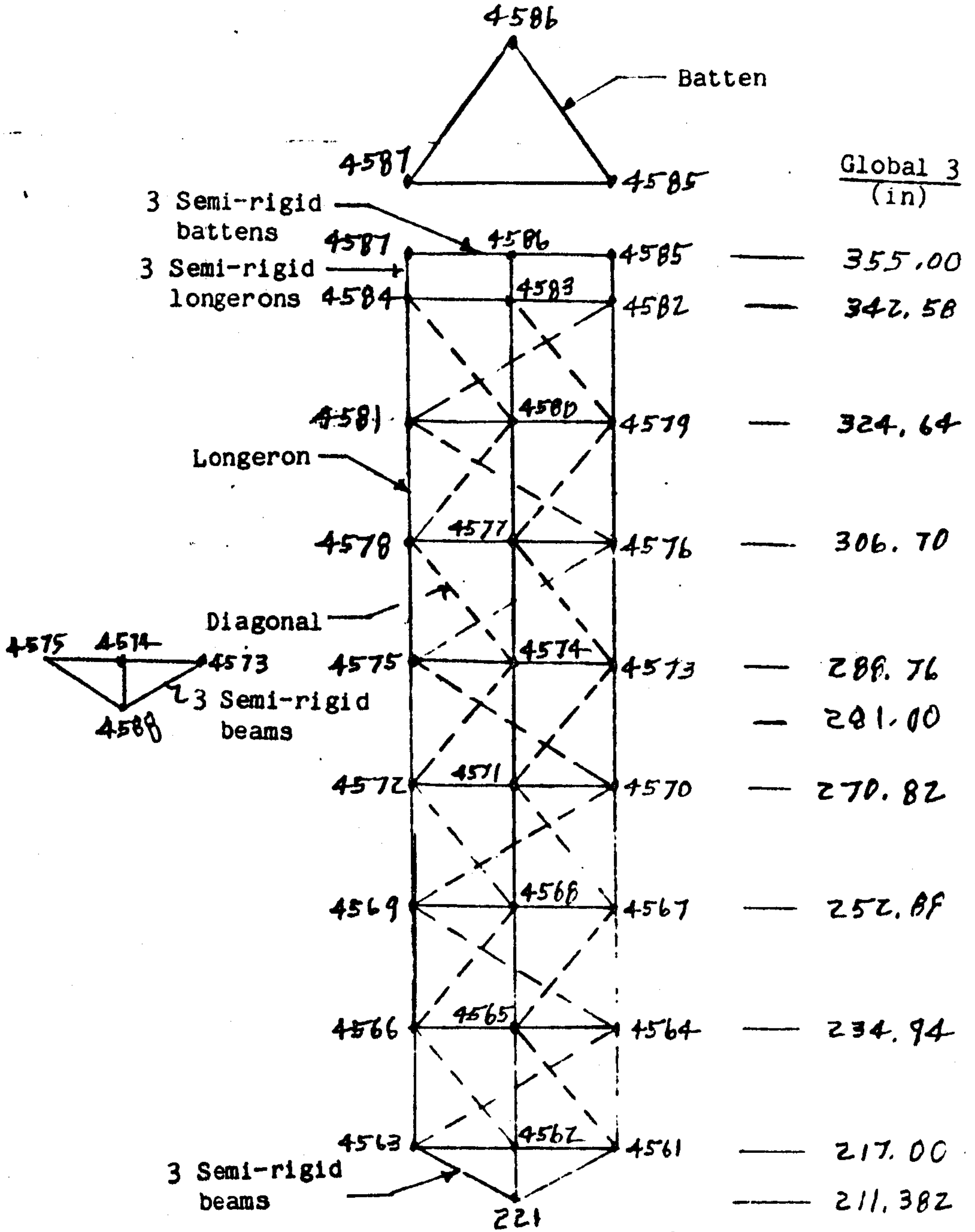


Figure 32. Feed Mast Truss Beam Elements and Grid Point Locations

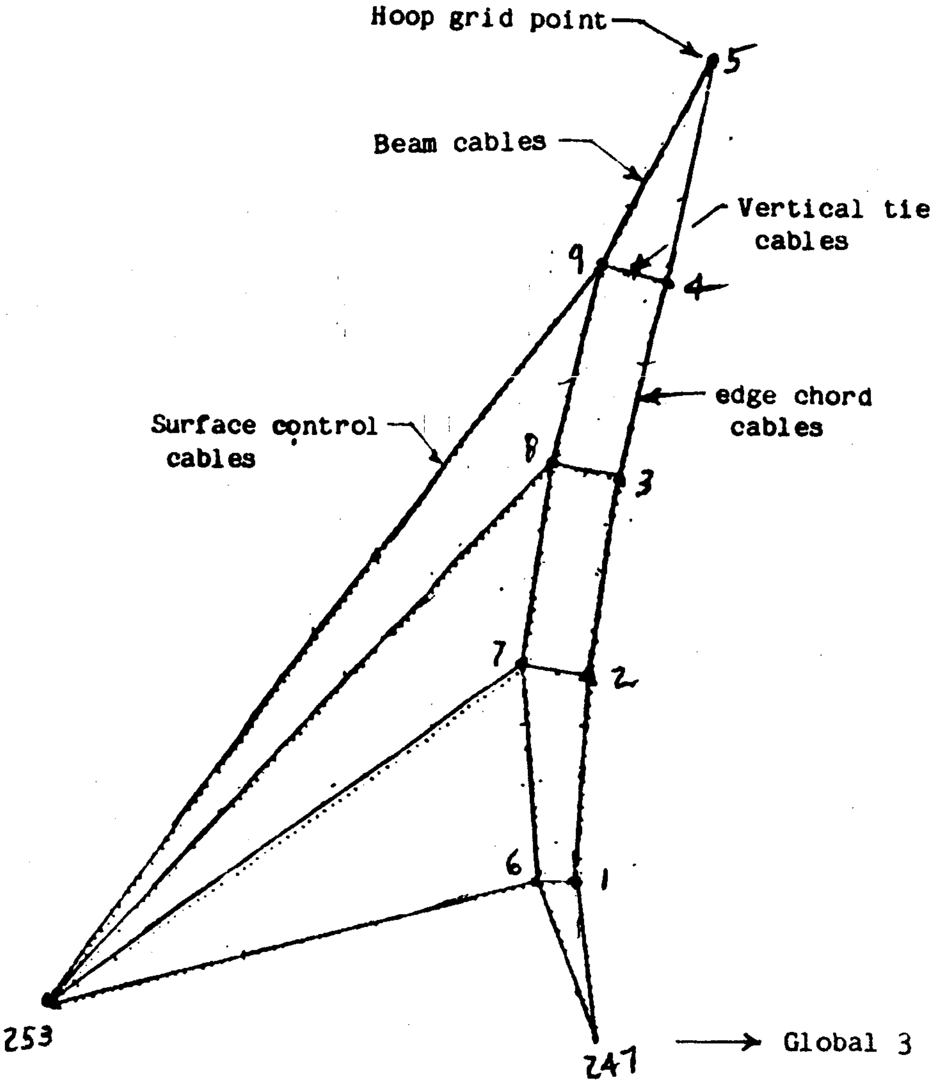


Figure 33. Reduced Model 1st Ray Cable Locations (0 degrees)

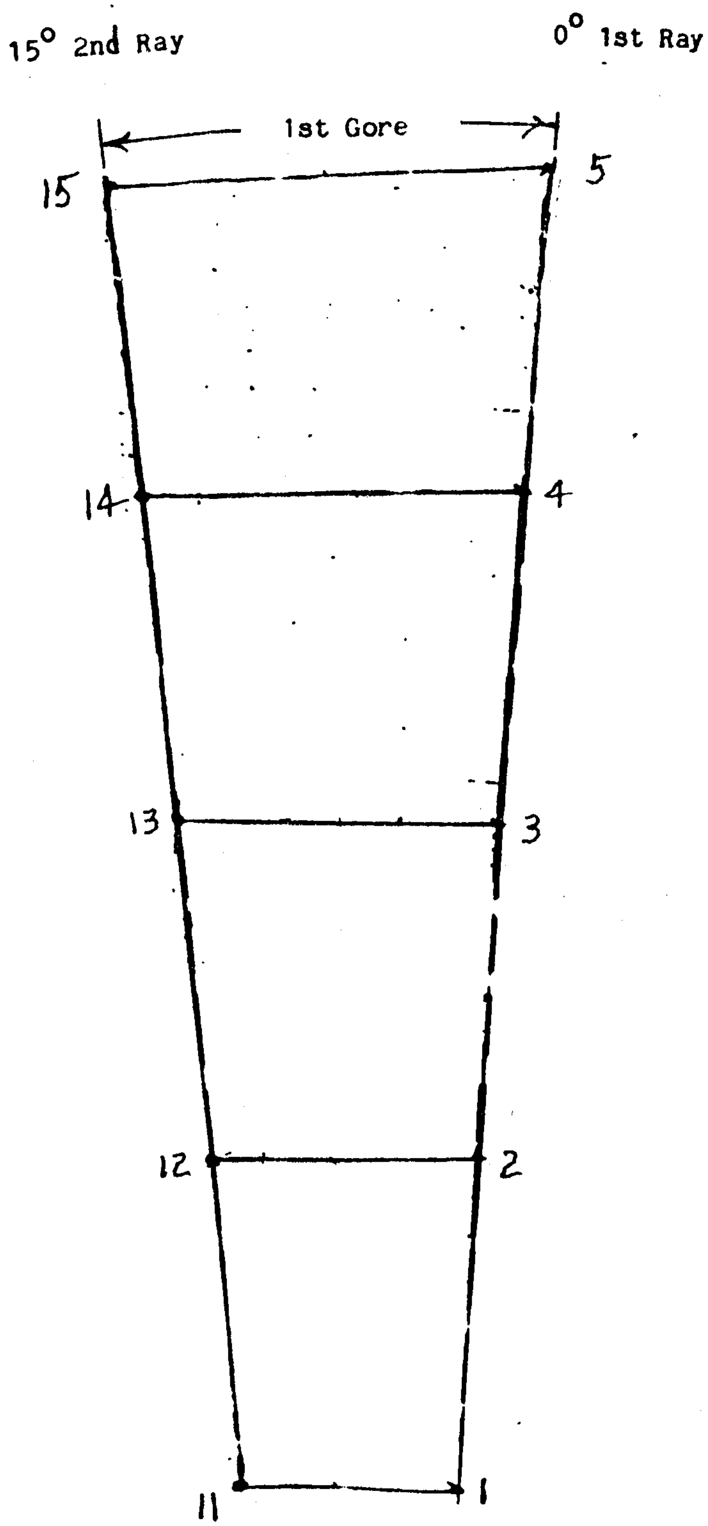


Figure 34. Reduced Model 1st Gore Cable and Web Elements
(0 to 15 degrees)

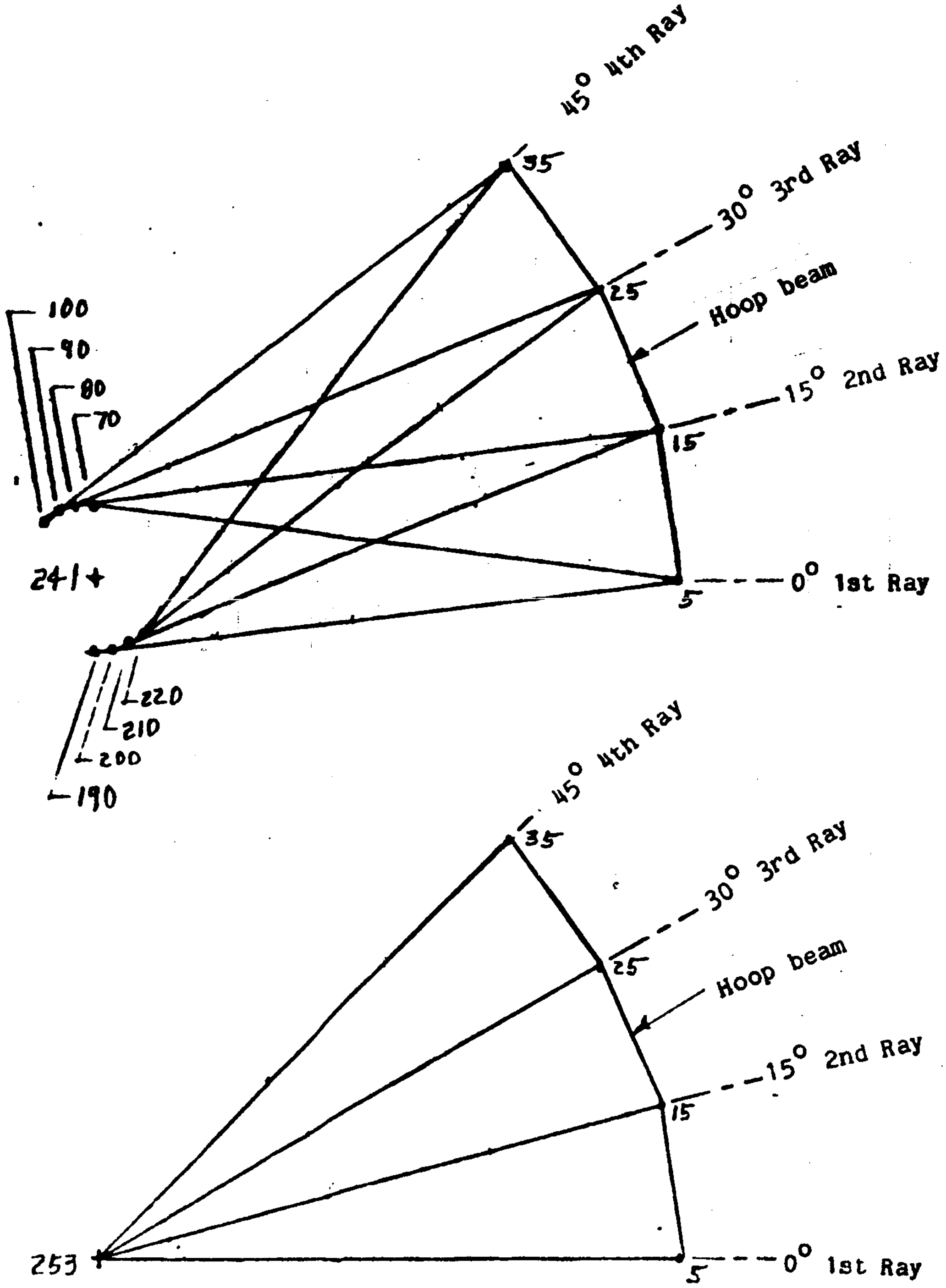


Figure 35. Reduced Model Hoop Support Cables (0 to 45 degrees)

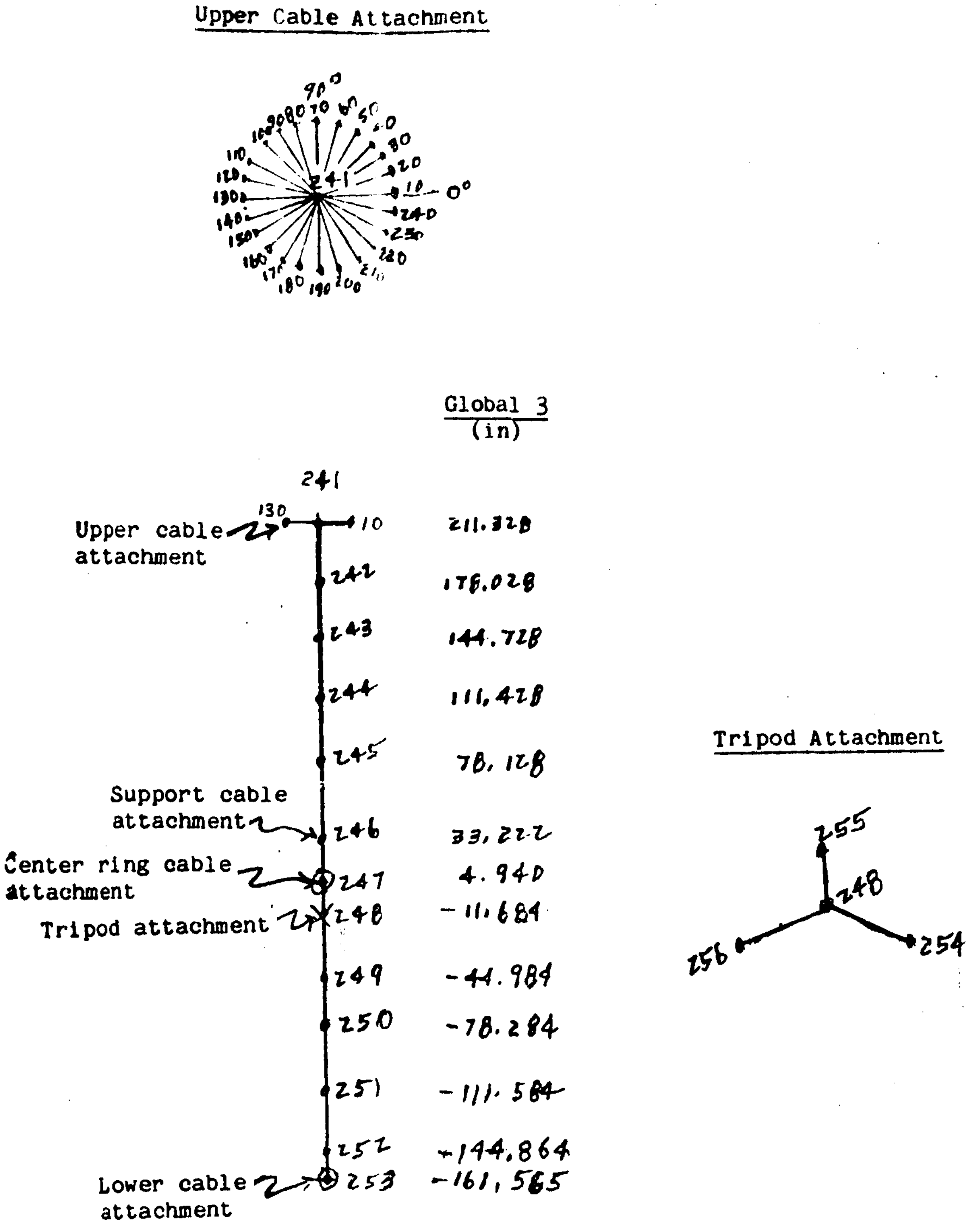


Figure 36. Reduced Model Mast Elements

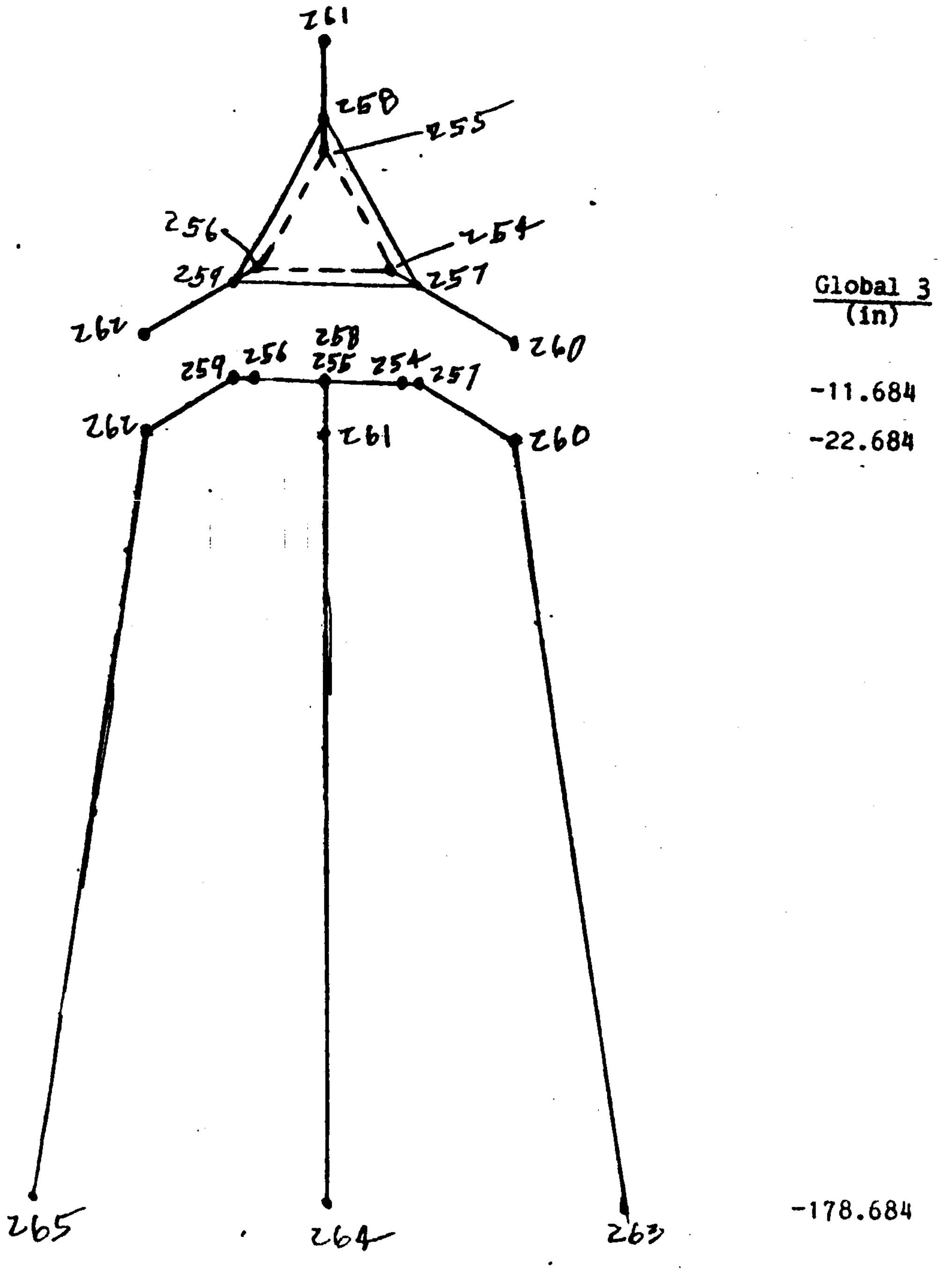


Figure 37. Reduced Model Tripod Support Structure

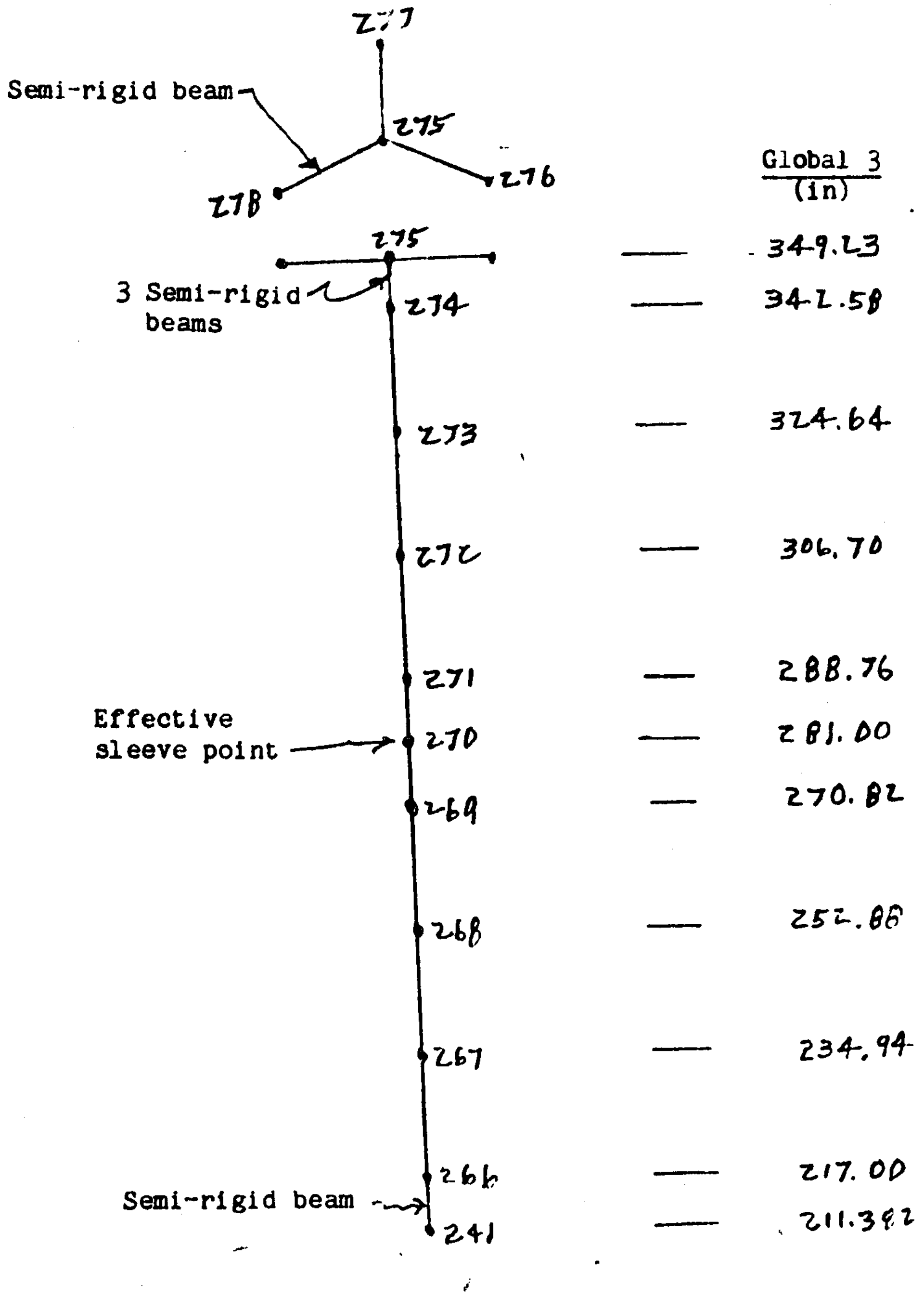


Figure 38. Reduced Model Feed Mast

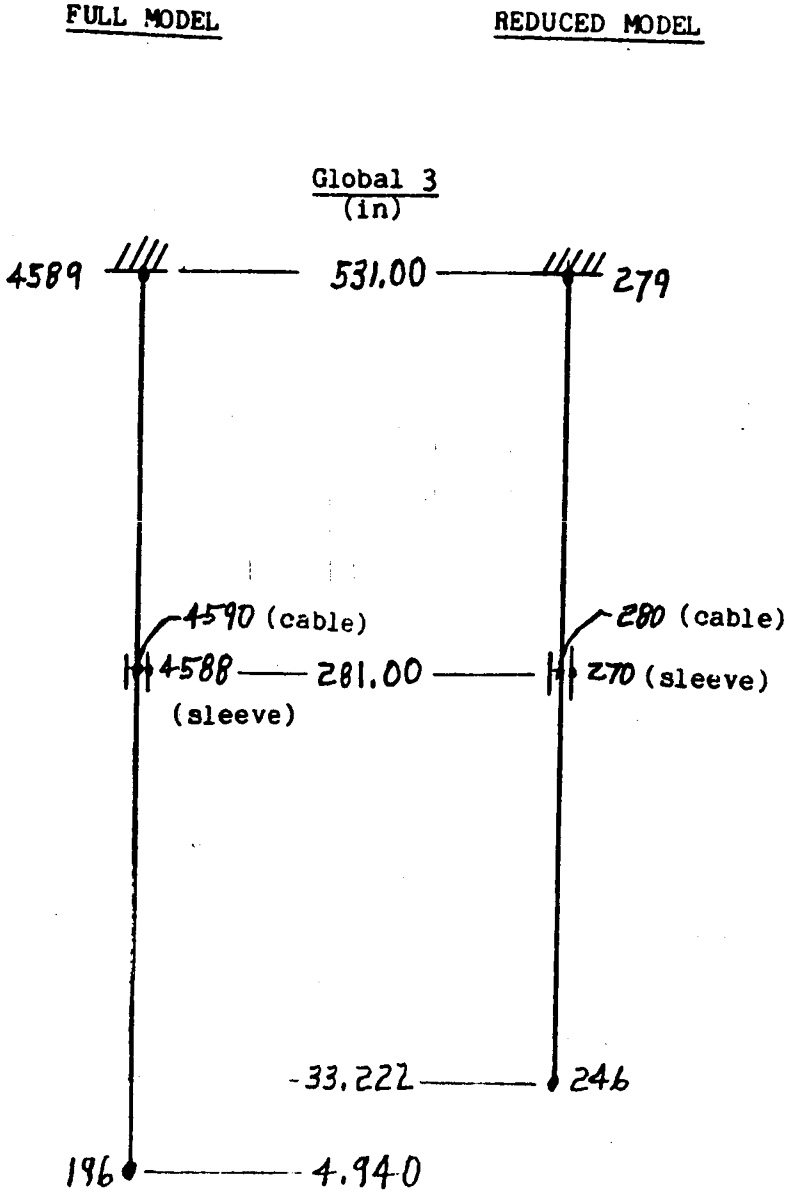


Figure 39. Cable Grid Points for Full and Reduced Model

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Final Report

16. Abstract

Presented is structural dynamics modeling of two multi-body space structural configurations. The first configuration is a generic space station model of a cylindrical habitation module, two solar array panels, radiator panel and central connecting cube. The second configuration is a 15 meter hoop column antenna. Test and analytical eigenvalues for both configurations are referenced. Discussed is the special joint elimination sequence used for these large finite element models, so that eigenvalues could be extracted.

The generic space station model aided test configuration design and analysis/test data correlation. The model consisted of six finite element models, one of each substructure and one of all substructures as a system. Static analysis and tests at the substructure level fine-tuned the finite element models.

The 15 meter hoop column antenna is a truss column and structural ring interconnected with tension stabilizing cables. To the cables, pretensioned mesh membrane elements were attached to form four parabolic shaped antennae, one per quadrant. Imposing thermal preloads in the cables and mesh elements produced pretension in the finite element model. Thermal preload variation in the ninety six control cables was adjusted to maintain antenna shape within the required tolerance and to give proper pointing accuracy.

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