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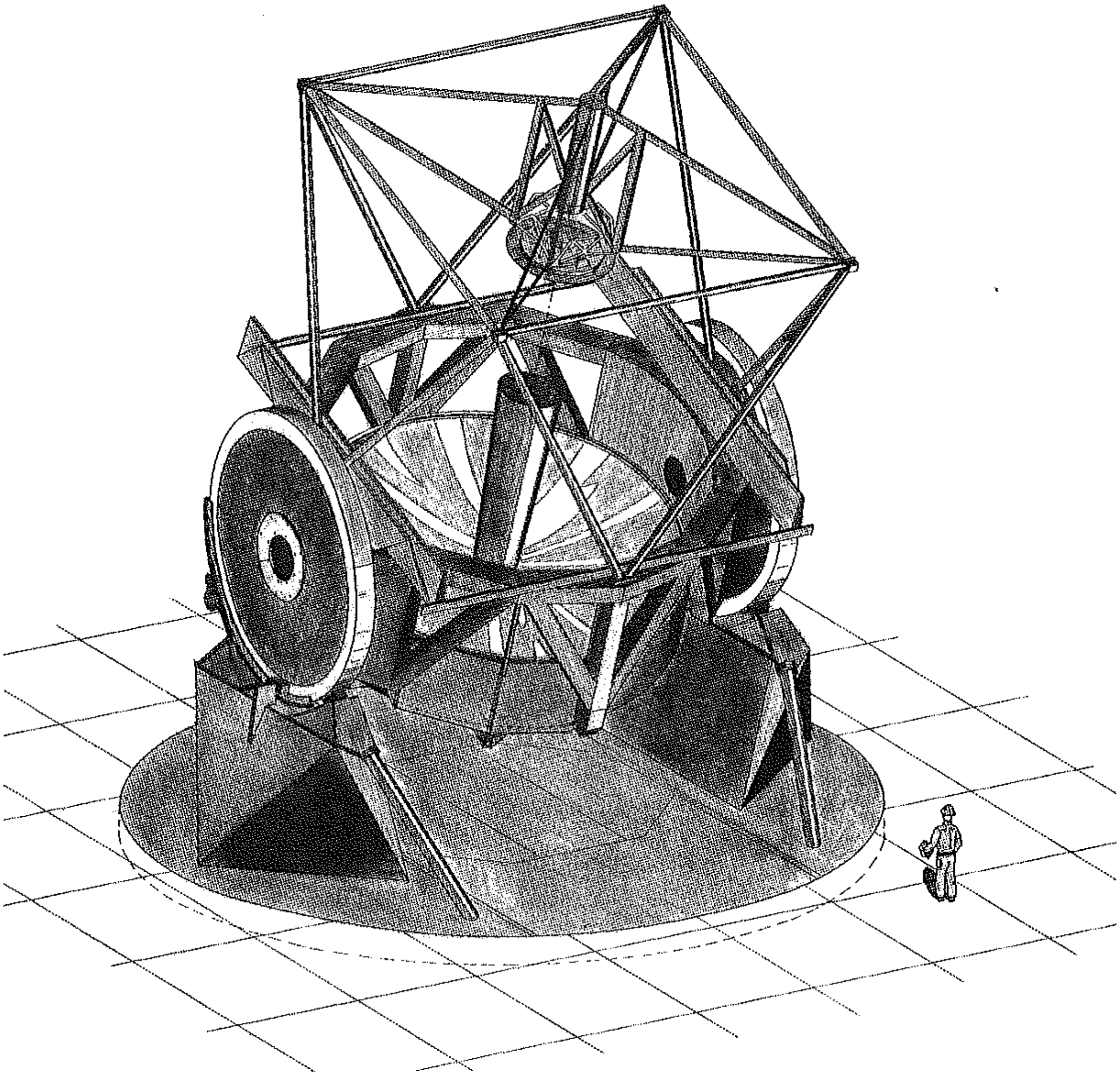

Further Analysis of the Tripod Disk Mounting

Steven M. Gunnels
Consultant, L & F Industries
Huntington Park, California

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PREFACE

You may have already noted that the telescope design displayed on the cover for Report No. 26 is different from earlier reports. During the past months we have been evaluating a telescope design that differs from the ALT-AZ Disk. Fabrication and maintenance were the driving forces. We call it the Tripod Disk design. (For a preliminary report I refer you to Magellan Report No. 19). From an evaluation of the study just completed, along with earlier ones of the Alt-Az Disk design, we have concluded that the Tripod Disk design is superior in performance, less costly to manufacture, and easier to maintain, especially in removing the primary mirror. We therefore suggest that the newer design becomes the one of choice. This issue of the Magellan Reports gives a summary of the Tripod Disk mounting as now conceived and its analysis.

W. A. Hiltner

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1.0 INTRODUCTION

This report summarizes the preliminary design of the Magellan Project 8 Meter Telescope in the Tripod-Disk configuration. The purpose of this work has been to define the telescope structure and major mechanical systems, and to predict modal performance. Static analyses (gravity and wind performance) have not been included due to the strong impact the (yet undefined) primary mirror support system will have in these areas.

2.0 STRUCTURAL AND MECHANICAL CONFIGURATION

2.1 SYSTEM DESCRIPTION:

The Magellan Telescope design summarized herein consists of an Alt-Azimuth mount, using hydrostatic bearings to define the altitude and azimuth axes. The system is shown on drawings E271065 (rendering), E271063 (system layout consisting of six sheets), and E271064 (mirror cell removal system). Sheet numbers below will be references to the multiple-sheet drawing, E271063. Graphics plots included as Figures 1 through 14 are also useful in understanding the structural design.

As illustrated in E271065, the mount can be considered a hybrid between a fork mount and the previously-considered Alt-Az Disk (ref. Report No. 5). The azimuth axis is defined using a large, round, thin disk (subsequently referred to as the "azimuth disk"), in combination with a large diameter plane bearing and stationary azimuth pintle/drive disk (ref sheet. 2).

The altitude axis is defined using two "altitude disks" in combination with two short structures, or "tripods". Although the tripods are not currently recognizable as such, each connects one side of the optics support structure (OSS) to the azimuth plane bearing at three points. Each tripod therefore consists of a plate tripod (a plate weldment), two tripod braces (15" dia. tubes) which allow the tripod to span the OSS loads out to the azimuth plane bearing, and two pillow blocks which connect the two and support the OSS radial hydrostatic pads. The tripods permit the use of smaller diameter altitude disks than did the Alt-Az Disk. While this system may be closer to an Alt-Az Disk mount than a conventional fork mount, it is subsequently referred to as a Tripod Disk mount.

The 8.0 meter f/1.2 primary mirror and f/6.5 optical secondary mirror focus at the Cassegrain instrument location. Alternatively, an f/15 infrared secondary, which normally hides behind the wide field secondary (sheets. 1 and 6) is used at the same Cassegrain focus. In addition, two Nasmyth instrument locations, on the altitude axis, with instrument rotators mounted on the outboard faces of the altitude disks, are provided.

The two main rotating structural assemblies of the mount are the Optics Support Structure and the azimuth structure.

The OSS Assembly (sheets 1 and 3 and Figures 1 through 6) consists of three major subassemblies:

1.) The mirror cell assembly includes the cell structure, the primary mirror, and its support and ventilation systems. This structure is not yet defined in much detail, but has been assumed structurally as two 1/2" steel plates separated by a dimension of 30", with a perimeter shell as shown in Figure 6.

2.) The center section includes the center section bracing, altitude disk weldments, and mirror covers.

3.) The secondary end includes the secondary main truss, square frame, vanes, secondary center structure, and secondary mirror, cell, and support system.

The Azimuth Structure consists of the azimuth disk and tripods, as discussed above.

2.11 Primary mirror removal system (E271064):

The mirror cell cart consists of the lower aluminizing chamber mounted on four wheels and supporting three jacks. As shown in the projected elevation view and section B, two guides are bolted to each tripod at two places and the underside of the OSS at one place. Bronze wear blocks bolted to the edge of the lower aluminizing chamber are at a level just below the bottom end of the guides when the cart is driven into place under the cell. When being transported between the telescope and the aluminizing locations, the fully retracted jacks (inverted mounting) clear the floor.

Three hard points in the azimuth structure and service building are located under each jack position to accept a compact short-stroke hydraulic jack as shown in C-C. The hydraulic jacks register to the screw of the mechanical jacks with a dowel pin, and the hydraulic jacks are registered to the floor as shown. The hydraulic jacks are positioned manually to engage the dowel pin as the mechanical screw is initially extended. With the hydraulic jacks fully collapsed, the mechanical, self-locking machine screw jacks are actuated. The protective tube on the top side of the jacks is square, so that a square bronze block bolted to the top of the moving screw guides on the inside of the tube, and therefore keeps the screw from turning as it extends or retracts. The three jacks are electric motor driven with a coarse servo control to keep the assembly level. Backup level switches are used for system shut-down should the assembly tilt to an attitude beyond that representing a reasonable servo error.

The system is guided (+/- 1/4") by the edge guides until within about 3" of the level at which the lower aluminizing chamber and mirror cell flanges make contact. At that level, more precision guides (bullet-nosed pins) engage to better control their alignment. When the screw jacks are fully extended (due to internal mechanical stops or as limited by controls) a nominal 1" gap remains. This is then closed by the use of the hydraulic jacks, which have a stroke of 2 3/8". The cell is then unbolted from the OSS, and the above procedure is reversed to lower the system.

This three-point lift system guarantees even loading of the jacks. In addition, the load equalizer supporting two of the wheels kinematically defines nearly equal loading on the four wheels during transport or while at rest on the rails. As shown, two wheels are driven and connected with a synchronizing jackshaft. Caliper brakes (not shown) will be used to hold position when at rest, especially in the event of an earthquake.

The entire assembly including mirror cart (with integral lower aluminizing chamber) and complete mirror cell assembly is estimated to weigh approximately 140,000 lbs.

2.12 Utilities distribution:

The azimuth utilities distribution is indicated on sheets 2 and 4. Utilities are draped from the pier to either of four cable trays mounted in the center removable floor panel spanning the center hole of the azimuth disk. The utilities then twist +/- 270° on or adjacent to the azimuth axis as the telescope is rotated through its total 540° azimuth travel.

The removable floor panels are relatively thin to minimize the moment arm of the telescope c.g. above the azimuth radial pad support plane. However, they are fabricated box sections which have adequate strength and stiffness to support live loads of 200 psf (lbs./ft.^{2}) over their 22-foot span. The cable trays in the center removable panel (and hydrostatic pads underneath) are fully accessible, having a locally removable top panel.

Beyond this area, utilities are routed on the underside of the azimuth disk as required.

A utilities drape will be used to transfer to the optics support structure. Its size and location is yet to be determined.

2.13 Mirror covers:

Due to the circular shape of the center section of the Tripod Disk, the mirror cover requires a two-part system.

As shown on sheet 3, the top cover consists of two bi-parting assemblies, each being a "rigid bellows" type. The panels are made of aluminum skins and aluminum (or other) honeycomb core. The 2" thick panels will have adequate strength and rigidity to support personnel when closed with the telescope at zenith, if required. Each of the four panels in each assembly is connected using heavy piano hinges with a thin silicone rubber flashing on the mirror side.

The cover is edge guided as shown and has an approximately octagonal shape when closed (phantom lines, top view). A silicone rubber seal mounted near the top inside corner of the structure seals to the cover when it is closed so that the mirror cavity can be purged with purified temperature controlled air when the telescope is not in use. Each assembly is actuated by a series of four rotary actuators, electric motor driven.

The perimeter mirror cover is a series of four sliding panels as shown in view B-B (sheet 3). Each panel is a thin aluminum sheet (0.125 in.) bent in the center to conform to the shape of the center section bracing, and stiffened on all edges. With the 16" square bracing diagonals set to the outside plane of the 24" x 16" top chord, a space is left for the perimeter cover as shown in view J-J. Each panel is edge guided by aluminum bronze guides, with one centerline self-locking electromechanical actuator. Alternatively, if it cannot be conclusively shown in detail design that the panels are adequately guided, two separate synchronized actuators will be used.

The panels seal to a silicone rubber seal along the top and bottom edges when in the closed position. The "t" stiffener along the lower edge of each panel must be removed to install or remove the mirror cell.

2.14 Oil collection systems:

The oil collection systems are indicated on sheets 2 and 5. The azimuth plane bearing uses gutters which are seal-welded to the inside and outside diameters of the plane bearing ring. This oil is collected at seal-welded drains and plumbed back to the hydraulic pumping unit for filtering and re-use.

The azimuth radial bearing involves another gutter which can be bolted to the underside of the azimuth pintle as shown. Local dams at each of the four radial hydrostatic pads assures that all oil on the azimuth disk side of the pads drains to the gutter. Oil from the pintle side will drip directly into the gutter. Oil is then collected as described above.

The OSS collection system, partially shown in view M-M (sheet 5), uses a dam around the top of the plate tripod, with seal-welded drains as shown. More intricate dams around the radial pad pillow blocks will be required. In addition, a rolled steel angle drip lip will be used (sheet 1) on the faces of each altitude disk to preclude oil from running down the face of the disk.

2.15 Universal Vane System:

The Universal Vane System is shown on E271065 and sheets 1 and 6 of E271063. The system provides for simultaneous mounting of the two secondary mirrors. In this way, only the optical secondary assembly need be removed or installed to change between the optical and infrared configurations.

The view of the sky as seen by the primary is shown in view F-F, sheet 6. This feature is discussed in more detail in Report No. 8, Universal Vane System. The secondary support system is described in some detail in Report No. 13, F/6.5 Wide-Field Secondary Support System.

2.16 Ventilation of structure:

The ventilation of the telescope structure is accomplished by a simple and inexpensive system (ref. sheet 2). A blower exhausts the interior of the concrete pier. The blower can be mounted in a sheet metal duct which is connected to the pier and routed to an area which is generally downwind of the enclosure. A liquid filled moat seals the rotating interface between the azimuth disk and the pier (at their outside diameters, view A-A). With ventilation holes in the bottom plate of the azimuth disk, a negative pressure is established throughout the continuous volume of the telescope interior. The OSS can be exhausted in either of two ways: It can be connected to the Tripod via a duct which is rigid with a rotating joint at the altitude axis, or by a flexible duct.

Alternatively, the OSS could be exhausted directly to the enclosure environment by strategically placed fans within the OSS. The best fan for the current wind direction and telescope position could be automatically selected by the control system so that the air is exhausted downwind of the light path, to be subsequently flushed from the enclosure interior by the wind. Each fan would require a controllable damper so that air is drawn from the top end of the structure down to the fan (and open damper) in use at a given time.

If ventilation holes are placed strategically around the structure, ambient air will then be drawn into and through the structure, and eventually exhausted downwind. This will significantly reduce the thermal time constant for the telescope structure.

2.17 Miscellaneous descriptions and subsystems:

As can be seen on sheet 1, the azimuth disk is made in four pieces bolted together as shown in G-G, sheet 5. The mirror cell cart wheels run on rails integral to the joint and therefore these high loads do not have to be spanned by the removable floor panels over the center hole in the azimuth disk (sheets 1, 2, and 4). The bolted joints are hidden beneath the surface of the 4" thick flooring system.

This system consists of panels of 3" steel decking covered with 1 1/8" tongue-and-groove plywood (in turn covered by linoleum) covering the azimuth disk. The flooring system (much of which looks directly at the sky) has relatively low thermal mass and a moderate insulation value. It therefore isolates the thermal mass of the azimuth disk structure from the air in the enclosure, as well as allowing the azimuth disk to be a thinner structure for a fixed azimuth lateral support plane. The only projections penetrating this observing floor surface will then be the plate tripods and braces. It is estimated that the flooring system, including removable panels, will weigh approximately 20,000 lbs.

As indicated by hidden lines in the two elevation views of sheet 1, powered counterweights will be mounted in the altitude disk weldments. These provide balance due to any combination of removal or installation of the Cassegrain instrument and secondary mirrors. Two assemblies with 6,000 lb. weights each travelling approximately 130 in. are anticipated. OSS position locks mounted as shown in view A-A sheet 2, will also be provided at zenith, horizon, and desirable intermediate positions.

In an emergency situation, the telescope motion about both axes can be braked by sudden dumping of hydrostatic system pressure. The hydrostatic pads, which will be surfaced with bronze, will minimize damage to the bearing running surfaces due to such an event.

2.18 Nasmyth Instrument mounting:

As indicated on E271065 and sheet 1, the provision for mounting and access to the Nasmyth Instruments is similar to that for the Cassegrain Instrument. That is, an instrument rotator is provided at each altitude disk which is a stiff annular plate connected to the altitude disk by a large (approximately 60" diameter) precision bearing. The plate may have two instrument mounting bolt patterns; for large and small instruments. The rotator will be driven in rotation by a high-precision friction drive. The instrument is then cantilevered from its front mounting plane, just as the Cassegrain instrument.

Finite element analyses have predicted that the altitude disks have adequate local stiffness to limit sag of the (assumed infinitely stiff) instrument to less than 30 arcsec and 0.010 in. at the focal plane. The first resonant frequency due to this same local stiffness under the cantilevered instrument load was 37Hz. An instrument weight of 10,000 lbs. (with its center of gravity 72" from the rotator) was assumed.

A portable access platform (similar to or possibly the same as that used for the Cassegrain instrument) can be used. Instruments that do not require derotation in this alt-az mounting can either be used with the rotator drive turned off, thereby rotating with the altitude disks, or the drive can be controlled to keep the instrument from rotating about its horizontal axis if desirable to maintain constant gravity loading with respect to the instrument.

2.2 STRUCTURAL DESIGN:

The goals of the structural design have been high stiffness, low rotating mass, and ease of manufacture. High stiffness and low mass effect small deflections due to gravity and wind loading, and high structural resonant frequencies. In addition, the low mass may effect cost savings, but will also improve thermal response of the structure to ambient temperature changes. This will then have a beneficial effect on seeing. The OSS has also been designed to be wind efficient. That is, it has as a minimal wind profile in order to minimize secondary mirror misalignments due to wind loading, and to encourage flushing of the air above the primary mirror.

As can be seen on the drawings and graphics plots herein, the telescope is constructed using spaceframes (tripod braces, center section bracing, and secondary end structure) and monocoque, or plate fabrications (azimuth disk, tripods, altitude disk weldments, and mirror cell). Plates used are predominantly 1/2" thick carbon steel. All weldments are to be thermally stress relieved.

2.3 BEARINGS:

Hydrostatic bearings will be used throughout the system. While the oil pads for these bearings may eventually be custom designed and built, the preliminary design has been tentatively based upon standard catalogue bearings. These bearings have spherical seats and self-aligning pockets to assure proper function against surfaces which are imperfect due to manufacturing tolerances and structural deflections. For purposes of the finite element modelling, film thicknesses of 0.003 in. were assumed, with flow control compensation.

2.31 Altitude Bearings:

The OSS is defined to the azimuth system using four radial pads and four lateral pads. The radial pads (that is, pointing radially toward the center of each altitude disk) are SKF 325 x 420 (or equal). They have a working load of 85,000 lbs. each, determined by the OSS weight and the support geometry. These pads have a rated load rating of 132,000 lbs. While a smaller, more rectangular shoe would be more optimal here, the next smallest catalogue pad is rated at only 66,000 lbs. All four of these pads are "masters". That is, they do not have a floating hydraulic section but are rigidly mounted to the azimuth structure.

The four lateral pads (which "pinch" across the thickness of the altitude disks in pairs - ref sheet. 2) are SKF 225 x 290 or equal. These pads are defining pads which do not support any significant external load. They are hydraulically preloaded to an assumed load of 40,000 lbs. One of the four is a master. The other three are "slaves" (with hydraulic floating section). The hydraulic floating section will be fed pressurized oil through an orifice sized to provide stiffness under high frequency loading. This type pad is therefore subsequently referred to as a "high frequency overconstraint" (HFOC).

Therefore, of the eight hydrostatic pads used to define the OSS to the azimuth system, five are masters, defining five of the six degrees of freedom for the OSS. The sixth (rotation about the altitude axis) is defined by the drives.

2.32 Azimuth Bearings:

The azimuth structure is defined to ground using ten hydrostatic pads. Six pads are mounted under the azimuth disk and run against the large azimuth plane bearing while the other four define the system radially to the azimuth pintle (sheets. 1 and 2).

The six vertically-acting pads are actually two sets of three, each set defining its tripod to ground locally. These pads equally support the vertical weight of the entire telescope, and therefore have a load of about 80,000 lbs. each. They are SKF 325 x 420 (or equal) and all are masters. All six pads define only three degrees of freedom for the telescope: vertical translation, rotation about an axis parallel to the altitude axis, and rotation about the fore-aft horizontal axis. Therefore, there is obviously some overconstraint present. The overconstraint would be of no concern if the azimuth plane bearing were *perfectly* flat, since the geometry of the azimuth system would be invariant as the telescope is rotated around the azimuth axis. The plane bearing will not be perfectly flat. Therefore, the overconstraint is accommodated as follows (ref. E271065):

If one imagines the near side tripod as an absolute reference as the telescope rotates about azimuth, the degree to which the azimuth plane bearing is imperfect will cause the far tripod to:

1. Change elevation, which is accommodated by the fact that all connections to the OSS are free to articulate locally (spherical seats in hydrostatic pads plus articulated drives). In other words, the OSS angular position about a fore-aft horizontal axis can change relative to the reference tripod.

2. Rotate about an axis parallel to the altitude axis, which is accommodated by the fact that there is only one altitude encoder, and therefore the "rotating tripod" can rotate around the far altitude disk without twisting the OSS. Of course, the relatively thin azimuth disk must also twist to accommodate this motion.

3. Rotate about a fore-aft horizontal axis, which is accommodated by the articulated pads and the fact that only one of the four OSS lateral defining pads is a master. This therefore allows lateral motion of the pads at the far tripod relative to its altitude disk. Of course, since three of the four lateral pads have high frequency overconstraint, this is true

> only for low frequency relative motion of the far tripod. Since these effects would be due to tracking or slewing rotation about the azimuth axis and thermal effects, they are very low frequency. The azimuth disk must also bend out-of-plane to accommodate this motion.

The loading is equal on the six vertical azimuth hydrostatic pads by virtue of the fact that the centroid of the support under each altitude disk is over the centroid of its respective three-point tripod support pads. Therefore, the stiffness of the six pads is predictable and equal.

The four azimuth radial pads (sheets. 1, 2, and 4) define two degrees of freedom for the telescope; the two horizontal translations. Therefore, two (at 90° to each other) are masters, the other two slaves with HFOC. They are SKF 225 x 290 or equal, and are preloaded to 60,000 lbs. each, accomplished by the slave pad preload pressure.

2.4 DRIVES:

Friction drives are planned for both telescope axes. The altitude axis will use one "Direct Friction Drive" (ref. Report No. 18) for each altitude disk. The drives will be mounted near the back top corner of each tripod. They will drive against either the altitude disk directly or (more probably) a replaceable drive arc, as shown on sheets 1 and 2.

The azimuth axis drive concept uses two drives at 180° to each other driving against the stationary pintle/drive disk (sheets. 1 and 2, and View D-D sheet 5). The drives are mounted to the azimuth disk and therefore rotate with the telescope. The drives are discussed in some detail in report no. 18 (March 1990). However, the torque capacity of the drives must be increased, due to the higher moment of inertia about azimuth and smaller drive disk diameter of the Tripod Disk as compared to the Alt-Az Disk. This can be accomplished by the use of a larger amplifier driving the same motor. The new rated torque for each motor will be 550 ft-lbs to accommodate the 427 ft-lbs (approximate worst case) torque requirement.

In the case of both drives (altitude and azimuth) the drive boxes have stiff restraints only in the tangential (drive) direction. They are otherwise free to articulate except that they are guided by rollers registering against the edge of the drive disks which is perpendicular to the drive surface, and the dual preloaded-roller feature prevents rotation of the unit about an axis parallel to the rotation axis.

3.0 FINITE ELEMENT ANALYSIS

3.1 INTRODUCTION:

The finite element models are shown in the form of graphics plots in Figures 1 through 14. A video has also been made which aids in understanding the primary modeshapes. Two final models were used to determine modal performance, although a total of 97 models were created and run including initial and optimizing runs. The optimizing results are not included here, although some of the more important findings are included in section 3.4 below. Some examples of features tested are: azimuth and altitude drive positions, center section, altitude disk, and tripod optimizing, spaceframe vs. monocoque azimuth disk, tripod, and center section, altitude disk size, OSS width/azimuth disk diameter, and hydrostatic pad stiffness sensitivity.

TDTELM78 is a model of the complete telescope, with the OSS zenith pointing. TDTELM80 is the same structure with the OSS pointing approximately 45 ° off the zenith position.

These should be considered preliminary-design level models. They are not highly meshed, although should be adequate for their intended purpose: optimizing and first-order prediction of modal performance. The final modal analyses included:

TDTELM78
1007 nodes
1326 plate elements
390 beam elements
5,958 degrees of freedom

3.2 OPTICS, INSTRUMENT, AND TELESCOPE WEIGHTS:

The following weights were used in, or resulted from, the finite element models:

Primary mirror - 28,485 lbs. (U of A)
Primary mirror support and ventilation systems - 10,000 lbs. (assumed)
Secondary mirror, cell, actuators, and support structure - 1,832 lbs.
Instrument mounting base - 5,000 lbs.
Cassegrain Instrument - 5,000 lbs.
Counterweight assemblies - 16,000 lbs. (total for 2)

OSS Assembly - 242,500 lbs.:	Telescope (rotating) Assembly:
1.4E7 lb-sec^2-in (altitude axis)	485,000 lbs.
1.8E7 lb-sec^2-in (optical axis)	5.3E7 lb-sec^2-in (azimuth)
2.1E7 lb-sec^2-in (perpendicular)	

3.3 MODAL ANALYSIS:

The results of the finite element analyses are presented in Tables 1 through 3 and in the graphics plots in Figures 10 through 14. The inertia and stiffness properties of the OSS vary (with respect to a global reference) with zenith position. Therefore, the zenith and 45° positions were run to predict extremes of primary modal frequencies (it is assumed that the telescope will not operate frequently very much below the 45° position).

Table 1 provides the zenith results, Table 2 the 45° results, and Table 3 summarizes the minimum frequencies for each modeshape.

Support stiffness was achieved by creating springs from beam elements. For example, the azimuth vertical hydrostatic pad beam elements have the axial stiffness of a flow control compensated hydrostatic pad with a load of 80,000 lbs. and a film thickness of 0.003 in. All other stiffnesses (three rotations and two off-axis translations) for these elements is nil. Conversely, the azimuth drive model was more complex, in that it must have stiffness for rotation only. Due to the high servo gain possible with the high performance drives, they were modelled as virtually infinitely stiff. That is, even though the spring rate between the servomotor and drive disk is finite, if the gain is sufficiently high, the telescope is controlled at the encoder reference. Therefore, the rotation frequencies are indicating "locked encoder" and not "locked rotor" modes.

The natural frequencies and modeshapes included in Tables 1 through 3 are "primary modes" - defined here as those involving all or a major portion of the mass of the telescope. Secondary end local modes are discussed in Report No. 8, Universal Vane System, May 1989. It should be noted that secondary end local deflections shown in Figures 10 through 14 are exaggerated, since these models do not include the stiffening effects of vane pretension.

Primary modeshape no. 6 is not included in the graphics plots here, since it has very large secondary motion which is invalid due to this lack of vane pretension. However, the modeshape is similar to modeshape 2, except that the OSS is out of phase with the azimuth structure.

Brief modeshape descriptions are included with Figures 10 through 14. They have also been animated and included on video tape.

3.4 OPTIMIZING RESULTS:

Numerous structural features were tested and optimized during this work. Some of the more important results were:

1. The current azimuth drive location (sheet 1) is best for this drive disk/azimuth disk geometry. When rotated to other positions, either the azimuth disk gross in-plane bending is increased, or the local strain due to the drive tangent load is higher, or both.

2. The altitude drives are better at their present location than at the bottom of the altitude disk, due to improved locked encoder altitude performance.

3. The altitude disk lateral brace (one tieing the bottom of each altitude disk to the adjacent point on the mirror cell) causes about 1.1 Hz improvement in the lateral translation vibrational mode. These two braces must be removed or swung out of the way for mirror cell removal.

4. The azimuth drives and azimuth radial support pads must be on slightly different horizontal planes. As compared with them both being centered in the 24" azimuth disk thickness, the current position (drives 2 1/2" up, pads 6" down) diminished the affected frequencies by about 2% each. The current placing is therefore optimal as well as allowing the drive contact to be above the wetted area of the pintle. This will preclude oil contamination of the encoder and motor from occurring.

5 Larger altitude disks cause the altitude rotation frequency to increase and the lateral translation frequency to decrease. The rotation frequency is currently slightly lower than is lateral translation (9.7 vs 10.0). Larger disks would be somewhat more difficult to manufacture. Therefore, the current 20-foot altitude disk diameter is optimal.

6 Plate tripods had slightly superior performance to pipe tripods (monocoque vs. spaceframe) with additional OSS lateral restraints, and virtually the same performance with the current single lateral restraint at each altitude disk. The plate tripods were therefore chosen for their ease of manufacture.

7 The lightest feasible plate structure azimuth disk is 20,000 lbs. heavier than the heaviest feasible spaceframe azimuth disk, but has a little higher modal performance. Since the thermal inertia of the azimuth disk is isolated from the enclosure air, the plate structure was chosen for its slightly higher performance and simpler flooring system.

8 The current OSS center section bracing is slightly more efficient than the initial "helix diagonal" bracing tried and nearly as stiff as the solid box weldment center

section. It enables flushing of the air above the primary mirror.

FINITE ELEMENT ANALYSIS - SUMMARY OF RESULTS NATURAL FREQUENCIES AND MODESHAPES

TABLE 1
ZENITH POINTING

The following modal performance is from model TDTELM78, with the OSS in the zenith position. Modeshapes are shown and described in Figures 10 through 14. See also the discussion in the body of the report.

MODE	FREQUENCY hertz	MODESHAPE DESCRIPTION
1	9.7	First Altitude Rotation
2	10.0	Lateral Translation
3	14.9	Second Altitude Rotation
4	15.5	Azimuth Rotation
5	16.9	Vertical Translation
6	17.5	Second Lateral Translation

TABLE 2
45° POINTING

The following performance is from model TDTELM80, with the OSS pointing approximately 45° off the zenith position.

MODE	FREQUENCY hertz	MODESHAPE DESCRIPTION
1	10.0	First Altitude Rotation
2	10.3	Lateral Translation
3	13.6	Second Altitude Rotation
4	14.5	Azimuth Rotation

TABLE 3
MINIMUM FREQUENCIES BY MODESHAPE

The following are minimum values by modeshape, taken from Tables 1 and 2 above.

MODE	FREQUENCY hertz	CRITICAL POSITION	MODESHAPE DESCRIPTION
1	9.7	Z	First Altitude Rotation
2	10.0	Z	Lateral Translation
3	13.6	45°	Second Altitude Rotation
4	14.5	45°	Azimuth Rotation
5	16.9	Z	Vertical Translation
6	17.5	Z	Second Lateral Translation

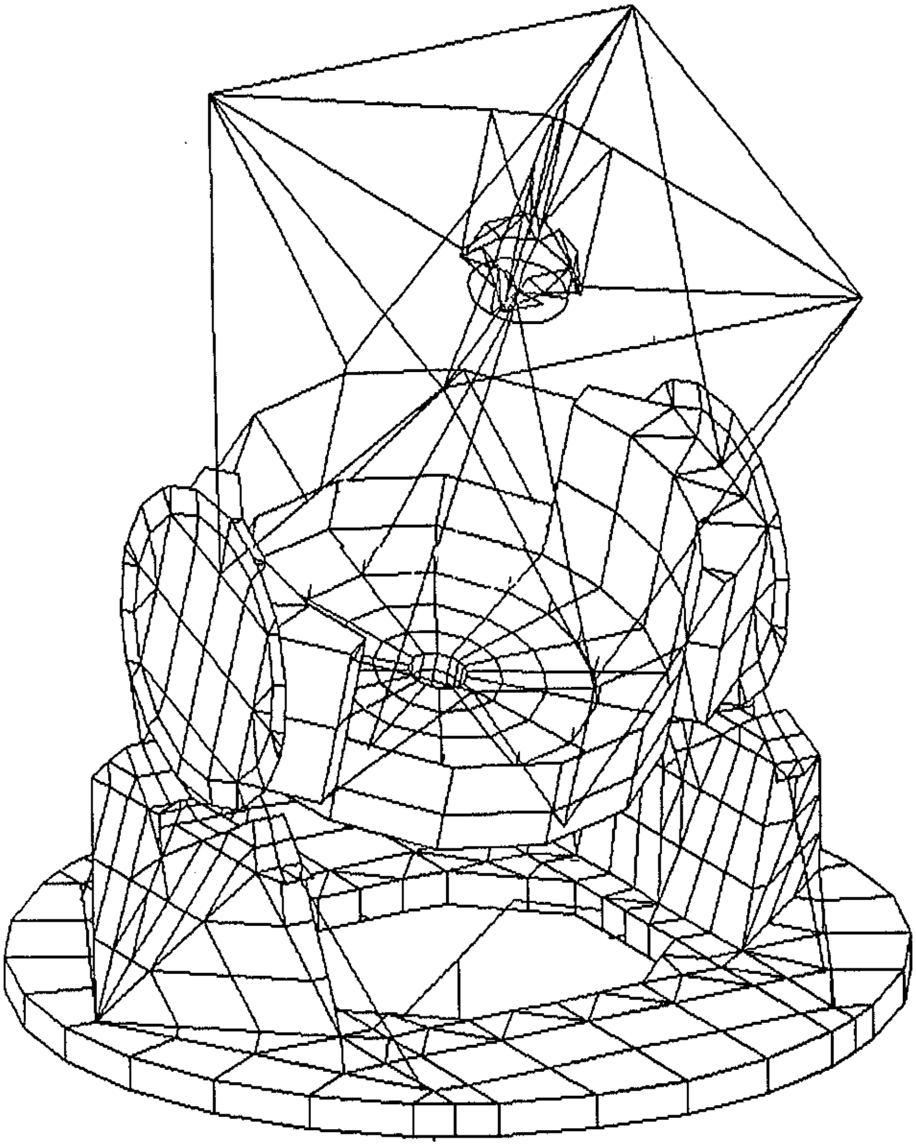


FIGURE 1 - Finite element model of complete telescope, shown here with hidden lines removed. OSS is pointing 20° off of the zenith position in this view. Model consisted of 1007 nodes, 1326 plate elements, 390 beam elements, and 5958 degrees of freedom.

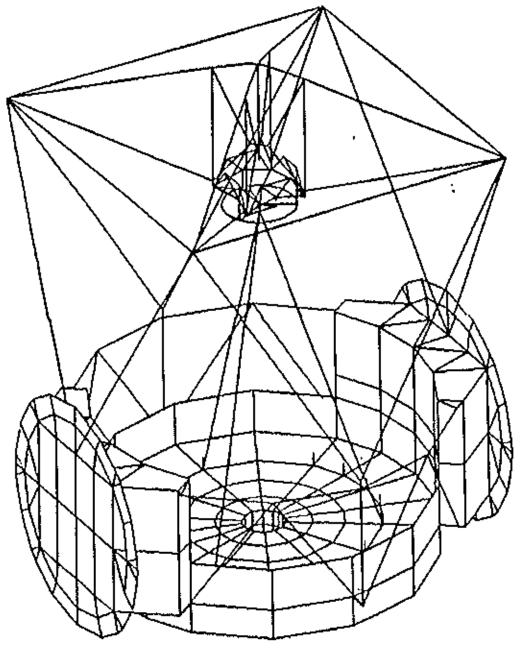


FIGURE 2 - Quartering view of OSS in the zenith position. Three and four node (five degree-of-freedom) thin plate/shell elements were used for structural members to be fabricated from plate. Six degree-of-freedom beam elements were used for spaceframe members, such as the center section bracing and secondary end structure. Beam elements were also used to define support and drive stiffnesses, and to facilitate the application of some nodal loads such as those simulating the mass and inertia of the primary mirror and support system.

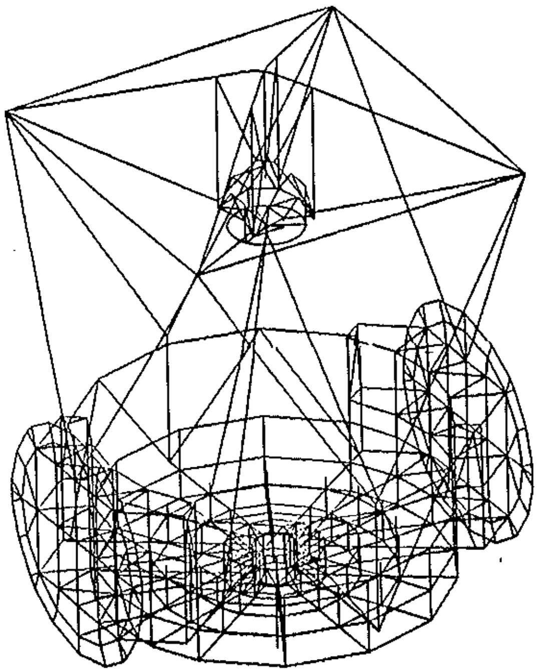


FIGURE 3 - Quartering view of OSS without hidden lines removed.

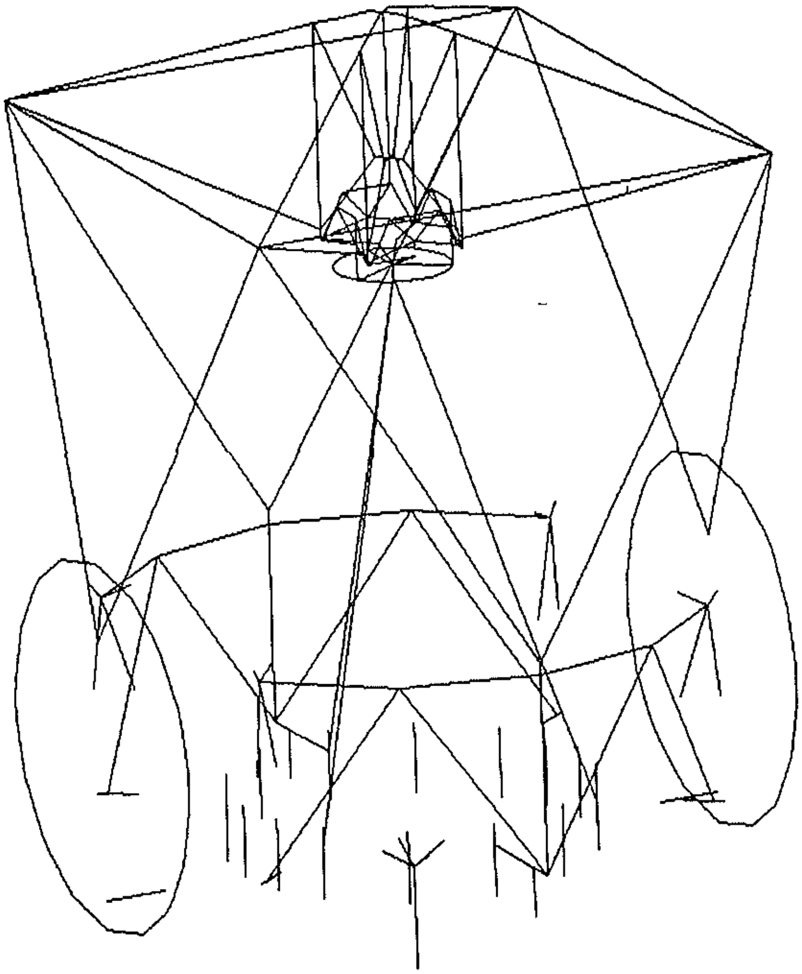


FIGURE 4 - Quartering view of beam elements in OSS, including secondary center structure, vanes, square frame, main truss, altitude disk rims, center section bracing, primary mirror target, primary mirror nodal load beams, and Cassegrain instrument.

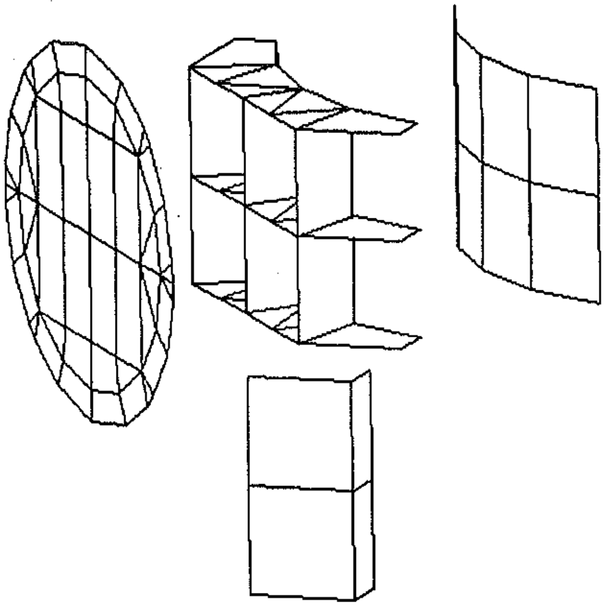


FIGURE 5 - Exploded view of one altitude disk weldment. All plate elements here are 1/2" steel, except for the altitude disk. The single thickness plate elements used to model the altitude disks had thickness, elastic modulus, and density adjusted to simulate the actual built-up structure: two 1/2" plates separated by approximately 17", plus internal gusseting.

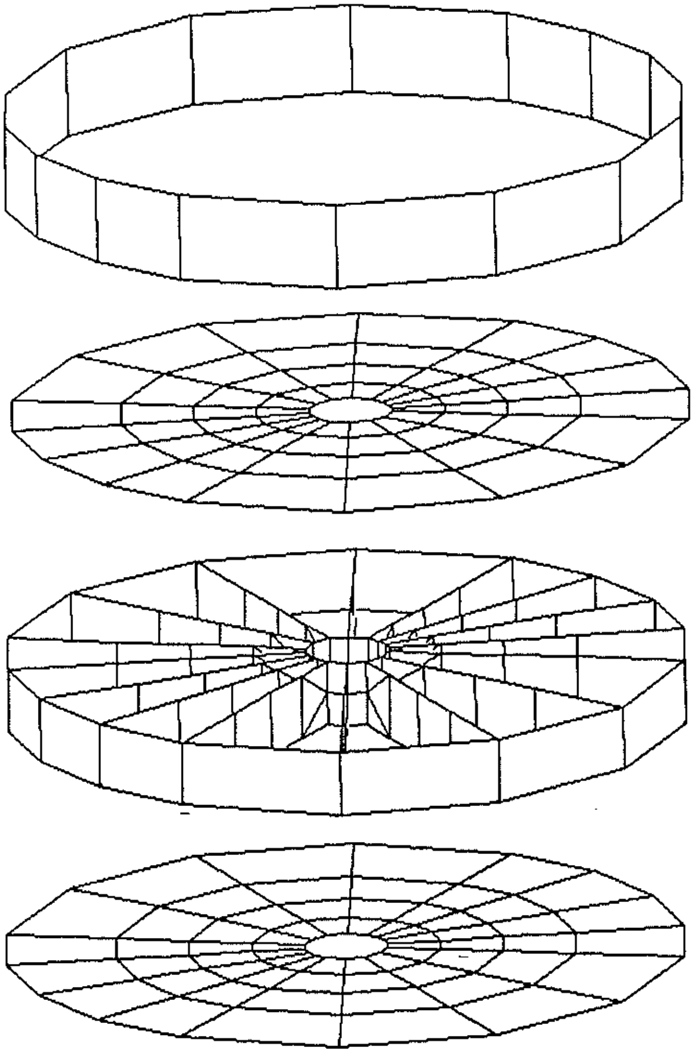


FIGURE 6 - Exploded view of mirror cell. All plate elements here are 1/2" thick steel.

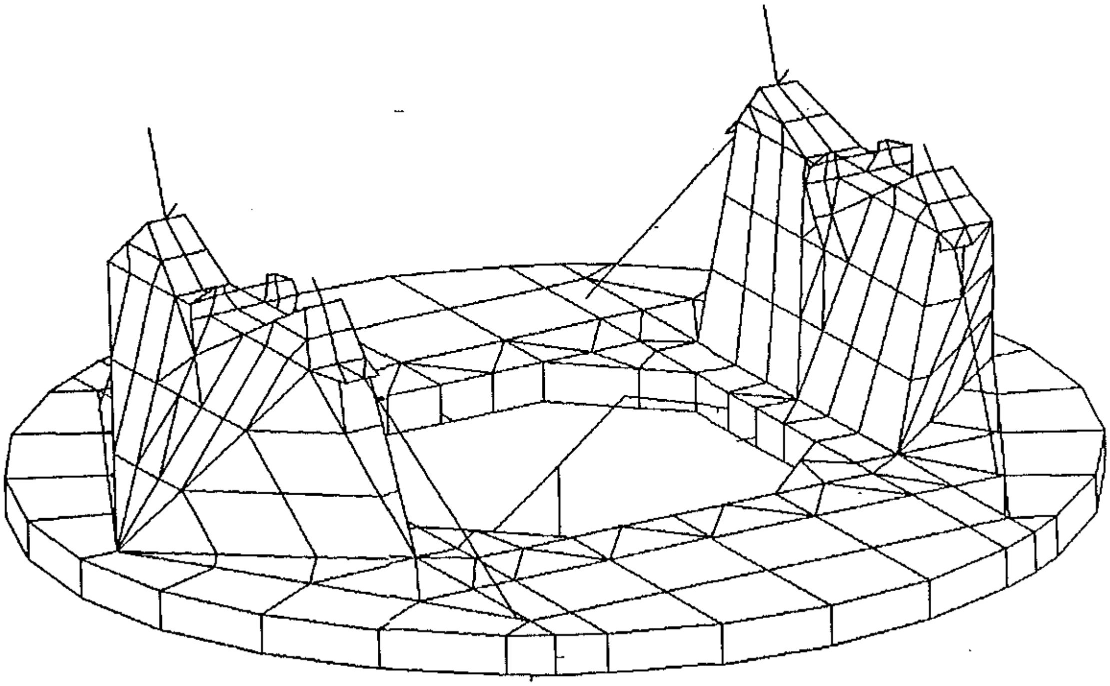


FIGURE 7 - Quartering view of azimuth structure, including the azimuth disk, plate tripods, and tripod braces.

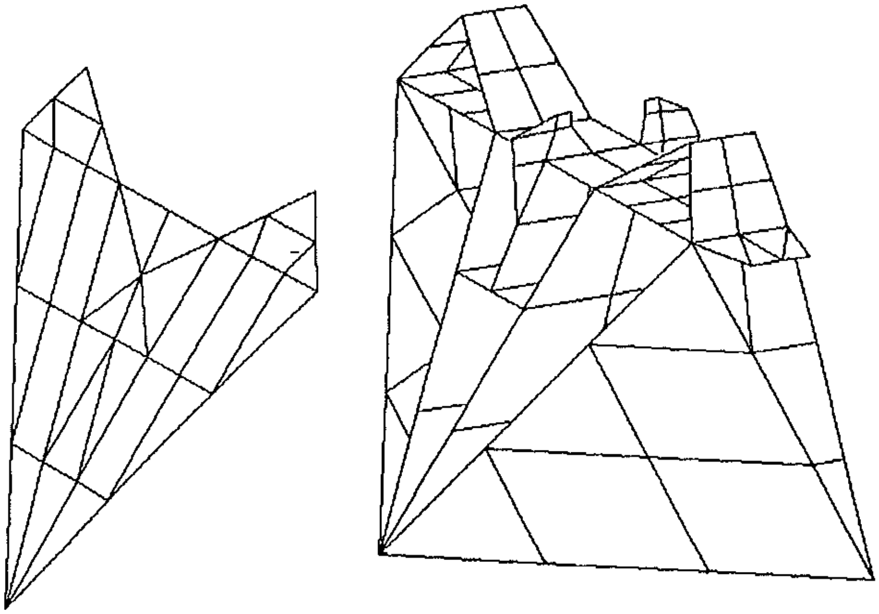


FIGURE 8 - One plate tripod with outboard plates removed to expose the internal structure. Most plates here are 3/4" and 1" thick, although heavier plates are used locally where necessary for machined joints or areas where high local stiffness is required.

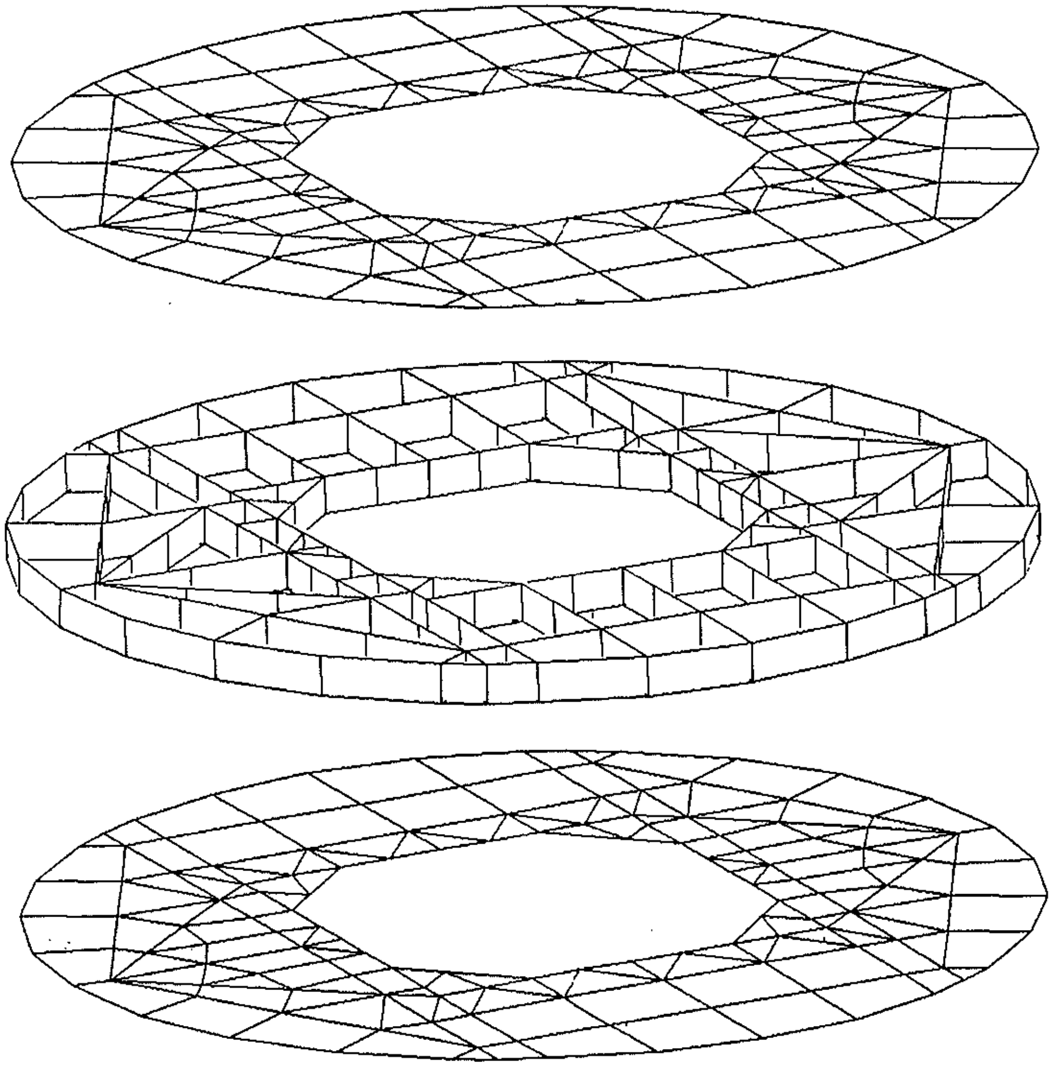


FIGURE 9 - Exploded view of azimuth disk structure. Most plates here are 1/2" thick. The material density of these plate elements was made artificially high to compensate for additional mass of the non-structural flooring system.

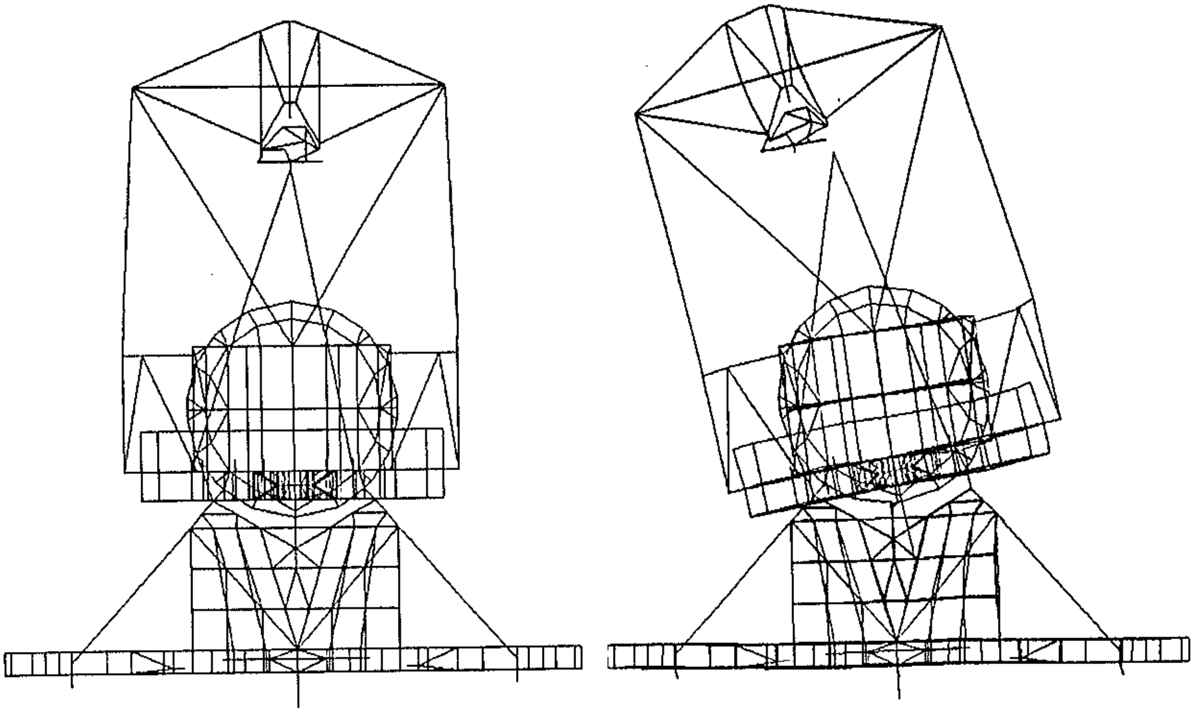


FIGURE 10 - Side view of model TDTELM78, the telescope modal analysis in the zenith position. The left view is of the undisturbed telescope. The right view is of modeshape 1, the first altitude rotation mode, at 9.7 hz. Although difficult to tell, the OSS and azimuth system are in phase here, both having displaced aft (to the left). The OSS motion (rotation about an axis parallel to the altitude axis) is dominant.

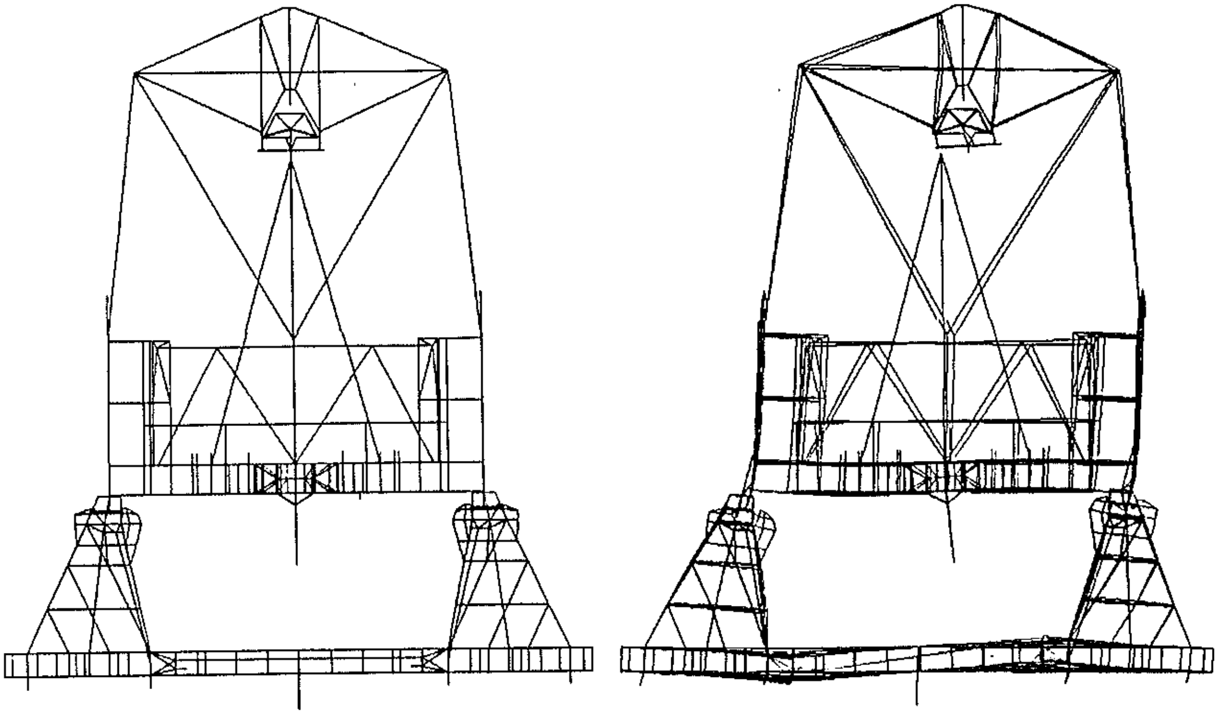


FIGURE 11 - Front view of modeshape 2, lateral translation, at 10.0 hz. Note that, while this mode may not couple to either locked encoder rotation mode, there is a slight rotation of the primary mirror target, and a significant decenter of the secondary mirror.

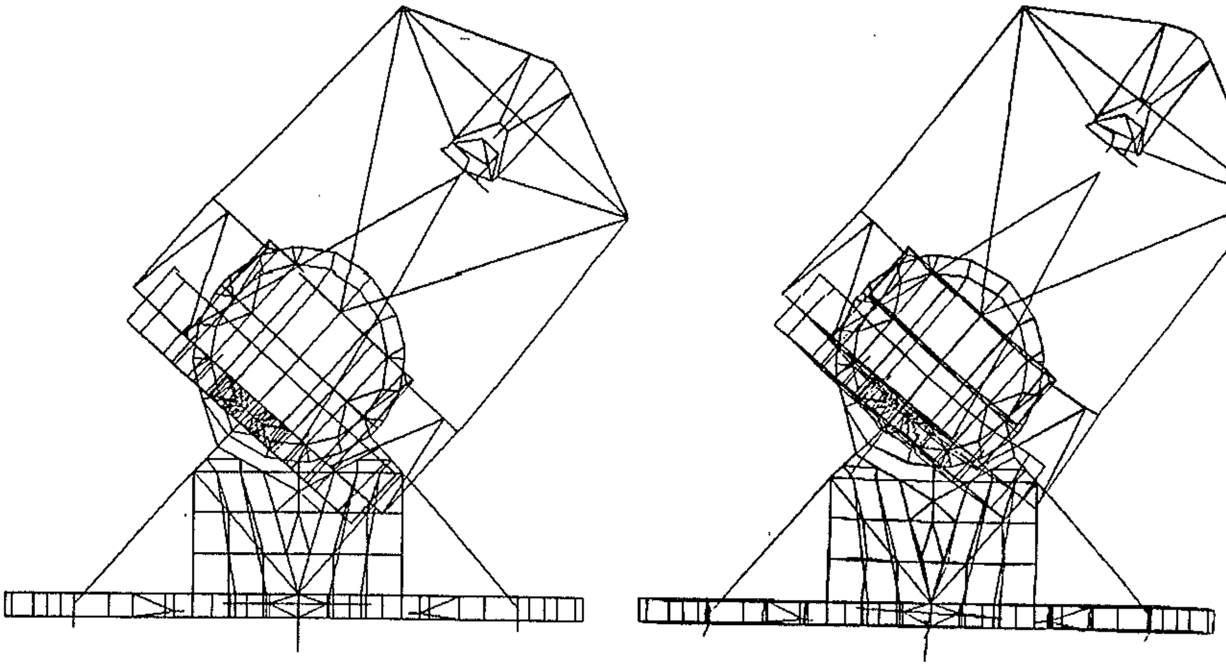


FIGURE 12 - Side view of model TDTELM80, the telescope modal analysis with the OSS 45° from zenith. The left view is of the undisturbed telescope. The right view is of modeshape 3, the second altitude rotation mode, at 13.6 hz. Allthough difficult to tell here, the OSS rotation and azimuth system are out of phase.

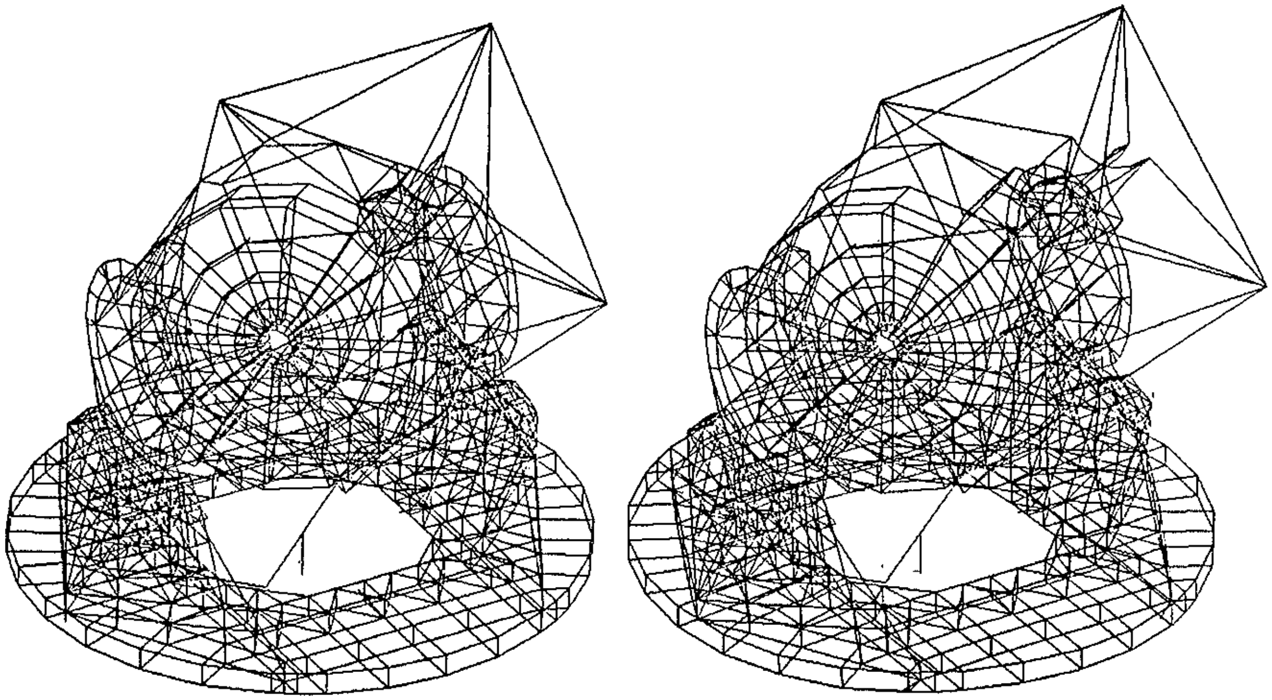


FIGURE 13 - Quartering view of model TDTELM80 undisturbed and modeshape 4, locked encoder rotation about the azimuth axis, at 14.5 hz. The local out-of-plane displacement of the secondary vanes here is invalid, since this analysis did not include the effects of vane pretension.

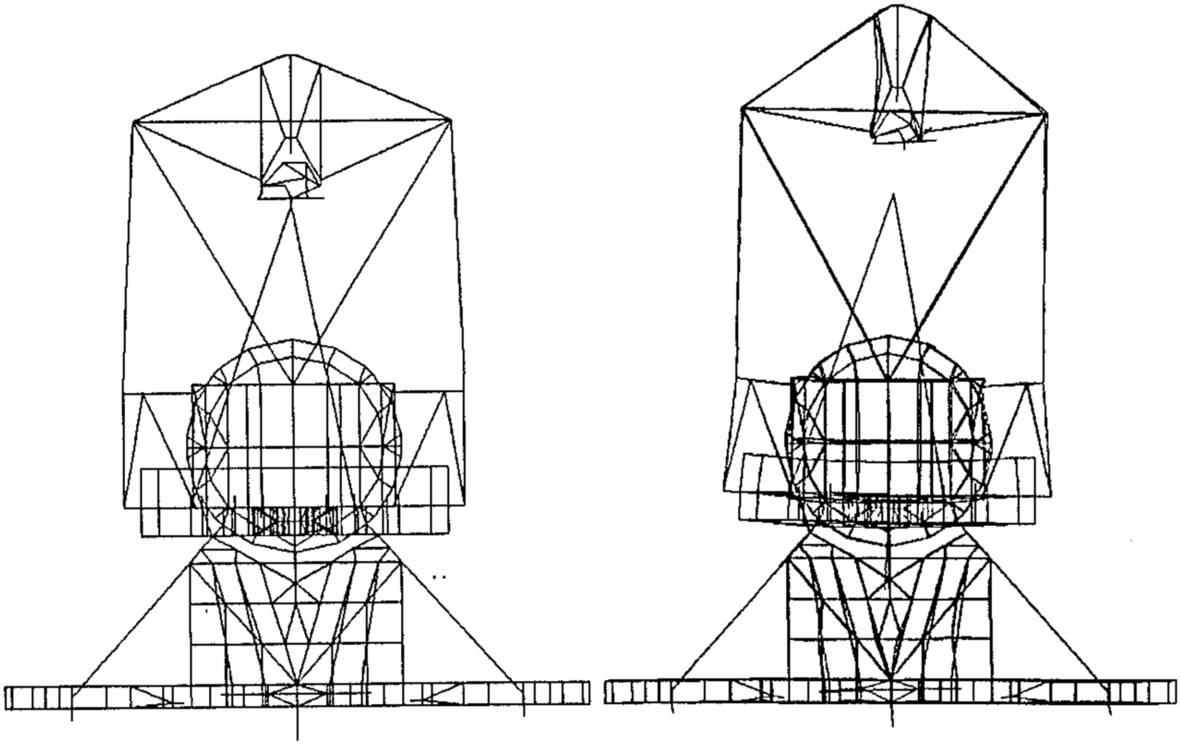
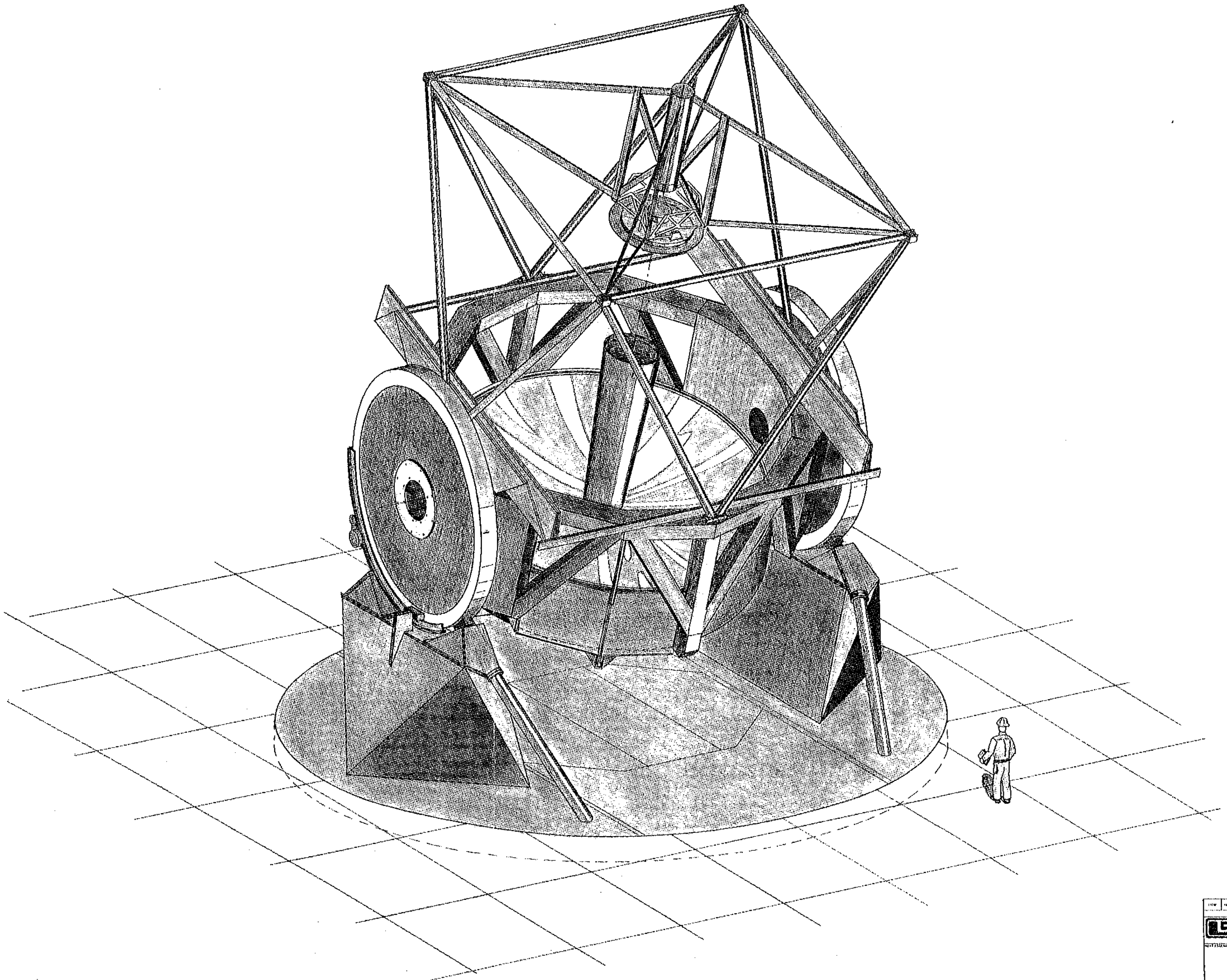


FIGURE 14 - Side view of model TDTELM78, undisturbed and modeshape 5, vertical translation, at 16.9 hz.

4.0 SUMMARY AND CONCLUSIONS

The preliminary design has been defined, and modal performance predicted, for the Magellan Project 8 Meter Telescope. First-order optimizing has been performed to maximize the primary mode frequencies. Some additional improvement in these, or decrease in weight (or both) can be anticipated by further optimization during detail design. Frequency response analysis is planned to better understand and predict the pointing and tracking of the system under external loads.



INDUSTRIES

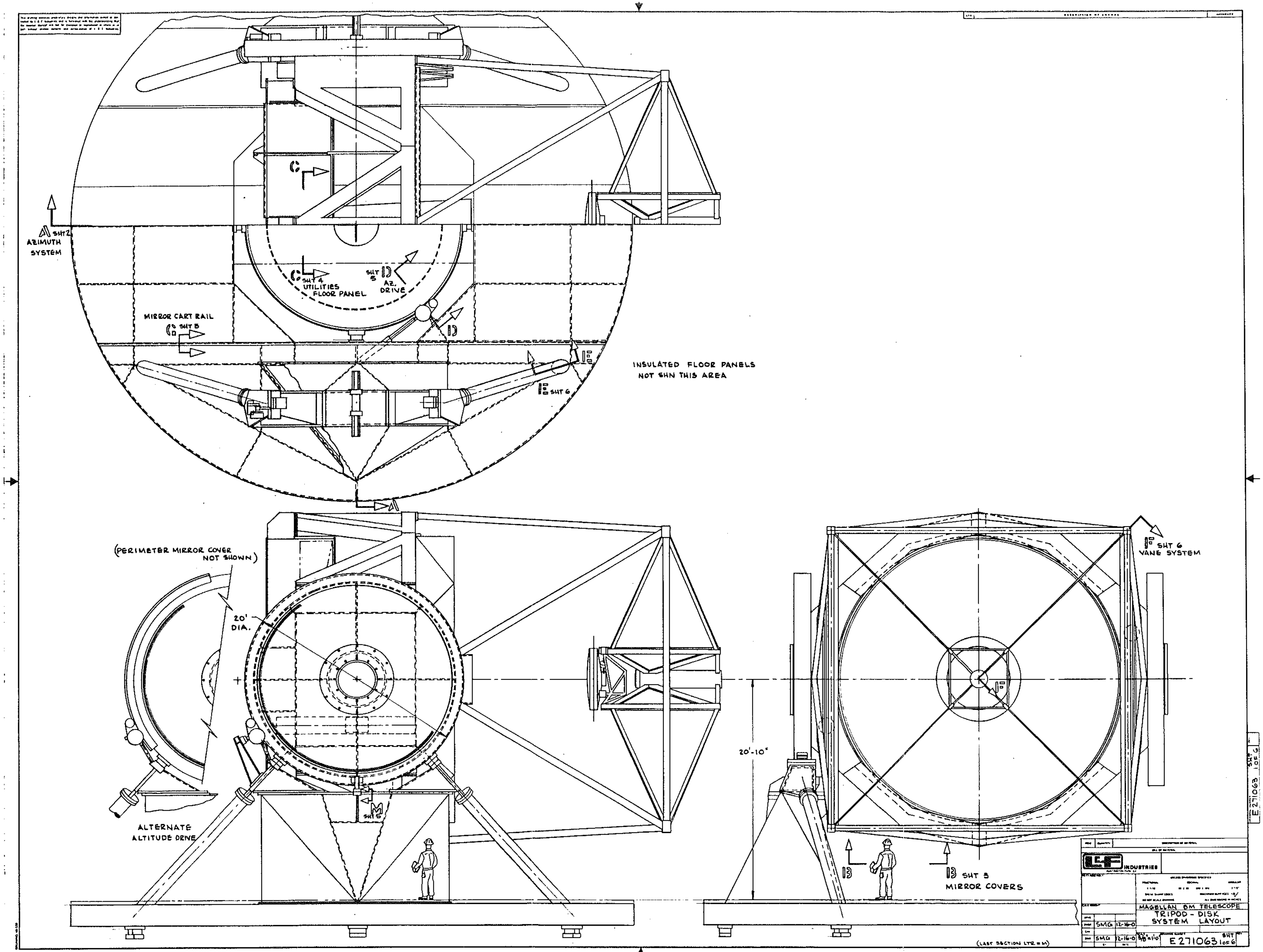
485,000 # ROT WT

	SMG	1-16-91
	SMG	1-16-91

MAGELLAN PROJECT 8M TELESCOPE
TRIPOD - DISK
RENDERING

E 271065

E 271065



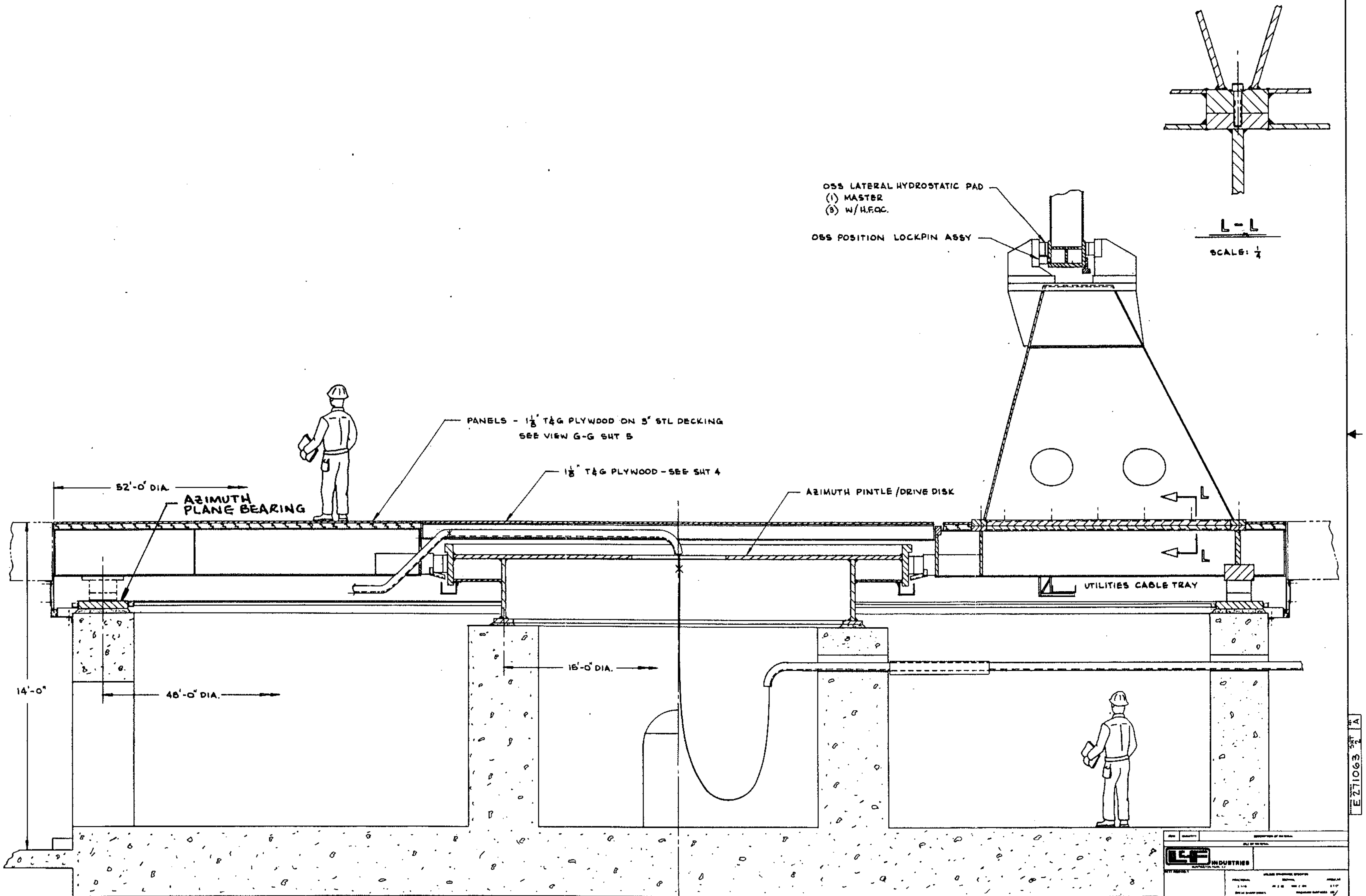
INDUSTRIES

MAGELLAN 8M TELESCOPE
TRIPOD - DISK
SYSTEM LAYOUT

SMG	12-16-0	
SMG	12-16-0	3/8"=1'-0"

E 271063 SHT 1 OF 6

A	MISC. REVISIONS, PINTLE AREA SMG 12-26-0



A - A SHT 1
SCALE: 3/4" = 1'-0"

L&F INDUSTRIES

MAGELLAN 8M TELESCOPE
TRIPOD - DISK SYSTEM LAYOUT
AZIMUTH SYSTEM

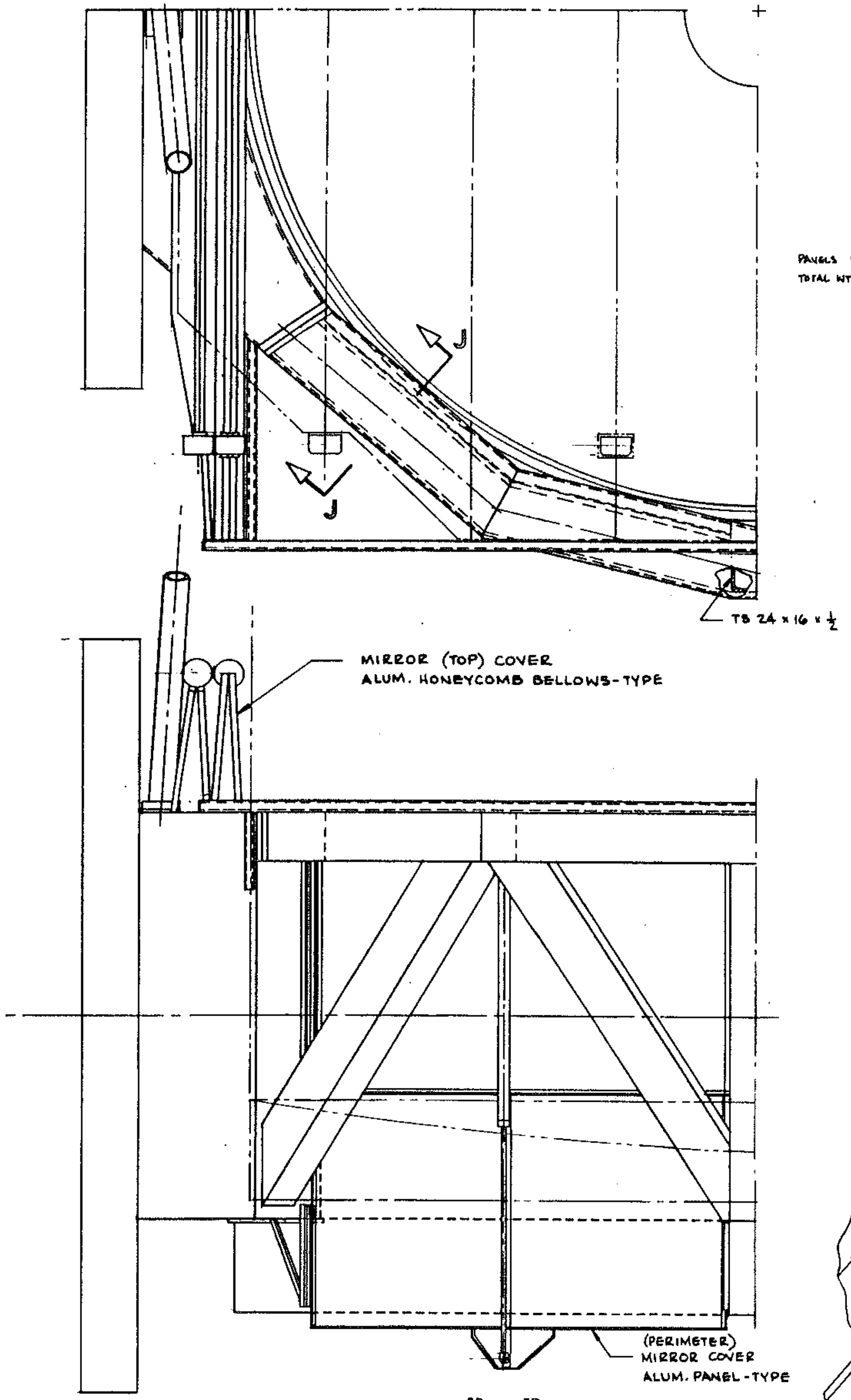
	SMG	12-15-0
	SMG	12-15-0

3/4" = 1'-0"
E271063 SHT 2 A

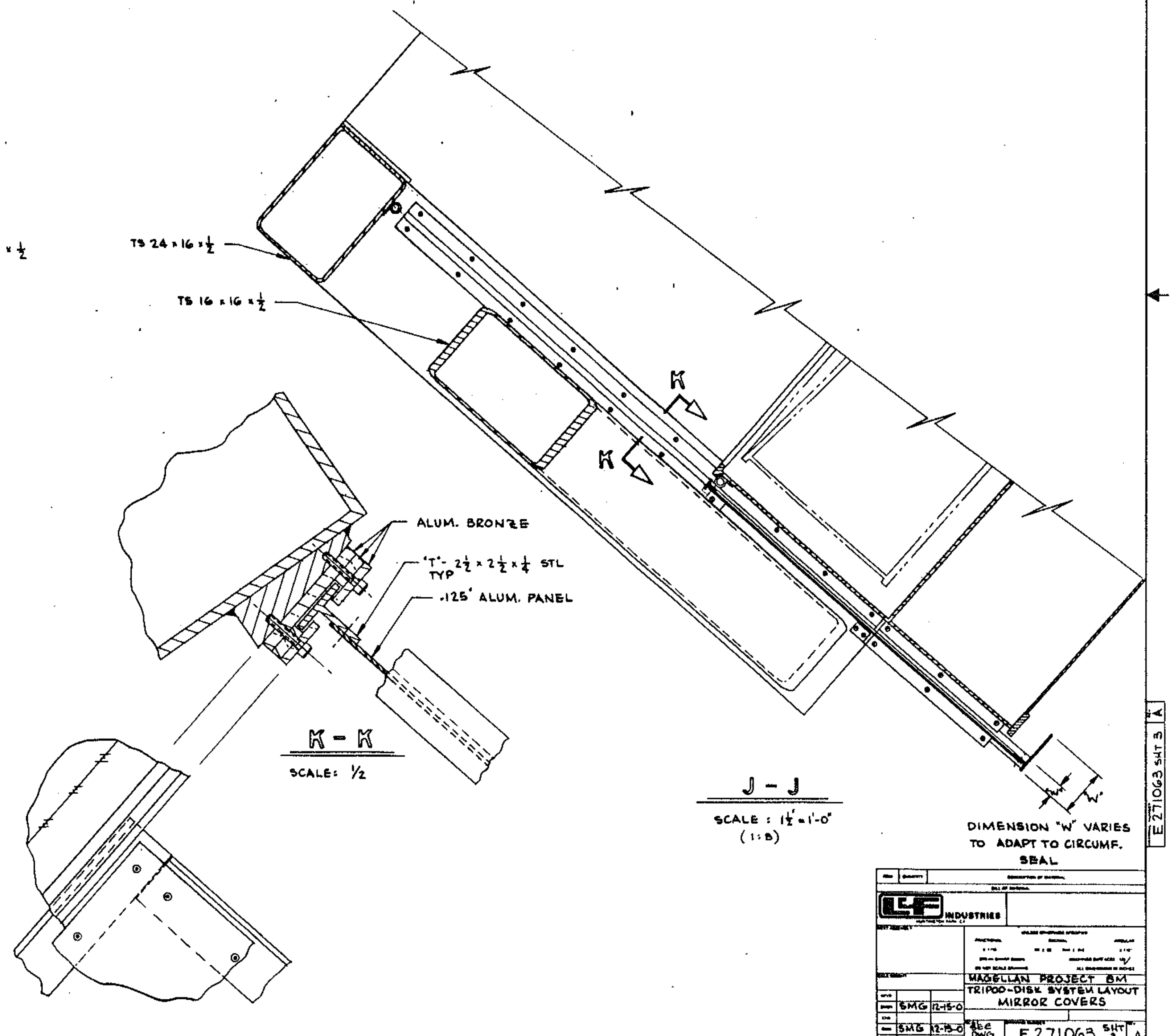
E271063 SHT 2 A

LTR	DESCRIPTION OF CHANGE	APPROVED
A	EXTENDED LEFT GUIDE, PERIMETER MIRROR CVR SMG 12-14	

PANELS 1250# (TOTAL)
TOTAL WT ≈ 2000#



B - B SHT 1
SCALE: 3/4" = 1'-0"
(1:16)



K - K
SCALE: 1/2

J - J
SCALE: 1 1/2" = 1'-0"
(1:8)

DIMENSION "W" VARIES TO ADAPT TO CIRCUMF. SEAL

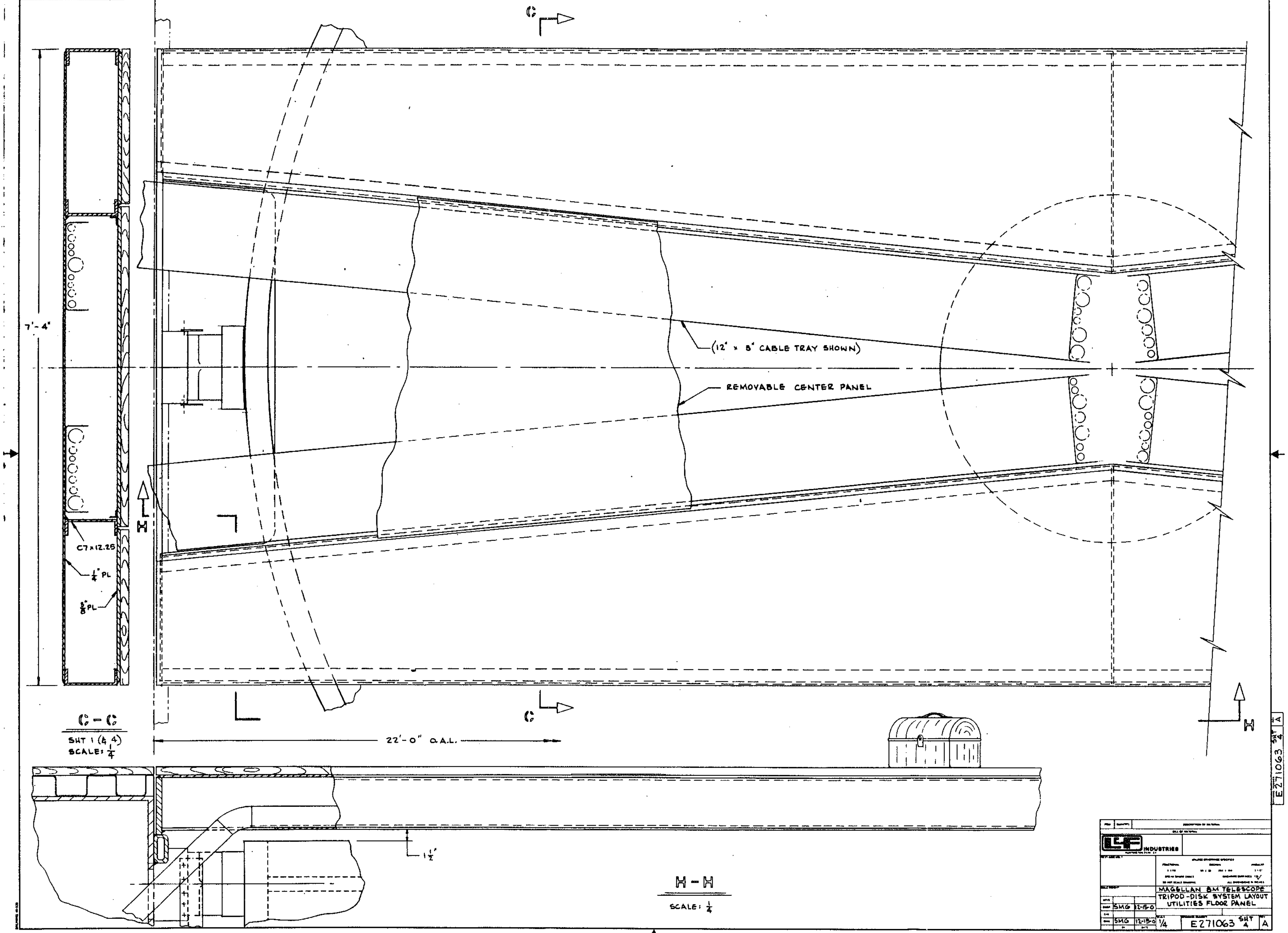
L&F INDUSTRIES

MAGELLAN PROJECT 8M
TRIPOD-DISK SYSTEM LAYOUT
MIRROR COVERS

SMG 12-15-0
SMG 12-15-0
SEE DWG
E 271063 SHT 3 A

E 271063 SHT 3 A

A	TAPERED EDGE STRUCTURE.	SMG 12-20-0



INDUSTRIES

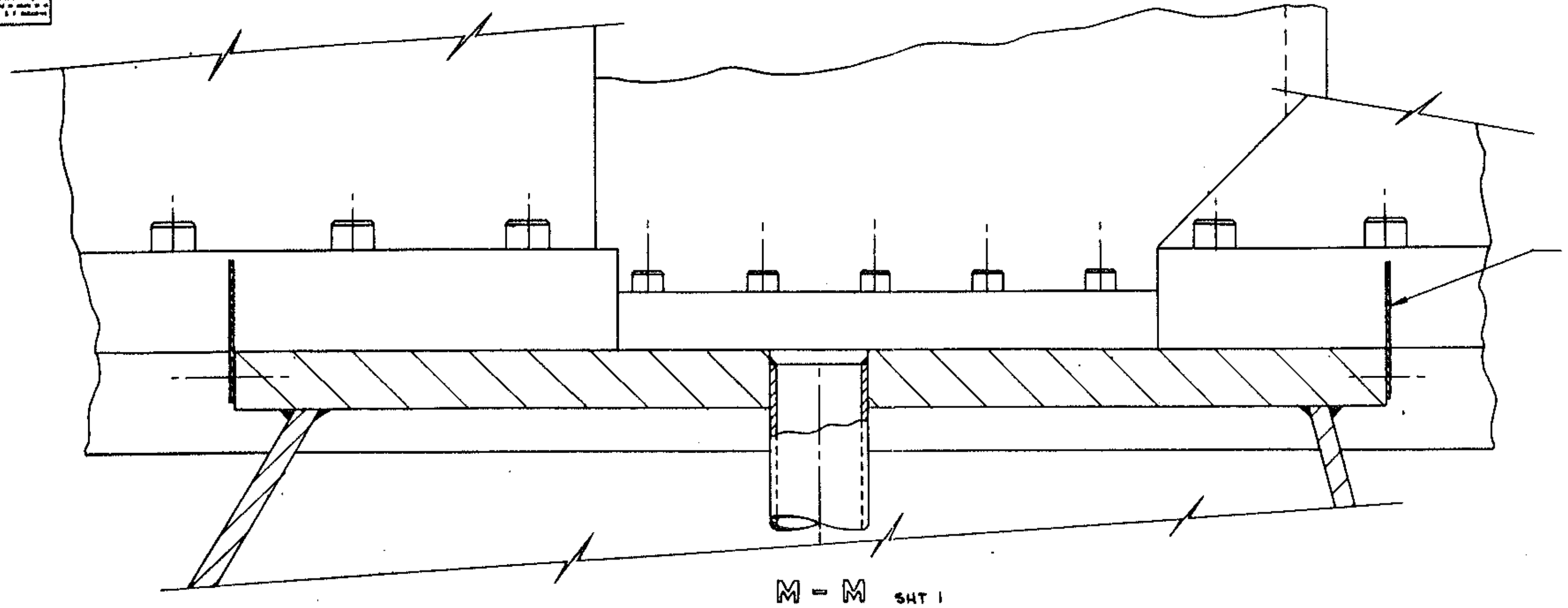
MAGELLAN 8M TELESCOPE
TRIPOD-DISK SYSTEM LAYOUT
UTILITIES FLOOR PANEL

SMG 12-15-0
SMG 12-15-0

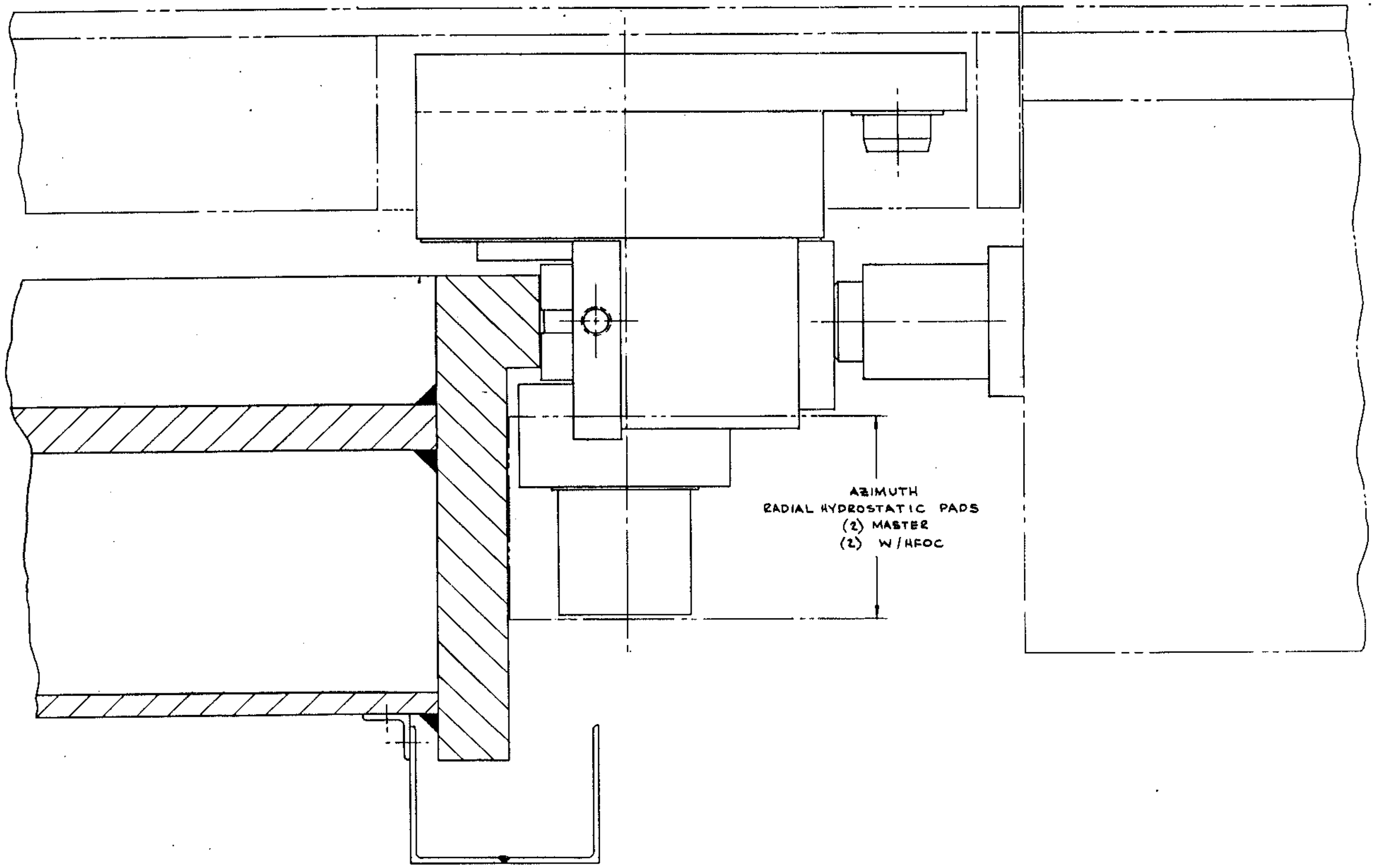
1/4 E271063 SHT 4 A

E271063 SHT 4 A

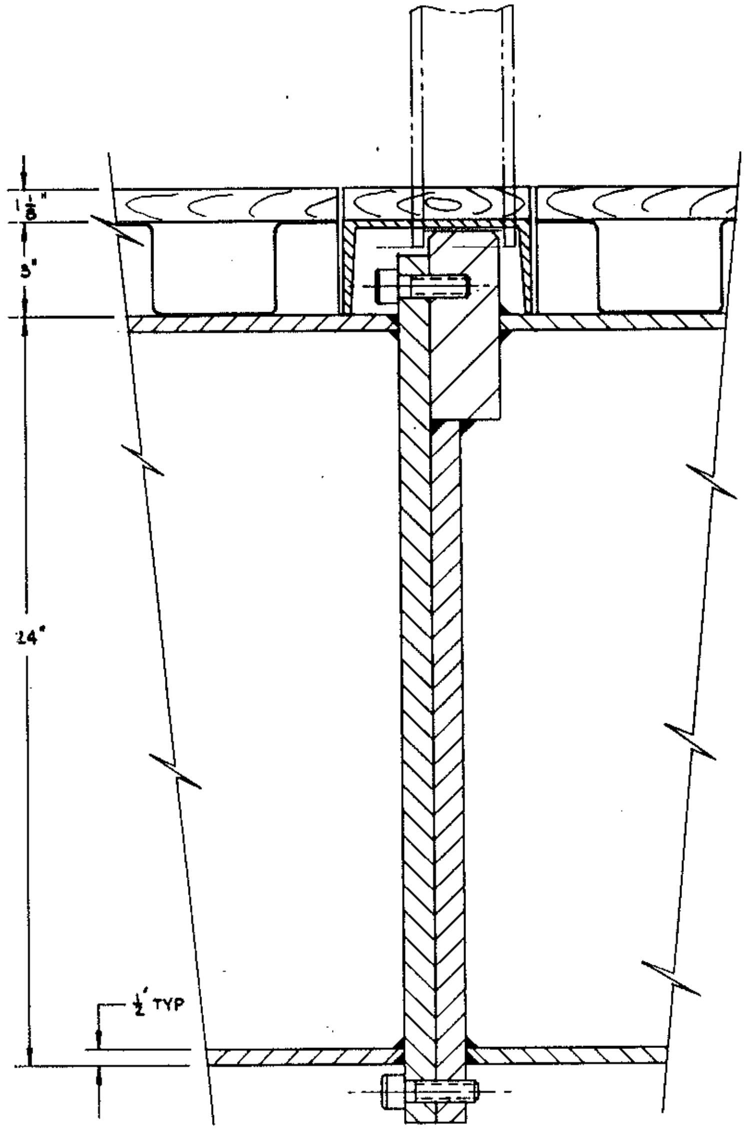
A	REVISED DRIVE	SMG 12-21-90



M – M SHT 1
SCALE: 1/2



D – D SHT 1
ROTATED 52° CCW
SCALE: 1/2



G – G SHT 1
ROTATED 90° CCW
SCALE: 1/2

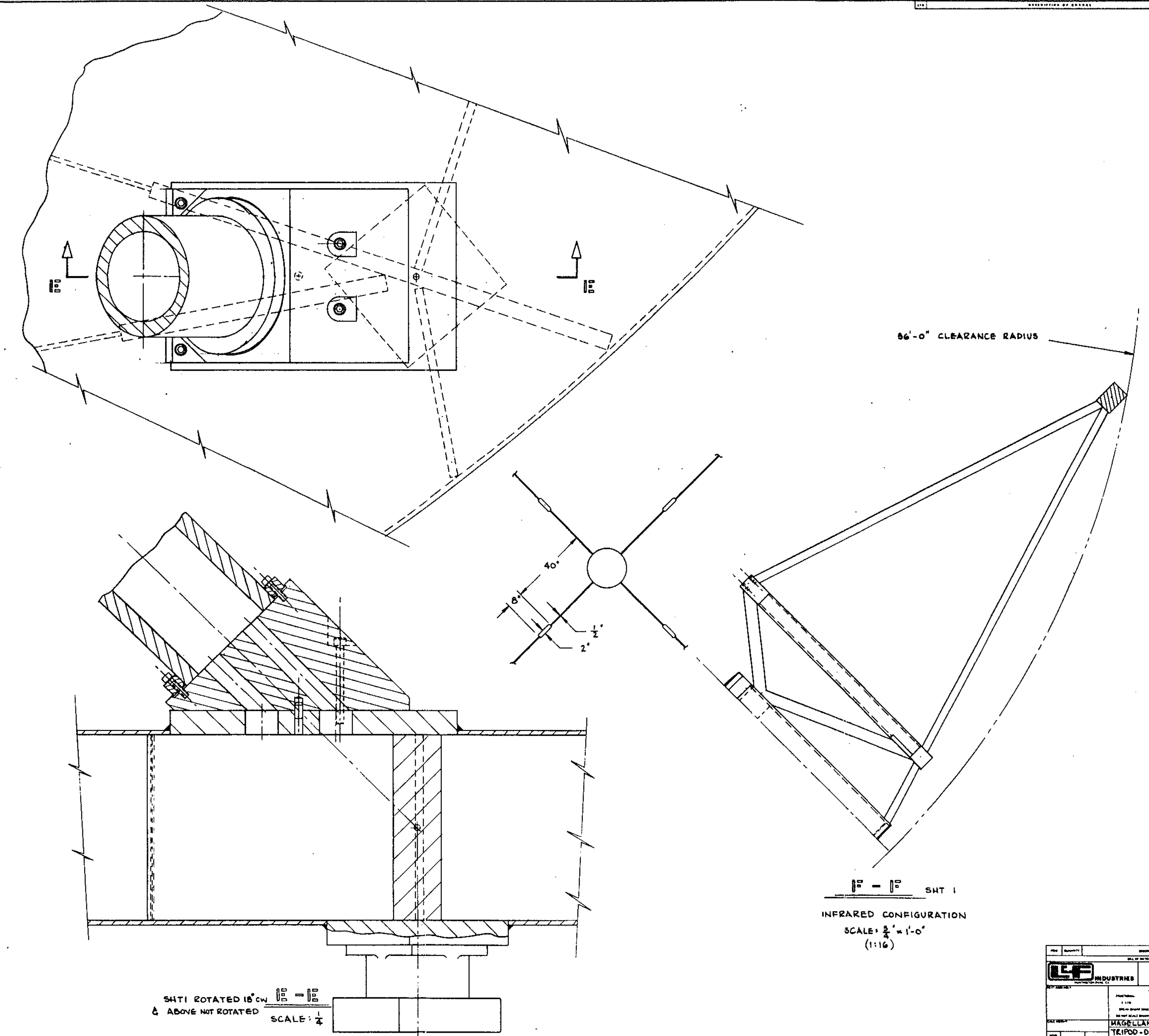
INDUSTRIES

MAGELLAN 8M TELESCOPE
TRIPOD-DISK SYSTEM LAYOUT
MISC. SECTIONS

	SMG	12-15-0
	SMG	12-15-0

1/2 E271063 SHT 5 A

E271063 SHT 5 A



F - F SHT 1

INFRARED CONFIGURATION

SCALE: 3/4" = 1'-0"
(1:16)

SHT1 ROTATED 18° CW
℄ ABOVE NOT ROTATED

E - E

SCALE: 1/4

INDUSTRIES

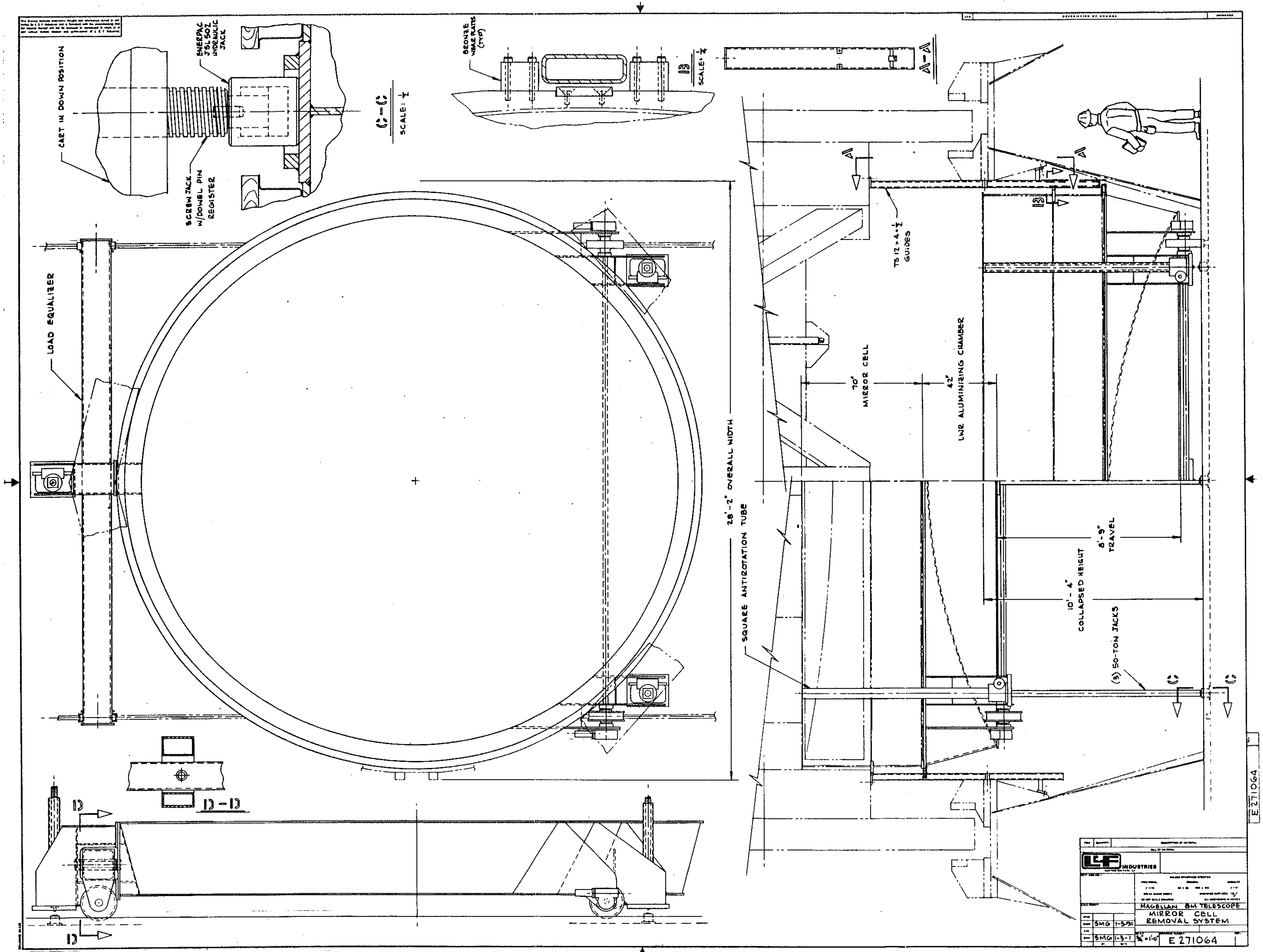
MAGELLAN 8M TELESCOPE
TRIPOD-DISK SYSTEM LAYOUT
MISC. SECTIONS

	SMG	12-17-0
	SMG	12-17-0

SEE DWG

E271063 SHT 6

E271063 SHT 6



L-F INDUSTRIES

MAGELLAN 8M TELESCOPE

MIRROR CELL REMOVAL SYSTEM

	SMG	1-3-91
	SMG	1-3-1

3/8" = 1'-0"

E 271064