Innovative Enclosure Design for the MROI Array Telescopes

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ABSTRACT

The Magdalena Ridge Interferometer (MROI) is a project which comprises an optical array of up to ten relocatable 1.4m telescopes arranged in a "Y" configuration. Each of these telescopes will be housed inside a Unit Telescope Enclosure (UTE) which can be lifted and moved onto any of 28 stations. This paper presents a general description of how the constraints imposed by the requirements for the close-pack configuration and relocatability led to the design of an innovative, compact and light-weight enclosure of small diameter and high structural strength. The unique internal lay-out gives sufficient space inside to house, not only to house the telescope mount, but also associated electronics, nasmyth table opto-mechanical equipment and beam relay system interface.

Keywords: astronomy, observatory, enclosure, interferometer

1. THE MAGDALENA RIDGE OBSERVATORY INTERFEROMETER

1.1 General Goals

Funds allocated by the United States Congress are administered by the New Mexico Institute of Mining and Technology (NMT) to build the Magdalena Ridge Observatory. The project is supervised by the Naval Research Laboratory (NRL) via the Department of the Navy and Office of Naval Research (ONR). The Observatory is sited on South Baldy, part of the Magdalena Ranger District of the Cibola National Forest in central New Mexico.

One part of the observatory is a long-baseline imaging interferometer, the Magdalena Ridge Observatory Interferometer (MROI). This comprises an array of up to 10×1.4m-diameter "unit" telescopes arranged in a "Y" configuration. Each of these utilises an elevation-over-elevation mounting, and deliver a collimated beam of starlight of diameter 95mm, which will be fed out horizontally towards a beam-combining area located near the center of the array (Figure 1 & Figure 2)

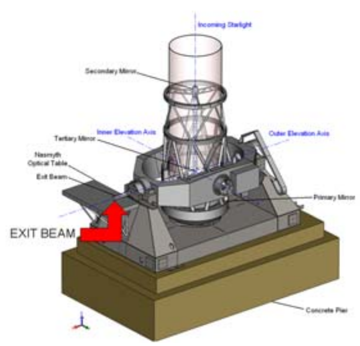

Figure 1 - The 1.4m aperture MROI elevation-over-elevation unit telescopes. (Courtesy of AMOS)

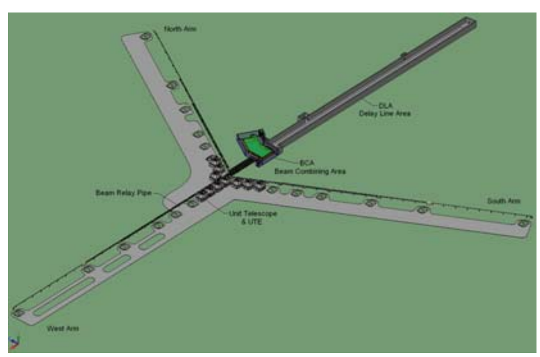

Figure 2 - Schematic plan view of the MRO Interferometer showing the general equilateral "Y" arrangement of the array arms with the proposed locations of the 28 telescope stations. The Beam Combining Facility, into which light from the individual telescopes will be directed, is the grey shaded structure running east from the vertex of the array.

Each unit telescope will be housed within an enclosure. This enclosure is capable of being relocated to any of 28 stations. These stations are fixed foundations with utility and data connections. The pattern of stations can be seen in Figure 2.

During telescope relocation, the telescope will be attached to the enclosure and be retained within it until the whole enclosure/telescope combination has been moved to a new location. This procedure is designed to protect the telescope from the environment during the relocation procedure and to avoid the delays and risk to both telescope and enclosure which could potentially result from removing the telescope from the enclosure at the beginning of the relocation and re-inserting the telescope back into to the enclosure at the end of the relocation procedure.

The enclosure, along with the housed telescope, is moved from one station to another using the relocation system.

1.2 Current Status

At the time of submitting this paper, the design of all major systems for the interferometer has been completed. Construction of the Beam Combining Facility (BCF) has been completed and this facility includes the interferometric laboratory, the delay line area, control room and administrative space. The first telescope is in its final stage of testing at AMOS in Liege, Belgium and orders have also been placed for the long lead items of the second and third telescopes. The design of the enclosure is complete (a more detailed discussion of the design is presented by other authors during this conference[1,2] and the RFQ for fabrication has been issued.

2. ENVIRONMENTAL CONDITIONS AT THE MROI SITE

The enclosures are designed to operate and survive without degradation within the environments described in this section. There are a number of different environments in which the various specifications are required to be met and these are defined as follows:

- The “Optimal Observing Environment” defines the environment in which the telescope and enclosure satisfy all performance specifications relating to the astronomical observing mode of the telescope.
- The “Reduced Performance Observing Environment” is defined as the environment in which the enclosure can be opened and closed (i.e. the transitions between the enclosure observation mode and its shut-down mode can be effected), the telescope can be operated, and the allowable mechanical, thermal and electrical stresses in all elements of the enclosure and telescope are not exceeded.
- The “Survival Environment” is the environment in which the allowable mechanical, thermal and electrical stresses in all elements of the enclosure are not exceeded, and the structural integrity of the enclosure is maintained. The enclosure will normally be put into shut-down mode before these environmental conditions are encountered.
- The “Telescope Relocation Environment” is the environment in which a telescope and enclosure can be transported from one array location to another and in which the allowable mechanical, thermal and electrical stresses in all elements of the enclosure, telescope and relocation system are not exceeded.

2.1 Optimal Observing Environment

Time of day: Sun’s upper limb below local horizon
Air temperature: -10°C to +20°C
Air temperature rate of change: -1.5°C/hr to +1.5°C/hr
Mean wind speed: 1 m/s to 10m/s
Maximum wind gust: 15 m/s
Wind gust profile: 1 m/s/s linear rise, 1m/s/s linear decay
Altitude: 3,048m to 3,231m (10,000ft to 10,600ft)
Relative humidity: 10% to 95%
Snow and ice load: < 25mm snow and < 10mm ice on enclosure.
Precipitation: None
Earthquake load: None

2.2 Reduced Performance Observing Environment

Time of day: Sun < 15 degrees above horizon
Air temperature: -25°C to +20°C
Air temperature rate of change: Unconstrained
Mean wind speed: 0 m/s to 17m/s
Maximum wind gust: 25 m/s

Gust profile: Unconstrained
Altitude: 0m to 3,231m (0ft to 10,600ft)
Relative humidity: 5% to 95%
Precipitation: None
Snow and ice load: Combined snow load and ice load < 50 kg/m2; combined snow and ice load center of Gravity < 1.5 m from center of enclosure.
Earthquake load: Maximum acceleration less than 0.2g along any axis, in the frequency range 0.5 Hz to 100Hz.

2.3 Survival Environment

Time of day: - Unconstrained
Air temperature: -30°C to +40°C
Air temperature rate of change: Unconstrained
Mean wind speed: 0m/s to 35m/s
Maximum wind gust: 55 m/s
Gust profile: Unconstrained
Altitude: 0m to 3,231m (0ft to 10,600ft)
Relative humidity: 0% to 100%
Precipitation: <120mm/hr rain (peak rate).
Hailstones up to 3cm diameter: Minor cosmetic damage to enclosure allowed.
Hailstones up to 6cm diameter: Functional and major cosmetic damage to enclosure allowed, telescope and Optics protected.
Snow and ice load: Combined snow load and ice load < 200 kg/m2
Earthquake load: Maximum acceleration less than 0.3g along any axis, in the frequency range 0.5 Hz to 100Hz.

2.4 Telescope Relocation Environment

Time of day: - Sun > 5 degrees above horizon
Air temperature: -5°C to +25°C
Air temperature rate of change: Unconstrained
Mean wind speed: 0 m/s to 10m/s
Maximum wind gust: 10 m/s
Wind gust profile: Unconstrained
Altitude: 0m to 3,231m (0ft to 10,600ft)
Relative humidity: 10% to 100%
Precipitation: < 2mm/hr
Enclosure snow and ice load: Combined snow load and ice load < 50 kg/m2; Combined snow and ice load center of gravity <1.5m from center of enclosure.
Earthquake load: Maximum acceleration less than 0.2g along any axis, in the frequency range 0.5 Hz to 100Hz.

3. TECHNICAL REQUIREMENTS FOR THE ENCLOSURE

The following sections highlight key technical requriements for the enclosure and are excerpted from Technical Requirements: Unit Telescope Enclosures and Relocation System for the MRO Interfeorometer[3]:

3.1 Operational Modes

The telescope enclosure must be designed to accommodate three modes of operation. These are:

- Observation Mode: relevant when the telescope is being operated for science and any other on-sky observations.
- Shut-down Mode: relevant when the telescope is parked and being sheltered from the environment.
- Relocation Mode: relevant when the enclosure is being used to transport the telescope from one telescope foundation pad to another.

The requirements on the enclosures that are specific to these different operating modes (and not more general requirements) are as follows:

- In the Observation Mode the enclosure shall allow the telescope to operate under the Optimal Observing Environment and Reduced Performance Observing Environment. In the Shut-down Mode the enclosure shall protect the telescope and its associated instruments under the Survival Environment.
- In the Relocation Mode the enclosure shall allow an enclosure and its associated unit telescope to be transported together (with the telescope remaining within the enclosure) between locations within the MROI array. In this case the enclosure will act as the mechanical interface between the telescope and a relocation system. Relocation will only occur under the conditions associated with the Telescope Relocation Environment.

3.2 Astronomical Observation Specifications

The enclosures shall be designed so as not to obscure the telescope beam in any portion of the telescope Operational Field of Regard. The Operational Field of Regard is such that all astronomical objects which meet *both* of the following criteria can be accessed:

1. They are above 30 degrees in elevation.
2. They can be accessed with an inner axis rotation angle between +40º and −50º (West & East respectively

In the close-packed array configuration (see configurations in section 4.1 below), an enclosure shall not obscure the operational field of regard of any nearby telescope.

Any enclosure movement necessary to meet the above requirement shall support the slew rate specifications of the telescope. The slew rate is 10 degrees within 20 seconds, and anywhere within the operational field of regard within 120 seconds. These times are the elapsed interval between the receipt of the slew command by the rotation motor controller and the time at which the enclosure has reached a complete stop at the end of the slew.

Any interior surface that can directly radiate out of the enclosure to the night-time sky and any part of the exterior surface of the enclosure which could be within 1 meter of the optical beam during telescope operation shall be covered with reflective Mylar film or similar low-emissivity material.

While in Observation Mode the enclosure shall be designed to not transmit vibrations into the telescope by observing the following procedures:

- The enclosure structure shall be designed to avoid bridging the vibration isolation gap between the enclosure foundations and the telescope foundations specified in section 3.3.
- All mechanisms that move when observing a target shall be mounted on suitable vibration isolators.
- When in Observation Mode, the enclosure shall have no loose or flexible components free to vibrate in the wind.
- When observing a target for a duration of 10 minutes or less, the dome shall remain in a fixed position during the observation of that target.

The enclosure walls shall be designed to shield the telescope from the wind by meeting the following criteria:

- Provide at least a 50% reduction in the wind speed to the envelope within the enclosure that is within 2.0m of grade, as compared to the external wind speed, for external wind speeds ranging from 5 m/s to 10 m/s.
- No more than 10% wind acceleration is permissible at the location of the secondary mirror, as compared to the external wind speed, for external wind speeds ranging from 5 m/s to 10 m/s.

3.3 Size and Space Specifications

The enclosure shall be sized to accommodate the unit telescope and associated hardware including Customer owned hardware. This Customer owned hardware includes optical table equipment, electronics and any equipment required for cooling/heating of the said equipment.

The enclosure shall be sized to allow for normal maintenance of the telescope and associated hardware to take place totally within the closed enclosure. It is acceptable for the performance of infrequent maintenance tasks, for example primary mirror or secondary mirror removal, to require opening of the enclosure.

The enclosures shall be sized to clear the telescope clearance envelope at all times while in observation and shutdown mode, including opening and closing of the enclosure. The full clearance envelope does not need to be maintained during relocation.

The design of the enclosure shall allow for the easy and safe removal and re-installation of all telescope mirrors (together with, as necessary, the mirror cells) in order to allow for periodic (estimated every 12 months) re-coating of the mirrors at an off-site coating facility. The responsibility for defining the mirror removal procedures rests with the Telescope Vendor.

The enclosure shall be sized to allow the operation of an array of up to 10 identical telescopes and associated enclosures in a "close-packed" configuration (see section 4.1, below**)**

3.4 Mechanical Interface-Related Specifications

The enclosures shall be designed to have separate foundations from the telescopes such that vibrations of the enclosures are not coupled to the telescope pier in a way that will impact the interferometric performance of the unit telescopes. The foundation design is outside the scope of this contract, but the Enclosure Designer will have to liaise with the A/E/C firm responsible for the foundation design to finalize the foundation specification.

The enclosure foundations will include an agreed-upon interface (plate, bolt pattern or equivalent). The foundation provided interface shall have a placement accuracy of ±12mm. All hardware that mates to the foundation interface shall be designed by the Enclosure Designer. The required placement accuracy of an enclosure will be determined by the Enclosure Designer.
The enclosures shall19 have a provision to allow the insertion of a Customer-owned 6.625" outer diameter (NPS-6) vacuum beam relay pipe, within which the horizontal exit beam from the unit telescopes will travel, through the enclosure walls at a beam height of 1.6m above grade.

The beam relay pipes will penetrate the enclosure walls in either of two positions, depending on which arm of the interferometer the enclosure is located on. Every enclosure shall be able to accommodate a beam relay pipe in either location.

The enclosures shall accommodate a pipe support, mounted to the enclosure frame, for the beam relay pipe on the western array arm.

Any gap in the enclosure left by the removal of a beam relay pipe shall be sealed against the elements and vermin.

The enclosure shall be designed to connect to a Customer provided liquid cooling loop.

3.5 Enclosure Thermal Specifications

The thermal management system of the enclosure shall be designed to attain the target air temperature for the following nights observation. The target air temperature shall be the anticipated temperature at sundown, calculated and input by the user at sunrise. For the purpose of design the following should be assumed:

- That the target air temperature will never be lower than -10°C;
- That the maximum external air temperature during the 24 hours prior to the sunset for which the target air temperature must be attained will never be more than 6°C above the target air temperature;
- That the most likely time for the maximum temperature in any given day is three hours prior to sunset;
- That it will be possible to continually operate the system used to manage the enclosure temperature at all times when observations are not being undertaken.

The design shall ensure that the difference between the target air temperature and that inside the enclosure shall be no greater than ±2°C for the three hour period prior to sunset.

The thermal management system of the enclosure shall be designed to meet the following thermal criteria 1 hour after sunset under the Optimal Observing Environment conditions:

- The temperature of any part of the enclosure within 15cm of the optical beam (in air) from the telescope shall differ in temperature from the outside air by no more than ± 2°C.
- The temperature of any exposed surface inside the enclosure shall differ in temperature from the outside air by no more than ±5°C.

It is a goal that the enclosure be vented to provide air flow within the enclosure during observation. For ambient wind speeds above 3 m/s the enclosure should provide an internal wind speed of at least 1 m/s around the majority of the telescope, especially in the region around the primary mirror.

Under the Optimal Observing Environment, all enclosure hardware shall dissipate a total of no more than 30W of power to the air within 15cm of the path traversed by a collimated beam of light passing through the clear aperture of the telescope.

Under the Optimal Observing Environment, the total heat dissipation to the air (averaged over any 5-minute period) of all enclosure equipment shall not exceed 200W.

3.5 General Functional Specifications

The enclosure shall have a door**,** or multiple doors, to allow personnel access to the telescope for normal maintenance procedures.

The personnel door shall open as to minimize the difficulty of opening and closing the door when drifting snow or ice has built up on the ground outside.

All doors shall have cipher or combination locks. The Customer shall have the ability to change the code at regular intervals. It is a goal that the doors use IEI eMerge access control keypads and locks for integration with existing facilities.
The Enclosure Designer shall provide adequate access and specify a procedure whereby the Unit telescope optical table (maximum weight 200 kg, dimensions 1.7 m × 1.1 m) can be brought into the enclosure or removed from the enclosure without removing the telescope.

The enclosures shall include personnel floors in all accessible areas.

The minimum design load rating for the floor of the enclosure shall accommodate the removal of the unit telescope optical table and other anticipated maintenance activities.

The floors around the electronics housing (if inside the enclosure) and the optics table shall be anti-static for electronics work.

The enclosure shall be sealed against infiltration of moisture, wind-driven dust, rain, snow, and vermin. Seals shall be resistant to freezing and cracking, and shall be resistant to the elevated UV radiation levels present at the MRO site.

Drip pans shall be provided to protect the telescope and associated components from any and all fluid drips and wear products related to any enclosure shutter or rotation mechanism.

3.7 Closure of Enclosure Aperture

It shall be possible to close the enclosure, switching to the ‘shutdown mode’, within 2 minutes. In the event of a power failure, it shall be possible for one person to manually close the enclosure, taking the enclosure from Observation Mode to Shut-down Mode, within 10 minutes. It is a goal to be able to perform this procedure in less than 5 minutes. Any tools required to close the enclosures manually shall be provided for each enclosure, permanently attached to or mounted near the closure mechanism.

3.8 Internal Lighting Specifications

The enclosure shall contain lights to illuminate the interior for maintenance work. Some of these lights must allow reduced output for critical optical alignment work.

It shall be possible to turn on/off the enclosure lights remotely from the Interferometer Control Area. The remote control shall be over TCP/IP.

3.9 Electronics Housings Specifications

The enclosure shall contain insulated and light-tight electronics housings within the enclosure or attached to the outside of the enclosure for electronics and equipment associated with the control of the enclosure. Additional space within these housings shall be reserved for Customer-provided and Telescope Vendor provided electronics; comprising 64U (2223 mm) of standard 19 in. (482 mm) rack space with a minimum depth of 24 in. (610 mm). 42U must be located within a single cabinet or within adjacent cabinets. If adjacent cabinets are used, one must have a minimum height of 32U.

The electronics housings shall seal the electronics from the outdoor environment including precipitation and dust while providing adequate air flow for cooling the equipment inside.

The electronics housings shall maintain an internal operating temperature between 0°C to 35°C while in operation and shut-down mode. Humidity shall be controlled to prevent condensation on any components within the housings. No active control of temperature or humidity is required during relocation.

Any cooling or heating system required for the electronics housing shall meet the heat dissipation and vibration requirements stated above in Sections 2.4 and 2.5

Adequate access & openings shall be provided to both the front and rear (relative to component fascias) of the rack for equipment maintenance.

3.10 Utility Specifications

The enclosure, and all housed equipment, shall be powered from a 208V 60A three-phase service. All housed equipment includes the unit telescope in addition to all telescope vendor supplied and customer supplied equipment within the electronics housings.

The enclosure shall provide a 208V 10A and 120V 16A service for the unit telescope.

GFCI protected 120 VAC duplex outlets shall be provided in all interior walls of the enclosure.

The enclosure shall provide routing for of all utilities including data, power, liquid cooling, etc throughout the structure.
Spare cabling space consisting of at least 6 square inches shall be provided for Customer-installed data cabling.
Spare cabling space consisting of at least 4 square inches shall be provided for Customer-installed low voltage cabling.
Spare cabling space consisting of at least 4 square inches shall be provided for Customer-installed cooling piping.
The enclosure shall provide a raceway between the electronic housings and the unit telescope mount.

3.11 Control Specifications

The enclosure shall be designed to work as a stand-alone piece of equipment for site acceptance testing. All systems shall function with manual or computer terminal input of commands by the customer through local controllers.

The environmental control system, including temperature control, humidity control and ventilation system components shall be controlled by Automated Logic Corporation (ALC) controllers using the BACnet protocol.

All control for environmental control devices shall be independent for each unit (fan coil, louver, ventilation opening, etc). Local control switches for each device shall be located conveniently within the UTE. Remote control of the devices, over TCP/IP, is required.

The shutter aperture shall be electrically powered and move in either direction between the fully-open position and the fully-closed position. Local control switches shall be located conveniently within the UTE. Remote control of the UTE shutter aperture and monitoring the UTE shutter aperture is required
.
The motor controllers for rotation control (if a rotating design is implemented) shall be integrated with the rotation encoder system. Communication protocols for the system shall be Modbus, BACnet or another protocol approved by the Customer.

The rotation system shall accept absolute position inputs, either manually or through a computer console. The precision of the rotation system may be determined by the Enclosure Designer depending on the shutter aperture size to permit observations of 10 minute duration.

TCP/IP gateways shall be provided on all systems within the enclosure to enable connectivity for remote control and monitoring of the rotation system (if implemented) as well as the shutter, HVAC system, interior lights, emergency stop and lockout status.

The TCP/IP gateways shall, as a minimum, include commands for aperture open, aperture close, rotation position, vent(s) open, vent(s) close, reporting of status and positions/settings of any enclosure hardware (e.g. interior lights, fans, cooling units, temperature sensors, etc) and error states. Depending on the dome & environmental control design, additional commands may be required.

3.12 Safety Specifications

The enclosure shall provide travel limits and interlocks to ensure fail safe operation of all aspects of the enclosure.

Any part of the enclosure prone to unpowered movement shall be equipped with a manually operated clamp capable of restraining the unpowered motion.

If operating the enclosure under power with clamp(s) applied could result in equipment damage or danger to personnel, interlocks shall be provided to prevent it. Interlocks and limits dependent on more than one subsystem, i.e. telescope and enclosure, shall be the responsibility of the first vendor in this order: Telescope, Enclosure.
The enclosures shall be equipped with a means of "Lockout/Tagout" in accordance with OSHA 29 CFR-1910.147. The "Lockout/Tagout" system shall include the unit telescope. Lockout status indication shall be available in the enclosure and at any remote operating console via TCP/IP.

The enclosure shall be equipped with an emergency stop available within the enclosure. The emergency stop status shall be available over TCP/IP. The emergency stop shall be equipped with a contact bus. This contact bus shall allow integration with the Telescope Vendor supplied e-stop and Customer supplied Array e-stop systems.

It shall be possible to open the personnel door from inside the enclosure even if locked from outside – and without tools and in the dark.

The enclosures shall be designed with appropriate lightning protection, including grounding to the strap points of the Customer supplied lightning ground system and equipment ground system at each telescope pad, to minimize the likelihood of personnel injury or equipment damage.

3.13 Maintenance

The enclosures shall be designed and built so as to survive and perform as intended for a minimum lifetime of 20 years without any major renovation.

The Enclosure Designer shall recommend maintenance personnel and skill requirements, a maintenance schedule, maintenance training, a list of critical spares, and support costs in light of this operational lifetime.

The required preventive maintenance effort per enclosure shall not exceed 80 man-hrs/year.

4. CONFIGURATIONS AND RELOCATION SYSTEM

4.1 Configurations

the MROI unit telescopes will be operated in four typical configuratios:

Configuaration A Configuration B Configuration C Configuration D

Figure 3. The four typical configurations of the MROI

4.2 Relocation

The relocation system shall relocate the enclosure with the housed unit telescope and all ancillary equipment typically located within the enclosure. The unit telescope optical table, electronics housings and other equipment will be transported within the enclosure for a typical relocation. However, all electronics systems will be powered down during the relocation procedure.

It shall be possible to transport enclosures without a telescope inside.

The relocation system shall be designed to not exceed the allowable acceleration of the unit telescope.

It is a goal that under the Telescope Relocation Environment the design of the enclosure allows the relocation of any telescope to any unoccupied telescope station without requiring the prior relocation of any other telescopes and enclosures in the array.

The relocation system shall be designed to mitigate the risk of impact or collision during relocation.

The relocation system shall fit within the graded array arms of the MROI site

The relocation system shall be designed to protect the enclosure, unit telescope and all housed equipment under the conditions of the Telescope Relocation Environment.

It is a goal that the enclosure relocation procedure take less than one hour for a crew of three or fewer. The enclosure relocation procedure is defined to start with the enclosure in its normal shut-down state on its starting foundation, and is defined to end with the enclosure in its shut-down state on the destination foundation, with any relocation restraints removed. Note that the time taken to remove and insert the vacuum beam relay pipes, to prepare the telescope for moving, and for actually moving between stations is not to be included in the enumeration of the enclosure relocation time.

5. ENCLOSURE DESIGN

The requirement for the minimum spacing of the enclosures in the close pack configuration (configuration A), which was finally set at 7800mm, dictated the horizonal shape and layout resulting in a tight fitting enclosure whith a highly constrained internal layout. The minimum space between enclosures, specifically between the arms of the shutter, is 340mm which also had an impact on the vertical shape and height of the enclosure and dome in order to prevent vignetting.

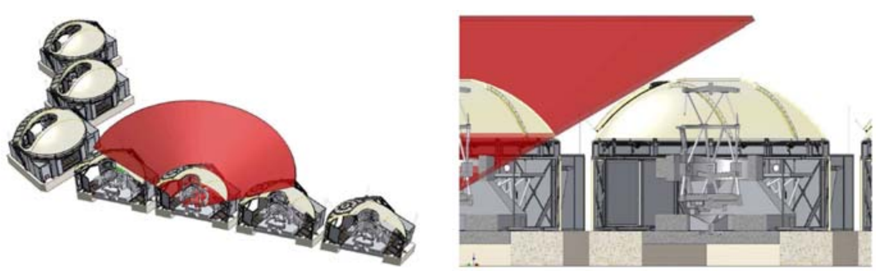

Figure 4. Light Path Boundary Cone Detail of Dome Aperture. (Courtesy of EIE).

5.1 Foundation

No bedrock has been located on Magdalena Ridge. The soil on which the MROI is constructed consistes of cobbled soil with a layer of clay. Surprisingly at such a high altitude (10,460) on a mountain ridge, there is also considerably groundwater with no clear understanding of its origin. This necessitated a long-drawn out and detailed analysis to balance cost with technical performance.

A double founddation has been designed in which the enclosure foundation "interlocks", or sits over the edges of the unit telescope mount (UTM) foundation but is separated from it by an insulating membrane to as a barrier to vibration transsission.

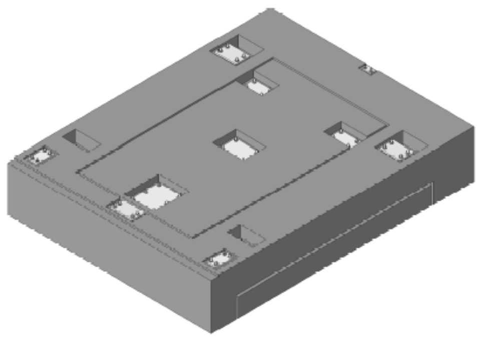

Figure 5. Station foundation showing the enclosure foundation seated over the UTM foundation but separated from each other by a vibration isolating mamembrane. (Courtesy of EIE).

The foundations will be constracuted with a number of interface plates embedded in the surface of the concrete: eclosure struture fixing plates, alignment points, grounding plate, and lifting jacks (as part of the relcation system).

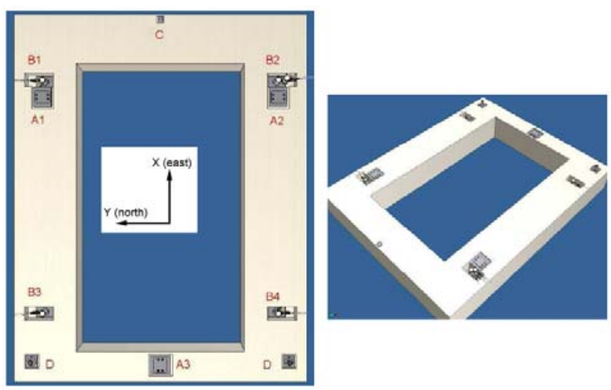

Figure 6. Enclosure foundation showing interface points: A = the fixing plates, B = relocation jacks, C = grounding plate, D = alighnment plates. (Courtesy of EIE).

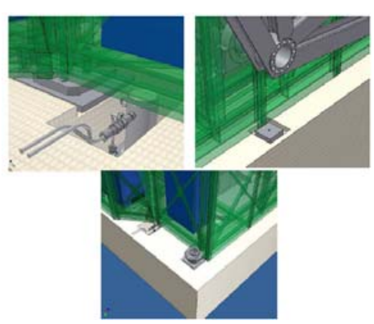

Figure 7. Close up of the interface foundation interfaces. (Courtesy of EIE).

4.2 Structure

Tthe structure consists of steel members, the design of which was largely dictated by the dictated by the environmental conditions, many of which are are listed in Section 2. above, the need to be light and rigid enough to be lifted and relocated, and to be strong enough to support the weight of the telescope mount when both are lifted during relocation. The external covering which is fixed to the steel structure is a sandwich panel.

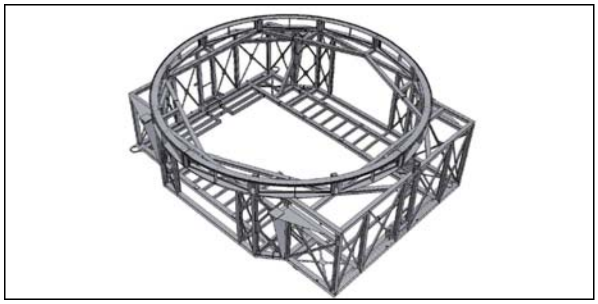

Figure 8. Isometric of the steel structural skeleton. (Courtesy of EIE).

4.3 Dome & Shutter

The design of the dome and shutter is dicussed in detail elewhere ??????? Suffice it to say here that the dome and shutter are constructed of lightweight composite material, the configuration of which was influenced by the need to prevent vignetting in the close pack configuration and.

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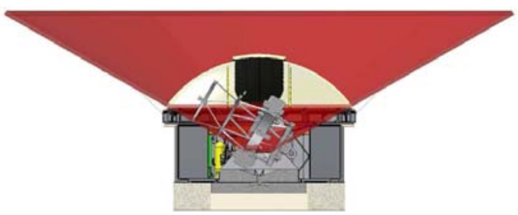

Figure 9. Light Path Boundary Cone with UTM detail at altitude angle of 30^0 (Courtesy of EIE).

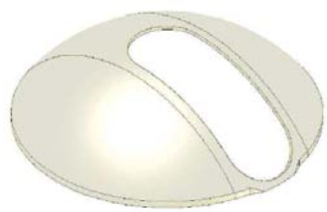

Figure 10. Isometric of the dome without the shutter. (Courtesy of EIE).

4.5 Utilites

Utilites to the enclosure, consisting of power, data, cooling fluid and compressed air (which is used to expand the inflatable seals between the dome and structure), pass through the enclosure wall at the "Interface Plate", a 725mm by 240mm installation on the face of the enclosure.

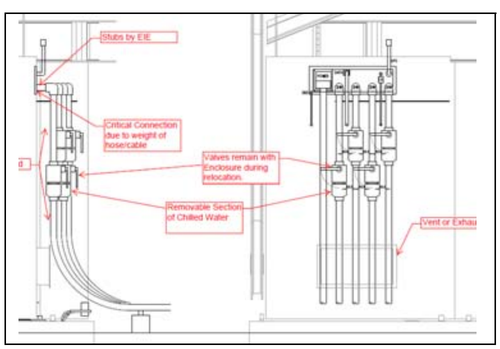

Figure 11. Detail of the Utility Interface Plate. (Courtesy of M3).

4.6 Relocation

The telescopes and enclosures can be relocated onto any one of the 28 station foundations in the array. In simple terms, the sequence for lifting the combination enclsure and telescope consists of jacking up the eclosure to mate with the telescope mount and then lifting both and transporting them by means of a modified reachstacker. When the enclosure/telescope combination is lowered onto a new station, the enclosure can be decoupled from the telescope mount by lowering the jacks under the enclosure.

Figure 12. Cartoon of the reachstacker trasnporting the enclosure with telescope inside. (Courtesy of EIE).

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