Requirements for the Unit Telescope Enclosures for the MRO Interferometer

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Revisions

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0.2	2006/09/08	JRR	2.5.1
0.3	2006/09/16	JRR	Reorganized section 2, etc.
0.4	2007/06/19	RJS et al.	Document Re-write based on INT-404-0004-Enclosure-Requirements-Summary.xls
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1.1	2007/07/23	CAH et al.	Included JR suggestions.
1.2	2007/07/27	RJS et al.	Minor revisions to cover & TBD notes. Removed AMOS provided images.
1.3	2007/08/02	RJS et al.	Incorporated IDT Review requests.

Table of Contents

Revisions 2
Table of Contents 3
1. Introduction 4
1.1. Background 4
1.2. Scope of Supply 5
1.3. Format & Structure of This Document 6
2. Related Documents 6
3. Enclosure Specification 7
3.1. Operational Modes 7
3.2. Astronomical specifications 8
3.3. Size and space specifications 9
3.4. Mechanical interface-related specifications 10
3.5. Enclosure thermal specifications 11
3.6. General functional specifications 12
3.7. Closure of enclosure aperture 13
3.8. Internal lighting specifications 14
3.9. Electronics housing specifications 15
3.10. Other equipment housing specifications 16
3.11. Utility specifications 17
3.12. Software/control specifications 18
3.13. Enclosure mobility specifications 19
3.14. Safety specifications 20
3.15. Maintenance 21
3.16. Code Compliance 22
4. Summary of interface documents 23
5. Acceptance Testing 24
Appendix A- Environmental Conditions at the MROI site 28
Appendix B – Close-packed Array Configuration 30
Appendix C – Proposed Documentation Requirements 31

1. Introduction

1.1. Background

Funds administered through the Office of Naval Research (ONR) have been awarded to the New Mexico Institute of Mining and Technology (NMT) to build the Magdalena Ridge Observatory. The observatory will be sited on South Baldy, part of the Magdalena Ranger District of the Cibola National Forest in central New Mexico. Further information about the observatory can be found on the web at http://www.mro.nmt.edu/.

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

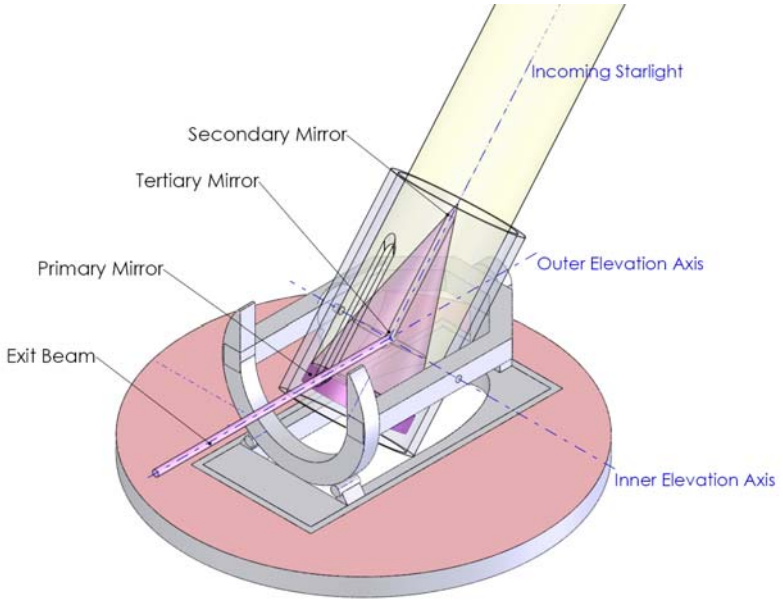

Figure 1 - Schematic cartoon of one of the 1.4m aperture MROI elevation-over-elevation unit telescopes. The detail of the mechanical arrangement is not meant to be representative of the detailed telescope design.

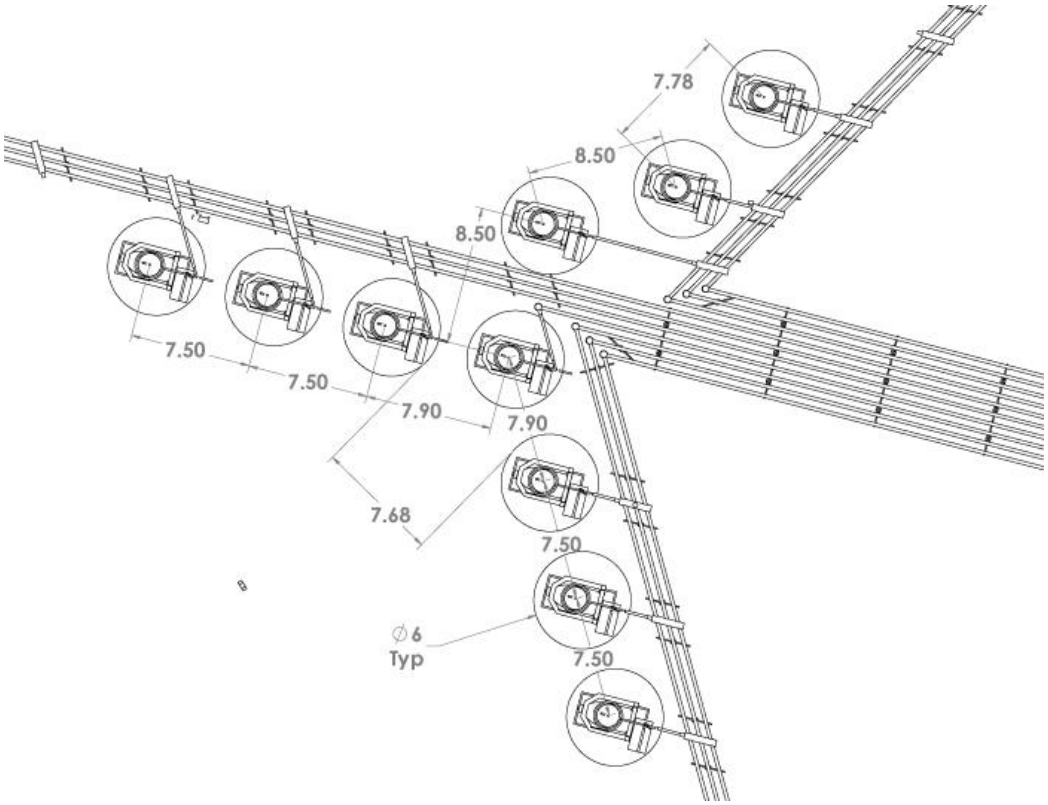

Figure 2 - Plan view of the central part of the MROI array stations and infrastructure. North is to the top and East to the right. Note how the light beams from the telescopes exit the telescope enclosure walls (denoted by the circles surrounding each telescope) in two different directions depending on which arm of the array they are located on: telescopes on the Western arm have beams that exit towards the North, while telescopes on the Northern and Southern arms have beams that exit towards the East

Each unit telescope will be housed within an enclosure. This enclosure shall be capable or being relocated to any of 28 stations. These stations are fixed foundations with utility and data connections as described in Section 3. The pattern of the stations can be seen in Figure 2 & Appendix B. 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.

1.2. Scope of Supply

The scope of this effort consists of the design, fabrication, testing, delivery, installation oversight, and documentation of enclosures for the first three (3) MROI unit telescopes. The telescopes, optics, transporter, and foundations will be delivered under separate contracts.

Vendors are encouraged to recommend minor changes in the specification that would result in significant cost savings. In doing so, vendors should specify the exact change and cost savings as an option.

The interfaces between the Enclosures and the following subsystems are expected to be managed by the preparation of a set of Interface Control Documents (ICDs) that are summarised in Section 4 of the document. These should cover, as a minimum, interfaces between the enclosures and (i) the telescopes, (ii) the enclosure foundations, (iii) the Unit

Telescope Control System, (iv) the Customer-provided utilities, and (v) the telescope-enclosure relocation system.

Issues arising in the course of construction that are not covered in the ICDs will be settled in conference between Customer and concerned Vendors.

1.3. Format & Structure of This Document

The superscripts in the preceding section and the following section refer to the acceptance testing plan described in Section 5.

Section 2 lists all related documents that shall be considered in the unit telescope enclosure design.

Section 3 lists the performance specifications for the unit telescope enclosures as well as the operations mode for the enclosure/telescope.

Section 4 lists the expected interface control documents related to the enclosure, for reference.

Section 5 defines the process by which acceptance testing of the enclosures is to be performed.

Appendices A & B include environmental data and information on the array design applicable to the relocation and observation modes for the enclosure.

Appendix C describes the documentation requirements for the Enclosure Vendor to be included in any design or procurement contract.

2. Related Documents

The following documents are hereby incorporated by reference:

- The MROI Unit Telescope RFP/Contract (XXXX-XXXX-XXXX, version X.X)
- The MROI Unit Telescope Requirements (XXXX-XXXX-XXXX, version X.X)
- The Interface Control Documents referred to in Section 1.2 and Section 4:
    - The Telescope/Enclosure ICD
    - The Enclosure/Foundation ICD
    - The Enclosure/ICS ICD
    - The Enclosure/Utility System ICD
    - The Relocation ICD
    - The Enclosure/Beam Relay Pipes ICD

3. Enclosure Specification

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[1] allow the telescope to operate under the Optimal Observing Environment and Reduced Performance Observing Environment specified in Appendix A.

In the **Shut-down Mode** the enclosure shall[2] protect the telescope and its associated instruments under the Survival Environment specified in Appendix A.

In the **Relocation Mode** the enclosure shall[3] 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 an external relocation system (transporter) acting as the mechanical support for the telescope during its relocation. Relocation will only occur under the conditions associated with the Telescope Relocation Environment specified in Appendix A.

3.2. Astronomical specifications

The enclosures shall[4]be designed so as not to obscure the telescope beam in any portion of the telescope **Operational Field of Regard.** This roughly corresponds to elevation angles of between 30° and 90°, but the reader should consult the MROI Unit telescope Requirements document for a precise definition. The approximate dimensions of the conceptually designed unit telescope are available upon request.

In the close-packed array configuration (see Appendix B), an enclosure shall[5] **not obscure** the operational field of regard (as specified in the Telescope/Enclosure ICD) of any nearby telescope.

Any enclosure movement necessary to meet the above requirement shall[6] support the **slew rate specifications** given in the Telescope/Enclosure ICD.

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[7] be covered with reflective Mylar film or similar **low-emissivity** material.

While in Observation Mode the enclosure shall[8] not **transmit vibrations into the telescope** by observing the following procedures:

- The enclosure foundation shall be isolated from the telescope foundation by not less than 1 inch of vibration damping expansion material or an equivalent air gap.
- All mechanisms that move during Observation Mode 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, the dome shall remain in a fixed position.

Designs that do not require moving the enclosure opening during observations are preferred over those that do.

TBD: The enclosure walls shall[9] be designed to provide at least a **50% reduction in the wind velocity** at the location of the primary mirror cell as compared to the external wind velocity under the Optimal Observing Environment conditions specified in Appendix A.

3.3. Size and space specifications

The enclosure shall[10] **be sized to accommodate the unit telescope and associated hardware** including Customer owned hardware. This Customer owned hardware includes the optical table, optical table equipment, electronics racks and any equipment required for cooling/heating of the said equipment.

The enclosure shall[11] **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[12] **be sized to clear the telescope clearance envelope** (as stated in the Telescope/Enclosure ICD) at all times, including opening and closing of the enclosure and during relocation.

The Telescope/Enclosure ICD shall[13] also address the **assembly, placement and removal of a Unit Telescope from an enclosure**. The enclosure vendor shall liaise with the Telescope Vendor to address this issue.

The design of the enclosure shall[14] **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 Optics vendor.

TBD: Should mirror removal require the attachment of lifting fixtures to the enclosure structure, the Optics Vendor will be charged with specifying these attachment points and their loading. The enclosures shall[15] be **designed to meet these mirror removal interface requirements**.

The enclosure shall[16] **be sized to allow the operation of an array of up to 10 identical telescopes and associated enclosures in a "close-packed" configuration** as shown in Appendix B.

Mechanical interface-related specifications

Interfaces with the Customer-supplied power, IT and lightning systems are covered separately in Sections 3.11, 3.12, and 3.14 of this document respectively.

The enclosures shall[17] 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.

Any part of the **enclosure foundations** which are more than 0.5 meter above the average grade level or require positioning to an accuracy of better than ±12mm shall[18] be supplied and installed by the Enclosure Vendor.

Within TBD months of award, the Vendor shall[19] complete the **Enclosure/Foundation ICD**, including anchor locations and maximum static and dynamic loads and locations of any embedded conduits. The Customer will use this information to design enclosure foundations for each of the 28 stations. The Vendor will review and approve the foundation designs prior to installation.

The enclosures shall[20] have a provision to allow the insertion of a Customer-owned 6-inch (or 8 inch) diameter 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.

As shown in Figure 2, 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[21] be able to **accommodate a beam relay pipe** in either location.

Any **gap in the enclosure left by the removal of a beam relay pipe** shall[22] be sealed against the elements and vermin as described in section 3.6 (General functional specifications).

The enclosure shall[23] be designed to **connect to any Customer provided liquid cooling loop**, or other cooling system, should this be provided and be required. The MRO is currently investigating installing an underground chilled (~5°C) water delivery system to supply each enclosure location.

3.4. Enclosure thermal specifications

The **thermal management system of the enclosure** shall[24] be designed to maintain the difference between the external air temperature and that inside the enclosure to be no greater than TBD ±5°C for the three hour period prior to sunset, while shielding the enclosure contents from direct sunlight.

The **thermal management system of the enclosure** shall[25] be designed to meet the following thermal criteria 1 hour after sunset under the Optimal Observing Environment conditions specified in Appendix A:

- The temperature of **any part of the enclosure within 15cm of the optical beam** 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.

Solutions that invoke thermal insulation of the enclosure walls, active day-time refrigeration, and the provision of user-operable louvers and fans may all be considered.

Under the Optimal Observing Environment specified in Appendix A, the enclosure shall[26] be vented such that the **ambient wind speed is reduced** by no more than 2/3 around the telescope. Measurements shall be made with no telescope within the enclosure.

Under the Optimal Observing Environment specified in Appendix A, all Enclosure Vendor-supplied hardware shall[27] **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 specified in Appendix A, the **total heat dissipation** (averaged over any 5-minute period) of all Enclosure Vendor-supplied equipment to the air within 3m radius of the telescope shall[28] not exceed 200W.

The design of the enclosure shall[29] **allow for the installation, at a later date, of a closed-cycle refrigeration unit** (with external vent) to assist in daytime cooling of the air inside the enclosure.

The design of the environmental control system shall[30] allow for associated **sensors to be integrated into the UTCS**.

General functional specifications

The enclosure shall[31] have a **door** to allow personnel access to the telescope for normal maintenance procedures.

The personnel door shall[32] 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[33] have **cipher locks**. The Customer shall have the ability to change the code at regular intervals.

The Enclosure Vendor shall[34] provide **adequate access and specify a procedure** whereby the Unit telescope optical table (maximum weight 200 kg, maximum dimensions 1.7 m × 1.1 m × 0.5 m) can be brought into the enclosure or removed from the enclosure without removing the telescope.

The enclosures shall[35] include **personnel floors** in all accessible areas.

The minimum **design load rating for the floor** of the enclosure shall[36] be 300 kg/m^2 for the average floor loading and 275kg over 100mm square for point loading.

The floors around the electronics housing (if inside the enclosure) and the optics table shall[37] be **anti-static** for electronics work.

The enclosure shall[38] be **sealed against infiltration** of moisture, wind-driven dust, rain, snow, and vermin.

Seals shall[39] **be resistant** to freezing and cracking, and shall be resistant to the elevated UV radiation levels present at the MRO site.

Drip pans shall[40] be provided to **protect the telescope and associated components** from any and all fluid drips and wear products related to any enclosure shutter mechanism.

3.5. Closure of enclosure aperture

It shall[41] be possible to **close the enclosure**, entering the ‘shutdown mode’, within 2 minutes by remote control.

In the event of a power failure, it shall[42] be possible to **manually close the enclosure**, taking the enclosure from Observation Mode to Shut-down Mode, within 10 minutes.

Any **tools required to close the enclosures** manually shall[43] be provided for each enclosure, permanently attached to or mounted near the closure mechanism.

3.6. Internal lighting specifications

The enclosure shall[44] **contain lights to illuminate the interior for maintenance work**. Some of these lights must allow reduced output for critical optical alignment work.

It shall[45] be possible to **turn off the enclosure lights** remotely from the Interferometer Control Area, via the Unit Telescope Control System and Enclosure Control System.

3.7. Electronics housing specifications

The Enclosure Vendor shall[46] provide an **insulated and light-tight electronics housing** within the telescope enclosure or attached to the outside of the telescope enclosure for Vendor supplied electronics and control equipment associated with control of the enclosure.

Additional space within this housing shall[47] be reserved for Customer-provided and Telescope Vendor provided electronics; comprising 60 in. height, or 1 × 36 in. height and 1 × 24 in. height, of standard 19-in. rack space with a minimum depth of 24 in.

The electronics housing shall[48] **seal the electronics** from the outdoor environment including precipitation and dust while providing adequate air flow for cooling the equipment inside.

The electronics housing shall[49] **maintain an internal operating temperature** of between 0°C to 40°C at all times, and without inducing condensation on any components within, except during relocation.

Any **cooling or heating system** required for the electronics housing shall[50] meet the heat dissipation and vibration requirements from Sections 3.2 and 3.5.

Adequate **access & openings** shall[51] be provided to both the front and rear (relative to component fascias) of the rack for equipment maintenance.

3.8. Other equipment housing specifications

The enclosures shall[52] be designed to accommodate a **liquid cooling system** to cool the Customer-owned electron-multiplying CCD camera (e.g. Andor iXon^{EM}+, Princeton Instruments PhotonMax) used for fast guiding and located on the Nasmyth optical table. The electron multiplying CCD camera will dissipate less than 25W of power to the liquid cooling system. If a Customer-provided chilled liquid loop is available, the cooling system may take advantage of this. If not, then a closed-cycle cooling system will be necessary.

If, in order to fulfill the above requirements, the cooling system discharges more than 50W of power to the air, then the enclosure shall[53] be designed to allow for any **resulting heat plumes** to be discharged at a distance of at least 4m from any telescope and not upwind (with respect to the prevailing wind direction at the MRO site) of any telescope within 20m of the source of the plume or to be discharged to a closed cycle 'ground source' cooling system (e.g. a chilled water loop) installed in conjunction with the enclosure foundations.

It shall[54] not be acceptable to require that parts of the enclosure designed to accommodate the CCD camera cooling system need to be **manually stowed in order to enter the enclosure shutdown mode from the observing mode**. It is acceptable to require some manual effort to enter the relocation mode from the shutdown mode, e.g. removal of any flexible air-duct hosing, but the time taken to do this will be counted as part of the total enclosure relocation time described in Section 3.13 (Enclosure mobility specifications).

3.9. Utility specifications

The enclosure shall[55] be **powered from a 480V 30A** three-phase service.

If required, the enclosure shall[56] provide a **lower voltage circuit** for the unit telescope.
[We need to check with AMOS to see if this is really needed.]

GFCI protected **120 VAC duplex outlets** shall[57] be provided in all interior walls of the enclosure.

The enclosure shall[58] 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[59] be provided for Customer-installed data cabling.

Spare cabling space consisting of at least 4 square inches shall[60] be provided for Customer-installed low voltage cabling.

Spare cabling space consisting of at least 4 square inches shall[61] be provided for Customer-installed cooling piping.

3.10. Software/control specifications

A Vendor-supplied **enclosure controller** shall[62] be provided and connect to the Customer-supplied switch.

The **connection** shall[63] be an RJ45 gigabit Ethernet port.

The enclosure shall[64] be provided with an **Enclosure Control system** (ECS) with the purpose of communicating with the Customer's Unit Telescope Control System (UTCS) through a simple and well-documented TCP/IP protocol over Ethernet from the Customer supplied switch at each telescope station.

The **ECS commands** shall[65], as a minimum, include aperture open, aperture close, vent(s) open, vent(s) close commands, 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 & ventilation design, additional commands may be required.

3.11. Enclosure mobility specifications

Under the Telescope Relocation Environment (Appendix A) the design of the enclosure shall[66] **allow the relocation** of any telescope to any unoccupied telescope station without requiring the prior relocation of any other telescopes and enclosures in the array. Should this prove infeasible or costly, the Enclosure Vendor should document this in their proposal.

The enclosure relocation procedure shall[67] 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.

It shall[68] be possible to **transport enclosures** without a telescope inside.

3.12. Safety specifications

The Vendor shall[69] 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[70] 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[71] be provided to prevent it.

Interlocks and limits dependent on more than one subsystem, i.e. telescope and enclosure, shall[72] be the responsibility of the first vendor in this order: Telescope, Enclosure, Relocation System.

The enclosures shall[73] be equipped with a means of **"Lockout/Tagout"** in accordance with OSHA 29 CFR-1910.147.

Lockout status indication shall[74] be available in the enclosure and at any remote operating console via the Enclosure Control System.

It shall[75] 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[76] 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.

The **interfaces to these grounding systems** shall[77] be defined in the Enclosure/Foundation ICD.

3.13. Maintenance

The enclosures shall[78] be designed and built so as to survive and perform as intended for a **minimum lifetime** of 20 years without any major renovation.

The Vendor shall[79] **recommend maintenance** personnel and skill requirements, a maintenance schedule, maintenance training, and support costs in light of this operational lifetime.

The **required preventive maintenance effort** per enclosure shall[80] not exceed 20 man-hrs/year

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3.14. Code Compliance

The enclosures shall[81] be designed to meet all applicable codes currently in effect for the state of New Mexico. This includes as a minimum:

- 2005 National Electrical Code, as amended by NMCID
- NFPA 1, Fire Prevention Code, 1997 Edition
- OSHA 29 CFR-1910
- New Mexico Commercial Building Code

The Vendor should note that the enclosure will not be a habitable structure – persons will only ever normally be present to service the equipment located inside it. It will thus fall under the New Mexico Commercial Building Code as limited access laboratory space and will be ADA exempt.

4. Summary of interface documents

The interfaces between the Enclosures and the following subsystems shall[82] be managed by the preparation of a set of **Interface Control Documents** (ICDs) outlined below. These should include, as a minimum, the following:

1. For the interface between Telescopes and the Enclosures: a **Telescope/Enclosure ICD** generated by the Telescope Vendor and approved by both the Customer and the Enclosure Vendor.

2. For the interface between the Enclosures and the 28 Enclosure foundations: an **Enclosure/Foundation ICD** generated by the Enclosure Vendor and approved by the Customer.

3. For the interface between the Enclosures and Customer's Unit Telescope Control System (UTCS): an **Enclosure/UTCS ICD** generated by the Enclosure Vendor and approved by the Customer.

4. For the interface between the Enclosures and Customer's utility provisions an **Enclosure/Utility ICD** generated by the Customer and approved by the Enclosure Vendor. This should include interfaces with the electrical grounding system.

5. For the interface between the Enclosures and the relocation system: an Enclosure/ **Relocation System ICD** generated by the Enclosure Vendor in conjunction with the Telescope Vendor and approved by the Customer and the Transporter Vendor.

6. For the interface between the Enclosures and the Beam Relay Pipes: an **Enclosure/Beam Relay Pipes ICD** generated by the Beam Relay Pipe vendor in conjunction with the Enclosure Vendor and approved by the Customer.

Issues arising in the course of construction that are not covered in the ICDs will be settled in conference between Customer and concerned Vendors.

5. Acceptance Testing

Detailed acceptance testing of the MROI unit telescope enclosures shall be performed in accordance with the Acceptance Test Plan developed by the Vendor at the Preliminary and Final Design Reviews and approved by the Customer. All tests and their results are required to be documented by the Vendor and delivered to the Customer. These tests are required to demonstrate that the MROI unit telescope enclosures meet the contract specifications. The Vendor is expected to have or obtain all and any special test equipment necessary to demonstrate compliance with the system requirements and interfaces.

What follows below is a reference from each requirement in this specification document. The table below will thus serve as a 'punch list' for product acceptance.

Each entry lists first the reference number, then a summary description of the requirement being referred to (the requirement in the main text is to take precedence over the summary description in all cases) and then a check or descriptive wording under the columns indicating the basic methods by which the Customer is expected to verify whether the requirement has been satisfactorily met by the Vendor.

In the column headings below **Design** refers to study of designs, proposed methods or procedures; **Analysis** refers to computational verification of results; **Inspection** refers to visual inspection of items or documents, studying of samples or test certificates; **Test** refers to measuring, activating or other actions appropriate to determine proper form, fit or function of the Vendor's solution to the given requirement.

Specification number		**Design**	**Analysis**	**Inspection**	**Test**
1	Operability in observing mode	X			
2	Operability in shut-down mode	X			
3	Operability in relocation mode	X			
4	Obscuration of field of regard				X
5	Obscuration in close packed configuration			X	
6	Slew rate specification				X
7	Low emissivity surfaces			X	
8	Vibration coupling into telescope			X	
9	Reduction in wind velocity at M1				X
10	Sizing to accommodate UT			X	
11	Sizing for maintenance			X	
12	Sizing for clearance envelope			X	
13	Sizing for UT Installation			X	

14	Sizing to allow fixtures needed for mirror removal			X	
15	Mirror removal interface			X	
16	Sizing to allow close packing			X	
17	Separate foundations to allow vibration de-coupling from UT	X			
18	Installation of foundation hardware elevated above grade			X	
19	Preparation of enclosure/foundation interface		X		
20	Provision for beam relay pipes			X	
21	Provision for 2 interfaces for beam relay pipes			X	
22	Sealing of beam relay pipe interface			X	
23	Connectivity to customer-supplied liquid cooling loop			X	
24	Thermal management of daytime internal temperature				X
25	Thermal management of post-sunset temperatures				X
26	Minimum internal airflow				X
27	Dissipation of power close to optical beam		X		
28	Dissipation of power close to enclosure		X		
29	Provision for self-contained air refrigeration unit			X	
30	Environmental Sensor Integration into UTCS			X	
31	Door provision			X	
32	Door opening under icy/snowy conditions			X	
33	Provision of cipher locks			X	
34	Access for optical table			X	
35	Provision of personnel floors			X	
36	Design load rating for floors		X		
37	Anti-static flooring requirement			X	
38	Sealing against infiltration			X	
39	Resistance of seals to ice/snow			X	
40	Provision of drip pans			X	

41	Speed requirement for remotely closing dome				X
42	Speed requirement for manually closing dome				X
43	Location of tools for manual dome closure			X	
44	Provision of internal lighting			X	
45	Provision of remote control of lighting			X	
46	Provision of electronics housing			X	
47	Space allocation for housing			X	
48	Sealing of electronics housing			X	
49	Internal temperature of electronics housing		X		
50	Specification on thermal and vibration disturbances from electronics housing			X	
51	Access to electronics housing			X	
52	Accommodation for EMCCD liquid cooling hardware			X	
53	Accommodation for venting heat from EMCCD cooling hardware			X	
54	Ability to enter shutdown mode without manual intervention to EMCCD cooling system			X	
55	Operation from 480V 30A 3-phase power source			X	
56	Provision of low voltage circuit within enclosure			X	
57	Specification and location of 120V AC outlets			X	
58	Provision of routing for utilities			X	
59	Provision of spare cabling space for data			X	
60	Provision of spare cabling space for low voltage electrical			X	
61	Provision of spare piping space for cooling			X	
62	Provision of enclosure controller			X	
63	Connection interface with Customer-supplied switch			X	
64	Provision of Enclosure Control System (“ECS” software)				X
65	Definition of minimum ECS functionality				X

66	Provision for enclosure relocation	X			
67	Time for enclosure relocation				X
68	No-telescope enclosure transportation			X	
69	Provision of travel limits and interlocks			X	
70	Mitigation of unpowered movements			X	
71	Provision of interlocks			X	
72	Responsibility for shared interlocks and limits			X	
73	Lockout/tagout procedure			X	
74	Lockout status indication			X	
75	Access to locked personnel doors			X	
76	Lightning protection			X	
77	Electrical grounding interface			X	
78	Minimum lifetime		X		
79	Recommended maintenance schedule		X		
80	Preventative maintenance needs		X		
81	Code compliance			X	
82	ICDs			X	

Appendix A- Environmental Conditions at the MROI Site

The enclosures must be 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.

Optimal Observing Environment

- Time of day: Sun's upper limb below local horizon
- Air temperature: -15°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: 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

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: 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 100 Hz.

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: 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: Magnitude 5.5 on the Richter scale.

Telescope Relocation Environment

- Time of day: - Sun > 5 degrees above horizon
- Air temperature: -10°C to +25°C
- Air temperature rate of change: Unconstrained
- Mean wind speed: 0 m/s to 10m/s
- Maximum wind gust: 25 m/s
- Wind gust profile: Unconstrained
- Altitude: 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: Magnitude 3.5 on the Richter scale.

Appendix B – Close-packed Array Configuration

The figure below shows the desired spacing of MROI unit telescopes in their close-packed configuration. The center-to-center spacings of the pivot points of the unit telescopes are given in metres: the Unit Telescope vendor has been charged with designing a telescope that will meet this packing arrangement.

Note how the light beams from the telescopes exit the telescope enclosure walls (denoted by the circles surrounding each telescope) in two different directions depending on which arm of the array they are located on: telescopes on the Western arm (right of figure) have beams that exit towards the North (upwards in figure), while telescopes on the Northern and Southern arms have beams that exit towards the East (towards the right in figure).

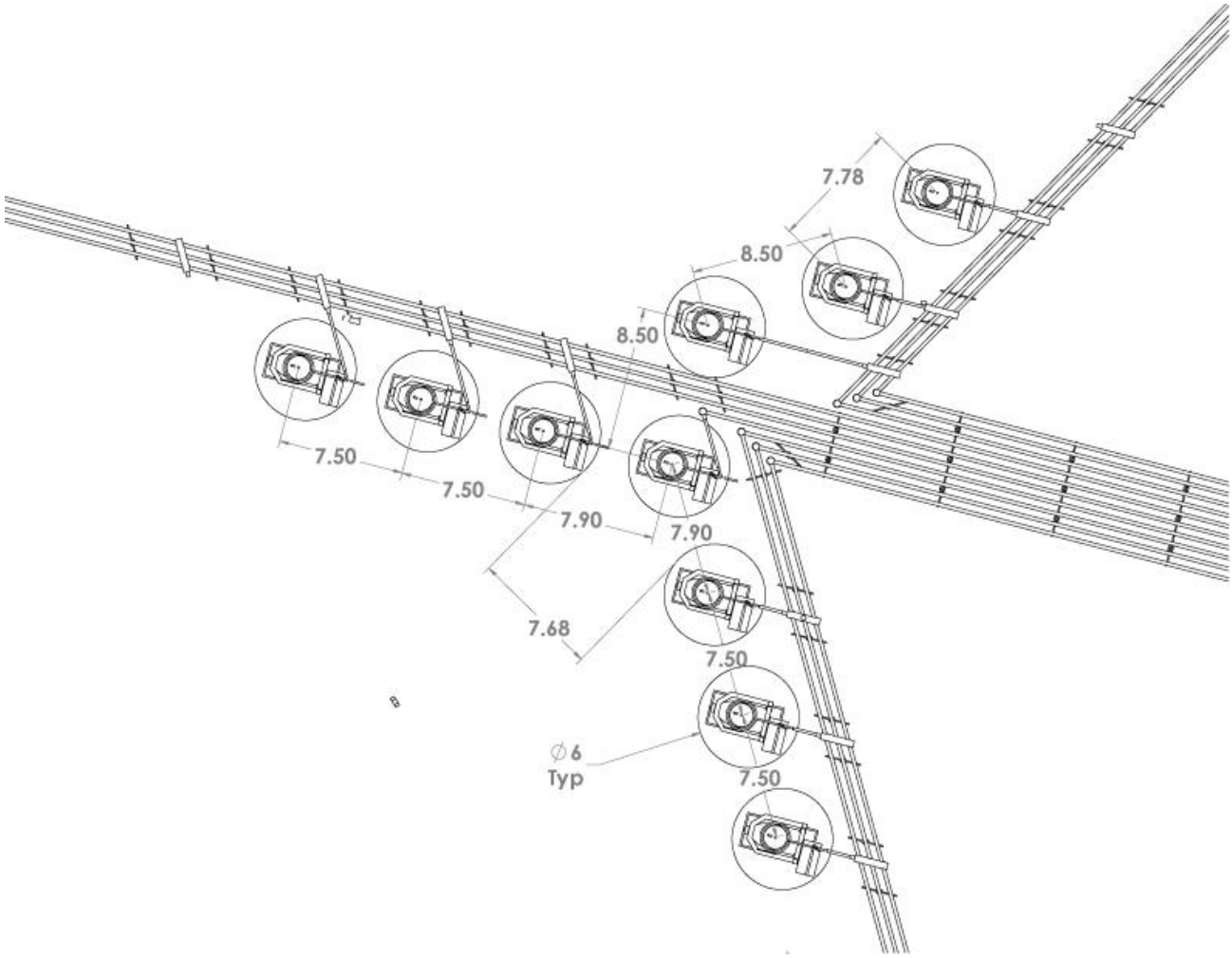

Figure B1 - Schematic cartoon of the ten MROI Unit Telescopes when located in their close-packed configuration. The mechanical arrangement of the elevation-over-elevation mount telescopes is for illustration only, and is meant to be representative of the actual telescope design. Distances are measured in meters. North is to the top and East to the right.

Appendix C – Proposed Documentation Requirements

It is intended that the Vendor will develop and document detailed and complete maintenance procedures and schedules. These procedures shall be comprehensive and sufficient to guide all scheduled and unscheduled maintenance necessary to keep the system fully operational. The Customer's preferred organization of the manual is described below:

Section 1: Safety - Detail any special precautions necessary to prevent harm to personnel and equipment. Describe lock-out/tag-out procedure, emergency stops, etc. Include Material Safety Data Sheets for lubricants and heat transfer fluids.

Section 2: General Description and Everyday Usage - Detail basic operation of the enclosures, including move procedures, shutting down, and preparing for observations. Provide functional descriptions of all subsystems, including electrical and fluid system schematics, shutter drives, etc.

Section 3: Software Manual - Present the enclosure control program listing and a separate list of all monitor and control points.

Section 4: Preventative Maintenance Schedule - Present the preventive maintenance task list including scheduled intervals and manpower requirements.

Section 5: Preventative Maintenance Procedures - Present the preventive maintenance task descriptions, keyed to their schedule. Include replacement parts lists and lists of any special tools required.

Section 6: Extraordinary Maintenance Procedures - Present task descriptions for the most likely unscheduled maintenance procedures. Include replacement parts lists and lists of any special tools required.

Section 7: Recommended Spare Parts - Present the recommended spare parts list, including estimated usage rates, manufacturers and part numbers, lubricant specs and viscosities, etc.

Section 8: Drawings - Present a complete as-built drawing set. As a minimum these must be provided in soft-copy in both native CAD (i.e. editable) and PDF formats. The native drawings should include all assemblies and details, as well as all underlying solid models and libraries. Any proprietary components for which details will not be provided are to be identified in the proposal.

Section 9: Supplier lists - Present a list of manufacturers and recommended vendors for all components. Include part numbers and contact information sufficient to procure identical components.