	Magdalena Ridge Observatory Interferometer	Document No. _Rev.
		INT-412-TSP-0001_5.0
	NEW MEXICO TECH	

MROI Pier Subsidence Notes

D. Buscher, C. Haniff, J. Kern, J. Young

Date	Rev
January 31, 2005	Rev_5.0

THIS IS AN INTERNAL WORKING NOTE OF THE MAGDALENA RIDGE OBSERVATORY INTERFEROMETER

MRO
New Mexico Tech
801 Leroy Place
Socorro, NM 87801, USA
Phone: (505)835-6431
Fax: (505)835-6807

The functional requirements of the Unit telescope foundation and pier are as follows:

- Provide precise and stiff mounting interface for the UT mount;
- Be optimized for high specific stiffness to meet the minimum structural frequency requirements of the Unit telescope specification;
- The operational requirements of the Unit Telescopes require that any deformations or deflections due to the effects of gravity or other normal causes be free of discontinuities, hysteresis, and other non-repeatable deformation and deflection effects in order to meet the positioning (pointing) tolerances specified for the Unit Telescope;
- Stiffly transfer all static and dynamic loads from the mount to the ground;
- Serve as a reaction mass for the UT;
- Other TBD.

Characteristic	**Preliminary Requirement**	**Conditions**
Number	28	Foundations/Piers loaded with either a UT or a dummy weight. The UT's are expected to weigh between 10 and 20 metric tons .
1) Nominal height relative "technical slab" Tolerance	TBD by UT Manuf.	
2) Vertical Subsidence (lifetime)*	10 mm (0.4 inch)	
3) Vertical Subsidence (yearly)**	3.0 mm (.12 inch)	
4) Tilt Subsidence (lifetime)*	< 3 milliradian	
5) Tilt Subsidence(yearly)**	< 0.06 milliradian	
6) Translation due to wind load on telescope (< 20 mph mean velocity)	10 micron <1Hz 0.1 micron >1Hz	
7) Tilt due to wind load on telescope (< 20 mph mean velocity)	<1.0 micro radians	
* Subsidence is likely to be highly non-linear over the 20 year design life. (most of the subsidence in the first one or two years, followed by much less in the ensuing years).		
** Following an initial 2 year period of settlement, the yearly subsidence and tilt of the Unit Telescope foundation and pier should vary in small increments over the remaining 18 years.		

1. Nominal height relative "technical slab" will be determined by the telescope vendor. -30cm seems a reasonable value to establish at this point. A tolerance of +0/-5cm will also be established by the telescope vendor, but should be well within the range of the mount's leveling system. Note that there is a -0- positive tolerance, the range is all negative. This is to ensure that all elevations are at, or below the nominal height.

2. The lifetime vertical subsidence value of 10 mm seems a reasonable target assuming a 20year design life of the interferometer. The telescope exit beam is ~10cm and is directed at the center of a ~15cm dia. turning mirror.

3. We can tolerate Vertical Subsidence of probably 0.25mm/month, i.e. 3mm/yr. (most of the subsidence in the first one or two years, followed by much less in the ensuing years)

4. We will probably redo the pointing model at least once/month (the base spec is once/night). We can therefore probably easily allow 2.5 arcsec/month, i.e. 30 arcsec/year. (0.1454 milliradian x 20 yr = 3 milliradian) If this starts costing real money, we can go back to redoing the pointing model nightly and relax the spec by a factor of 10 or more.

5. See 4, above

6. Translation due to wind disturbances is established by the MROI system design document which requires that the low-frequency (<0.1Hz) optical path stability of the UTs should introduce no more than a few tens of microns of extra OPD over a time of order 6 hours. Random optical path length perturbations on the order of a few microns are introduced by the atmosphere, therefore let us set the

translation limit of the UT Foundation and Pier at 10 micron <1Hz 0.1 micron >1Hz. The >1Hz limit may be increased to 1.0 microns given sufficient isolation between the enclosure and the UT pier.

7. The tilt induced beam shear (wind driven telescope pier) is not be the determinant in establishing the tilt displacement of the pier, but rather the wavefront tilt itself. The shear requirement is ~1/400000 (2.5 u-rad) and the tilt requirement is 1.4 u-rad (see note 6 under beam relay). 1.4 u-rad is the total budget, we should establish the Tilt due to wind load on telescope (< 20 mph mean velocity) at <1.0 u-rad.

The functional requirements of the Enclosure foundation and pier are as follows:

- Provide precise and stiff mounting interface for the UT enclosure;
- Stiffly transfer all static and dynamic loads from the enclosure to the ground;
- Subsidence must be such that the enclosure will not interfere with the UT mount;

Characteristic	Preliminary Requirement	Conditions
Number	28	
1) Nominal height relative "technical slab" Tolerance	Tbd Tbd	This will be established by the telescope vendor.
2) Vertical Subsidence * (Differential to UT pad)	< 1cm (.4 inch)	Foundations/Piers loaded with either an enclosure or a dummy weight. The enclosure's are expected to weigh less than 10 metric tons.
3) Vertical Subsidence (yearly)** (Differential to UT pad)	3 mm (0.2 in)	
4) Tilt Subsidence (lifetime)* (This assumes a conventional dome structure, may vary with a different design)	< 3 milliradian	
5) Tilt Subsidence(yearly)**	n/a	
6) Translation due to wind load on telescope (< 20 mph mean velocity)	100 micron <1Hz (.004") 10 micron >1Hz (.0004")	
* Subsidence is likely to be highly non-linear over the 20 year design life. (most of the subsidence in the first one or two years, followed by much less in the ensuing years).		
** Following an initial 2 year period of settlement, the yearly subsidence and tilt of the Enclosure foundation and pier should vary in small increments over the remaining 18 years.		

- Serve as a reaction mass for the enclosure;
- Other TBD.

1. Nominal height relative to "technical slab" and tolerance will be determined by the telescope vendor.

2. The lifetime vertical subsidence value of 10 mm seems a reasonable target assuming a 20year design life of the interferometer.

3. We can tolerate probably 0.25mm/month, i.e. 3mm/yr. (most of the subsidence in the first one or two years, followed by much less in the ensuing years)

4. We need some estimate of how much clearance it is realistic to expect between the enclosure and the dome, and from that derive the *relative* tilt spec of the two foundations. The only real requirement is that over the lifetime the building doesn't tilt enough to hit the telescope ! (or at least get too close for comfort)

5. We can tolerate probably 0.25mm/month, i.e. 3mm/yr. (most of the subsidence in the first one or two years, followed by much less in the ensuing years) I.E. we don't really have a yearly requirement, just a lifetime requirement.

6. Translation due to wind disturbances is set at 10x the requirement for the telescope foundation assuming >20db isolation from telescope foundation.

The functional requirements of the Beam relay pipe and optic foundations and piers are as follows:

- Provide precise and stiff mounting interface for the vacuum cans;
- Stiffly transfer all static and dynamic loads from the vacuum cans to the ground;
- Provide mounting interfaces as required for distribution trays, mountings for cables and other utility distributions along the array arms (Relay Optic Footing and Piers only);
- Other TBD.

Characteristic	Preliminary Beam Relay Pipe Footing and Pier Requirement	Preliminary Beam Relay Optic Footing and Pier Requirement	Conditions
Total Number of Piers (Vertex, North, South, West)	~ 89 (14, 22, 25, 28)	~ 58 (6,17,17,18)	Individual sections of beam relay pipe weigh approximately 100 lbs. Individual vacuum cans weigh approximately 100 lbs
1) Average Height Relative to Datum Tolerance on Height	~ 1.2 meters (47 inch) +0/-5cm (2 inch)	~ 1.2 meters (47 inch) +0/-5cm (2 inch)	
2) Vertical Subsidence (lifetime)*	1cm (.4 inches)	1cm (.4 inches)	
3) Vertical Subsidence (yearly)**	3.0 mm (.12 inch)	3.0 mm (.12 inch)	
4) Tilt Subsidence (lifetime)*	17.5 milliradians	17.5 milliradians	
5) Tilt Subsidence(yearly)**	15 milliradians	0.15 milliradians	
6) Tilts due to disturbance forces i.e.: wind and ice (< 20 mph mean velocity)	2 milliradians (wind) 1 milliradians (ice)	0.7 micro radians (wind) 1 milliradians (ice)	
7) Translation due to wind load (< 20 mph mean velocity)	100 microns	10 micron <1Hz 0.1 micron >1Hz	

* Subsidence is likely to be highly non-linear over the 20 year design life. (most of the subsidence in the first one or two years, followed by much less in the ensuing years).

** Following an initial 2 year period of settlement, the yearly subsidence and tilt of the Relay Pipe and Optic Footings and piers should vary in small increments over the remaining 18 years.

1. Average Height Relative to datum is expected to be ~1.2m, based upon a 1.5m UT exit beam height and the present concept of the turning mirror vacuum cans.

2. We can tolerate measurable amounts of vertical subsidence, the turning mirrors are fairly close to the UTs and the ~15cm turning mirror is considerably larger that the ~10cm beam

3. We can tolerate probably 0.25mm/month, i.e. 3mm/yr. initially. (most of the subsidence in the first one or two years, followed by much less in the ensuing years)

4. The lifetime tilt subsidence requirement is related to how far we would have to tilt the mirrors to realign the optics. Estimate is that we can easily afford to realign the mirrors over a 1 degree range.

5. Tilt subsidence of the Relay optic must be differentiated between the inter-night and intra-night requirements. The experience at all interferometers is that you have to realign at the beginning of every night all optics which are subject to outdoors diurnal temperature cycling. This is because the thermally-induced creep during the day is inevitably many times larger than the intra-night requirement
Hence the inter-night stability requirement is unrelated to the intra-night stability requirement. The inter-night requirement is related to the capture range of the alignment optics, which one could expect to be of order the field of view of the relay system. This is approximately 100mm/200m = 0.5mrad.

The tighter requirement is the intranight requirement. Consider the worst case, the Optic pier at the extremity of the West arm. If the DL cart is at the far end of the delay line, the distance between the 2 points is 439m. We have a requirement of +/- 0.25mm on the cart trajectory introducing 0.5mm shear at the output of the DL. From this requirement can flow one that states that the tilt of the Beam Relay Optic Footing and Pier should introduce no more than 0.25mm beam displacement of the input beam at the DL cart. Given a 439m optical lever, the pier/mount combination must tilt no more than 2.84 x 10^-7 rad. (5.69 x 10^-7/2 for the reflection). Of this .3 u-rad, budget 2/3 to the pier and 1/3 to the can, 0.2 u-rad. i.e. 0.2 microrad/12 hours, which leads to 12 microrad/month or 0.15 milliradian/yr.

Annual tilt subsidence of the Beam Relay Pipe Footing and Pier may be relaxed considerably by a factor of 100 to 15 m-rad.

6. The tilts due to disturbance forces i.e.: wind and ice are also driven by an allowable 0.5mm shear at the output of the DL. We should distinguish wind from ice as a load, because of the need to realign the optics once per night in any case. If the ice loading changed significantly during a night, it is probably not an observing night! Wind loading is a different matter, and should meet the intranight requirement stated in 5, since if you align the optics in the wind and then the wind drops, you don't want to have to realign.

For 1% visibility loss, circular aperture diameter D,
tilt = 0.0885*(lambda/D)
For lambda = 1.6 microns:D = 1.4m => 0.10 microrad = 0.021 arcsec D = 0.1m => 1.4 microrad = 0.29 arcsec
In all cases, the path length difference across the diameter of the beam is
phi = 0.0885*lambda or lambda/11.5 = 0.14 microns for lambda = 1.6 microns
Reminder - need to divide angles by 2 to get mirror tilt!

Tilts due to disturbance forces of the Beam Relay Pipe Footing and Pier may be relaxed considerably by a factor of 1000 to 2 m-rad.

7. Translation due to wind disturbances of the Beam Relay Optic Footing is established by the MROI system design document which requires that the low-frequency optical path stability of the UTs should introduce no more than a few tens of microns of extra OPD over a time of order 6 hours. Random optical path length perturbations on the order of a few microns are introduced by the atmosphere, therefore let us set the translation limit of the Beam Relay Optic Footing and Pier at 2 microns.

For the Beam Relay Pipe Footing and Pier, relax this limit by a factor of 10, or 20 microns. Here that the relay pipes, though loosely coupled, are still connected through bellows to the cans. We should perhaps distinguish how much static versus dynamic isolation we expect between the cans and the pipes and therefore the relative stability to static and dynamic wind loading.

The functional requirements of the Delay Line Steeplechase piers and foundations are as follows:

- Provide precise and stiff mounting interface for the delay lines;
- Stiffly transfer all static and dynamic loads from the delay lines to the ground;
- Provide mounting interfaces as required for distribution trays, mountings for cables and other utility distributions along the delay lines;
- Other TBD.

Characteristic	Preliminary Requirement	Conditions
Number	35	
1) Nominal height relative "technical slab" Tolerance	1.2m 10cm	This will be established by the delay line design.
2) Vertical Subsidence (lifetime)*	10 mm (0.4 inch)	Foundations/Piers loaded with either an enclosure or a dummy weight. The enclosure's are expected to weigh less than 10 metric tons.
3) Vertical Subsidence (yearly)**	3.0 mm (.12 inch)	
4) Tilt Subsidence (lifetime)*	N/A	
5) Tilt Subsidence(yearly)**	N/A	
6) Translation due to wind load on surrounding DLA structure (< 20 mph mean velocity)	10 micron <1Hz 0.1 micron >1Hz	
* Subsidence is likely to be highly non-linear over the 20 year design life. (most of the subsidence in the first one or two years, followed by much less in the ensuing years).		
** Following an initial 2 year period of settlement, the yearly subsidence and tilt of the Enclosure foundation and pier should vary in small increments over the remaining 18 years.		

1. Average Height Relative to datum is expected to be <1.2m, based upon a 1.5m UT exit beam height and the present concept of the beam relay system.

2. The lifetime vertical subsidence value of 10 mm is established equal to that of the Unit telescopes.

3. We can tolerate Vertical Subsidence of probably 0.25mm/month, i.e. 3mm/yr. (most of the subsidence in the first one or two years, followed by much less in the ensuing years). This value is established equal to that of the Unit telescopes.

4. The delay line supports are presently conceived as mechanical flexures and will accommodate significant tilt of the footings in the longitudinal direction. Transverse to the beamline (assuming the steeplechase is a monolith), tilt is accommodated within the vertical subsidence (1 & 2) requirement.

5. Ditto

6. Translation of the Delay Lines due to wind disturbances is established equal to that of the Unit telescopes. This is a similar environment to the telescope/enclosure system wherein a surrounding, and mechanically isolated enclosure surrounds a vibration sensitive instrument. As with the UT/enclosure, we expect >20db isolation from DLA structure therefore the >1Hz requirement may be relaxed to 1.0 micron