



Technical requirements for the installation of survey monuments at the MRO Interferometer

INT-402-TSP-0100 rev 0.2

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Mar 25, 2009

Draft

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1 Introduction

The Magdalena Ridge Observatory Interferometer (MROI) will be a high-sensitivity imaging optical/IR interferometer consisting of an array of 10 “unit telescopes” which operate together to form a single “aperture synthesis telescope”. Each unit telescope will send a parallel beam of starlight to a beam-combining facility located close to the array center, where the light will be combined to generate the interferometric signals used to reconstruct astronomical images. The telescopes will be relocatable amongst a discrete set of 28 stations or “piers”, arranged along an equilateral “Y”, with each arm approximately 200 meters in length.

This document covers the requirements for the monuments that will be used in surveying the positions of the equipment that is installed along the arms of the array and inside the BCF.

2 Background: intended uses for monuments

This section is intended to give the reader an idea of what the monuments will be used for, in order that the requirements in later sections can be better understood. Statements in this section should not be taken as setting out requirements or superseding requirements set out elsewhere in this document.

2.1 Unit telescopes

Light from stars enters the unit telescopes (UTs) and is redirected via mirrors into the beam relay system (BRS – see next subsection) and from there into the central laboratory building called the beam combining facility (BCF). In order to operate the array, it is necessary to determine the geometrical path taken by the light through the system, and this requires knowledge of the 3-dimensional positions of the UTs. Only the relative positions of the UTs are relevant – a position offset of the whole array would have no effect.

In addition, it is important to place the telescopes in a known *orientation* with respect to a geodetic reference system, i.e. with reference to the orientation of the Earth and its rotation axis, so that the telescope can point accurately at stars.

The position and orientation of each UT is mechanically defined with reference to a set of “locating points” at each pier. A selection of the monuments presented here will be used, together with a total station, to measure the positions of these locating points for each pier and hence determine the positions and orientations of the UTs.

2.2 Beam Relay System

Each UT sends a parallel beam of light into the BRS, which consists of ten 8-inch-diameter vacuum pipe runs, up to 200m long, which lead from the telescopes to the BCF. Also part of this vacuum system are “beam relay mirrors”, housed inside “vacuum cans”, which redirect the light through the system. Some of the monuments will be used to align theodolites used when setting up the positions of the vacuum pipes, the vacuum cans, the mirrors, and their supports. Four of the sets of pipes need to be co-aligned with their corresponding delay lines (see next subsection), meaning that alignment needs to be maintained over a distance of approximately 450m.

2.3 Delay Lines

The light from the beam relay system is sent into delay lines, which are housed in the delay line area (DLA), a 200-m long section of the BCF. The delay lines are 16-inch vacuum pipes containing a high-precision computer-controlled “trolley” running on the inside of the pipes. The straightness of the pipe run affects the trajectory of the trolley and, as mentioned above, 3 of the delay line runs need to be aligned with the relevant BRS pipe runs. The delay-line pipes will be built out of 12-foot sections and each section will be aligned as it is installed, by sighting with a theodolite an alignment template which is inserted at each pipe join in turn. The monuments in the DLA and in the beam combining area (BCA) will be used to align the theodolite for each pipe run.

2.4 Maintenance

Each of the above subsystems will occasionally need realigning, for example when a section of the delay lines needs replacing to change vacuum seals. Therefore the monuments must be available at later dates in order to perform similar operations to those performed at initial installation.

3 Requirements for monuments

3.1 Monument locations

Figure 1 shows the nominal locations of all 46 required monuments. All monuments are at nominally at the array grade level, defined by the mean level of the BCA slab. These monuments can be classified into:

1. DLA monuments: 20 monuments in the delay line area. These monuments will be used to define the positions and directions of the 10 delay lines, nominally parallel and 24 inches apart.
2. BCA monuments: 10 monuments in the beam combining area. These will be used to align the delay lines and the BRS.
3. West arm monuments: 4 monuments, one at the end of each of the 4 BRS pipes going to the central telescope and the 3 telescopes at the ends of the West arm and used for aligning the BRS.
4. North/South arm monuments: 12 monuments, one at each end of the 3 BRS pipe runs going down each of the North and South arms of the array. These monuments will be used as references for aligning the BRS.

The monuments external to the BCF may be used in determining the positions and azimuths of the UT pier locating points.

3.2 Monument type

The monuments shall be of a type that is flush with or recessed in the ground, so as to present minimal tripping hazard. The deviation of the monument height from the monument grade level shall be documented for all monuments. Each monument shall have suitable measurement marks or location points for use with standard surveying equipment including total stations and their accessories.

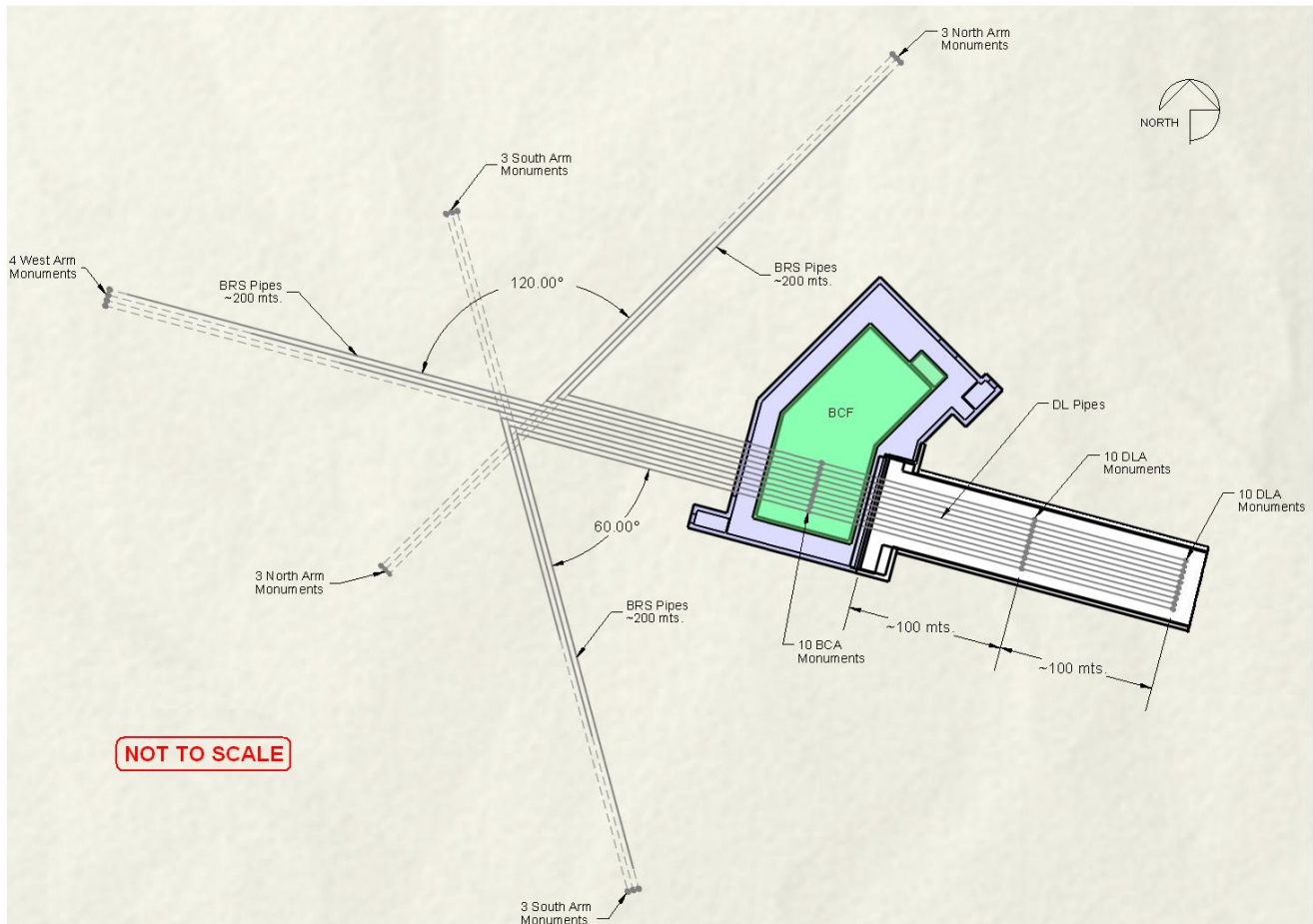


Figure 1: Cartoon of placement of monuments at the MROI array. The diagram is not to scale but serves to indicate the general location of the monuments.

3.3 Accuracy of monument locations

1. The DLA monuments shall be installed with respect to the existing set of monuments in the DLA to an accuracy of $\pm 2\text{mm}$ in all coordinates. The existing monuments were used in determining the optimum positions of the delay line pipes on the DLA slab and therefore provide the fundamental reference for the DLA.
2. The DLA monuments shall be installed with respect to each other such that the lines between pairs of monuments corresponding to the directions of runs of delay line pipes are parallel to each other to within 10 microradians.
3. Each BCA monument shall be installed colinear with respect to the relevant pair of DLA monuments to an accuracy of $\pm 0.5\text{mm}$ and to within $\pm 2\text{mm}$ in any direction of their nominal positions with respect to the DLA monuments.
4. The system of monuments external to the BCF, consisting of the West arm monuments and the North/South arm monuments, shall be positioned relative to each other to an accuracy $\pm 2\text{mm}$ in any coordinate per 100m of separation, with a maximum accuracy of $\pm 1\text{mm}$ for monuments within 50m of each other.
5. The West arm monuments shall be installed colinear with respect to the relevant DLA

monuments to an accuracy of $\pm 5\text{mm}$.

6. The orientation of the coordinate frame in which all monument positions are measured shall be referred to a coordinate system defined by the combination of (a) the local vertical at the center of the array and (b) the rotation axis of the Earth (i.e. true North) to an accuracy of better than ± 50 microradians.

3.4 Long term stability of monuments

The monuments shall be designed for a lifetime of 20 years. The monuments shall be installed such that their positions will drift less than $\pm 2\text{mm}$ in any coordinate over the 20 years after installation. For monuments installed inside the BCF this drift excludes any drift in the slabs into which the monuments are installed. The positions of the monuments outside the BCF should be selected to be in ground which will not be disturbed by subsequent construction work on the array.