CHARA TECHNICAL REPORT

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Telescope Enclosure Specifications

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1. INTRODUCTION - THE CHARA ARRAY

The CHARA (Center for High Angular Resolution Astronomy) of Georgia State University will build a facility for optical/infrared multi-telescope interferometry. This facility is called the CHARA Array. The facility will consist of seven (initially five - see below) telescopes, with evacuated pipes conducting the beams to a central laboratory. The laboratory will contain optical delay lines, beam combination optics, and detection systems. The facility will consist of these components plus the associated buildings and support equipment. The CHARA Array will be funded by the state of Georgia and the National Science Foundation. The facility will be located on a mountain site in the southwestern U.S.

2. OVERVIEW OF TELESCOPE ENCLOSURE SPECIFICATIONS

The primary requirements for the telescope and enclosure are to deliver a high quality and stable light beam to the central laboratory.

The telescope pier and the enclosure must rest on separate foundations, with minimal mechanical coupling between the structures. The enclosure should provide wind protection for the telescope, but should also flush rapidly to promote uniformity of internal and external temperatures.

Thermal characteristics should minimize convective heat transfer from the internal enclosure structure turbulence during nighttime operation.

It is desirable to raise the telescope and enclosure 10-20 feet above the ground.

The project is under a severe budget constraint and requirements may be compromised to meet these constraints.

3. TYPICAL USE PATTERN

The enclosures will normally be closed during the day, and the telescopes may be actively cooled to the expected nighttime temperature. The enclosures will be opened only after

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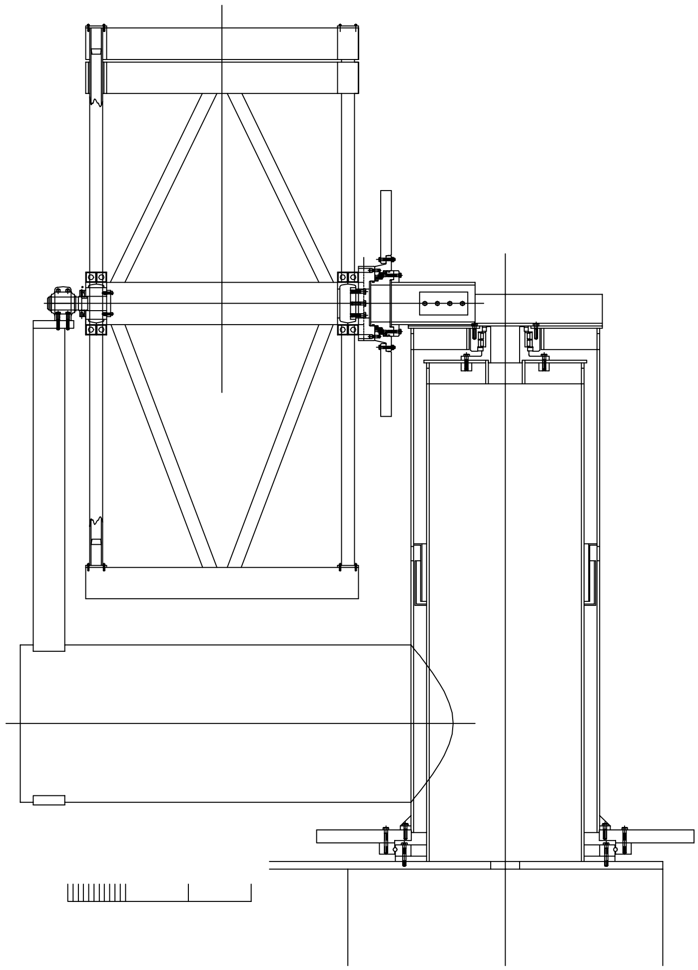

FIGURE 1. Telescope layout. The scale in the lower left represents a length of three feet.

the outside air temperature has completed most of its rapid decline at dusk, typically 30 minutes after sunset. The active cooling will be shut off during operation. Operation may continue until sunrise or shortly after.

The facility cannot operate successfully in cloudy or high wind conditions, and it will be closed at wind speed above 20-30 mph (sustained).

4. THE TELESCOPE

The telescope will be an altitude-azimuth instrument with the tube in an outboard yoke. The current concept for the telescope is illustrated in Figure 1.

The optical beam will be directed downward through the center of of the pier, and subsequently reflected horizontally into a vacuum pipe leading to the central facility.

The drive and control electronics for the telescope will be located in or near the enclosure.

5. HEIGHT OF THE TELESCOPE

It may be very desirable to raise the telescope above the ground. This may raise the telescope above the effects of pooling of cool air which may occur in calm conditions, and partially above turbulent boundary layer flow in conditions of wind.

Also, raising the enclosure above the ground will allow air flow beneath the structure and improve the thermal equilibration.

Since height of the structure can be a strong cost driver, this is an area of concern. At the present we are considering pier heights in the range 0-20 feet.

6. THE TELESCOPE PIER

The telescope with its mount structure sits on a pier which raises it above ground level. The pier must be massive and strong. The scientific operation of the facility will be compromised or nullified if the pier moves significantly during operation. The allowed motion of the pier depends on the resonant frequency, in the sense that the lower the frequency the larger the allowed motion. At a frequency of 1 Hz, the allowed amplitude of motion is about 40 microinches.

To achieve the pier stability, it is likely that it will be necessary to:

- Limit the pier height.
- Employ massive pier construction (eg concrete instead of steel pipe).
- Provide a wind shield for the pier.

The vacuum pipe which conducts the optical beam to the central laboratory will pass through the pier. The pipe will enter horizontally at a height which is terrain dependent. Because of this variability in the entry point of the vacuum pipe, it is highly desirable to be able to select the entry point after the pier has been installed.

Inside the pier, the horizontal vacuum pipe it will connect to a vertical vacuum pipe which will exit through the top of the pier and enter the telescope. At the junction of the horizontal and vertical pipes, there will be a vacuum junction box with approximate dimensions of a vertical cylinder, 36 inches in diameter and 24 inches high. It will be necessary to have access to this junction box for installation and service.

Figure 2 shows several possible concepts that may be considered for the pier, with typical dimensions and the location of the vacuum pipes.

The pier will probably be the subject of a separate technical report after the engineering design is carried out.

Proposals for the enclosure may include the pier or not. The vacuum pipes are not part of the enclosure or the pier construction packages, and will be installed after the pier is in place.

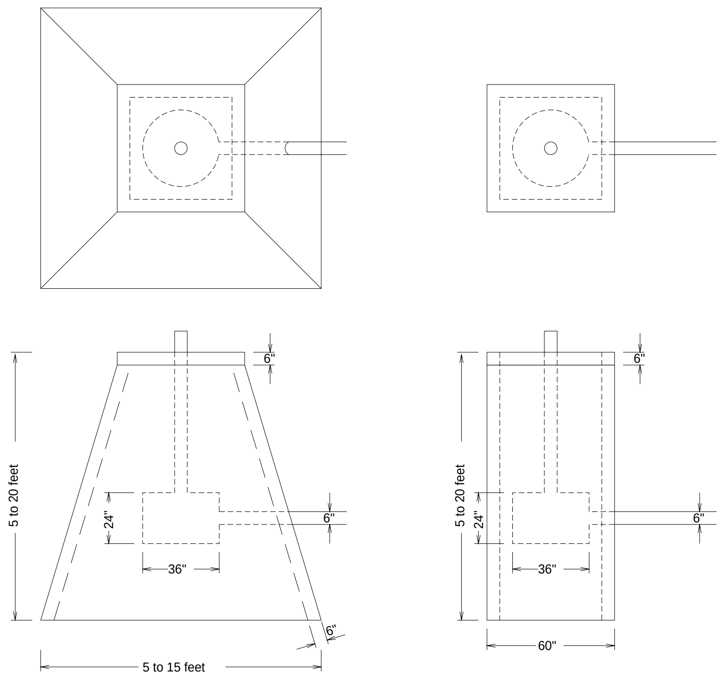

FIGURE 2. Possible pier designs, assuming a concrete structure.

7. SIZE OF ENCLOSURE

As the CHARA telescopes will not be general purpose telescopes, the enclosures can be relatively compact. There will be no observer presence during normal operation, no conventional instrument package, no instrument changes, and no requirement for storage space in the enclosure. It is acceptable for the enclosure to close only when the telescope is in a stow position (eg vertical or horizontal).

In addition to containing the telescope in its stow position, the enclosed space should suffice to:

- Allow access for two people to work on the telescope in the stow position.
- Permit the telescope to point to any direction above the horizon when the enclosure is open (but not necessarily with an unrestricted view - see discussion of sky coverage, below).

Also, the enclosed space should not be so constricted as to pose a safety hazard to personnel in the event of unforeseen activation of the telescope drives.

8. ACCESS BY USERS

Although the telescopes be will operated remotely, it is expected that access will be required on a regular basis for maintenance or adjustment. Convenient access will be needed for personnel with portable equipment (electronic test gear, tools). Less frequently, it will also be necessary to provide access for equipment which is too heavy for hand carry. A small which conveniently located may suffice.

9. POWER AND COMMUNICATIONS

The telescope and enclosure power requirements have not been quantified but are expected to be modest. Both power and electronic communications will be installed in underground or surface cableways which must enter the enclosure, most likely through the pier.

10. THERMAL CONTROL

In order to avoid convective turbulence in the optical path, it is desirable to minimize the thermal capacity and/or temperature differential of all telescope and dome components. Where high thermal capacity materials are required, they should be designed to allow rapid temperature equilibration (nominal 30 minutes or less) or should be appropriately insulated.

In order to achieve the required beam quality, we expect that it will be desired to cool the enclosure interior and telescope during the day to temperatures near the expected nighttime temperature. At typical mountain sites, this requires a temperature differential during the day of about 20 F. In order to minimize cooling costs it is desirable to have an insulated enclosure with an exterior finish or paint which minimizes absorption of solar energy.

In order to facilitate daytime cooling, the telescopes will provide access ports for circulation of conditioned air around the mirror and mount. The actual implementation of daytime cooling may depend on the site and the type of structure selected for the enclosure, and the operation of the cooling will be season, weather and budget dependent.

It will be necessary to minimize dumping of heat into the telescope enclosure. Power loads in excess of about 50 watts should be isolated from the telescope, for example in a separately ventilated compartment. This probably means a separate compartment will be needed for the control system. The size of the drive electronics should not exceed 36-inch vertical extent of standard 17-inch electronics rack.

The wind plays an important role in equilibrating temperature during the night. The enclosure should open sufficiently that a modest wind of a few mph will flush the enclosure within a few minutes. In modern telescope enclosures, large surface area louvers are commonly used with sufficient distribution around the periphery of the enclosure to allow rapid flushing with any wind direction. The tradeoff between protection of the telescope from a light wind and adequate flushing of stagnant air is normally resolved with a rotating enclosure by allowing optimum flushing when the enclosure is open into the wind, and optimum protection when it is pointed orthogonal to or away from the wind. (To some extent the science program can be organized to utilize the enclosure in the preferred orientation for conditions.)

It is hoped that passive ventilation will suffice. However, if a site of very low wind is selected, it may be desirable to provide active ventilation of the enclosure. This is normally best accomplished with fans remotely located (to avoid mechanical disturbances) pulling air out of the enclosure interior and exhausting it on the prevailing downwind side at some distance.

11. WIND

At the sites under consideration, the wind is likely to have a strongly favored direction for extended periods of time.

Although the telescope is designed to operate in moderate wind, the enclosure can play an important role in protecting the telescope from excess wind loading and buffeting. An enclosure which allows the telescope and enclosure to be oriented in favored directions less subject to wind effects would be a distinct advantage.

The sites under consideration have a range of wind conditions, and the requirements on the enclosure may depend somewhat on the site selected. A site with higher winds would require greater shielding for the telescope, and a site with lower winds would require less protection and more consideration to flushing the enclosure in a low wind.

The dome footings will be isolated and physically separated from the telescope pedestal footing, in order to minimize shaking of the telescope.

12. REMOTE OPERATION

The opening and closing of the enclosures must be remotely controlled. Additional function which must be remotely activated if they are present include: any enclosure ventilation louvers; rotation of the enclosure; activation of a windscreen; the enclosure cooling system; ventilation fans.

13. NUMBER OF TELESCOPES

The CHARA goal is to construct seven telescopes. However, as currently funded, it has been necessary to defer two telescopes. Therefore the initial facility is only assured to have five enclosures.

However, the number of telescopes purchased may depend on cost, and the project is seeking additional funding, so vendors should bid on quantities of five and seven enclosures.

14. INSTALLATION AND SERVICING

It is common to use a crane for the installation of a telescope in a dome and for major disassembly.

The most elaborate standard maintenance procedure for a reflecting telescope is the removal of the primary mirror for aluminization. The CHARA mirror weight will be approximately 300 pounds, and it will be removed with the mirror cell for a total weight in excess of 600 pounds. The mirror removal procedure has not yet been determined. Possibilities include the use of a jackstand underneath the telescope, or of a sling and hoist above the telescope. It is necessary that the configuration of the enclosure facilitate mirror removal.

15. SKY COVERAGE

The telescope should point to any place in the sky above the horizon. There should be no vignetting for elevations greater then 30 degrees. It would be a small advantage if there were no vignetting to the horizon.

16. ENVIRONMENTAL FACTORS

The telescopes must be designed and constructed to withstand normal conditions and hazards associated with mountain top observatories in the southwest U.S.

16.1. Range of Conditions

The telescopes will be installed and operated at an altitude of 5000-8000 feet. Telescopes will be subject to temperature extremes in the range -15° C to +35° C. Winds may be as high as 70 mph (sustained) and 120 mph (gusts).

Facility operations will be limited to temperatures in the range -10° C to +25° C, winds no greater than 30 mph sustained (45 mph gusts), humidity no greater than 90% (non-condensing).

Additional environmental hazards include frequent, heavy thunderstorms with abundant lightning; relative humidity up to 100%; infrequent but possibly heavy snowfall; irregular power and occasional power failures; assault by squirrels, mice and other small animals; seasonally, large numbers of insects of various types.

16.2. Lightning Protection

Owing to their mountain top locations and extensive use of sensitive electronic equipment, telescopes are notoriously subject to lightning damage. Adequate lightning protection is a critical factor.

17. SAFETY AND FACILITY PROTECTION

The enclosure should provide or facilitate the installation of any interlocks reasonably required for protection of personnel and equipment. This might include locking out enclosure rotation when the personnel access door is open, or providing a signal which can be used to lockout power to the telescope drives when the enclosure aperture is closed.

18. CONTRACTOR ACCESS

Site access for heavy equipment may be limited at some possible sites. The sites may be as far as 200 yards by unimproved road from surfaced roads. Some areas are forested and clearing of trees may be restricted to the minimum.

19. RELIABILITY AND LIFETIME

Telescopes and enclosures are typically designed for a 20 year lifetime, but experience has shown that they often remain in operation considerably longer. The lifetime and expected frequency, nature and expense of foreseeable overhauls of the enclosure should be addressed.

20. DOCUMENTATION

The vendor will supply user and engineering documentation. The user documentation (one set for each enclosure) will contain instructions for the operation of the enclosure.

The engineering documentation (two sets) will include "as built" mechanical layouts and mechanical interfaces, and complete identification of all replaceable components or units, "as built" drawings of all electronics, and wire and timing diagrams (as appropriate) of all electrical and electronic interfaces. It will also include results of any modeling or simulations used in verifying the design.

A maintenance schedule will be provided, and all installation, alignment and maintenance procedures will be documented.

Computer copies of the design (CAD files) and documentation will be provided if available.

21. SCHEDULE FOR INTERACTION BETWEEN CHARA AND THE VENDOR

It is expected that there will be routine contact between the vendor and CHARA during the design. CHARA may also engage an engineering consultant to participate in discussions and design decisions.

The following specific meetings are planned: kickoff meeting, preliminary design review, critical design review, preliminary acceptance review of the first enclosure, and installation visit. All except the installation visit will probably take place at the vendor's facility.

Vendor will be responsible for travel costs incurred by the vendors employees, and CHARA will be responsible for travel by CHARA staff.

22. VENDOR OPTIONS

A potential vendor may choose to quote on a complete enclosure package to include excavations, footings, pier, enclosure, cooling system, lightning protection and electrical installation. Alternatively, CHARA will accept bids for just the fabrication of the enclosure with or without any of the additional items as well as installation.

23. SCHEDULE

It may be possible to begin the design of the enclosures as soon as the site has been selected, which should be in the period March-July 1995. It may be possible to let let the construction contract by Jan. 1996. Completion is expected by April 1997.

24. COST

Although the enclosures are a small part of the overall project, all aspects of the project are under considerable budget pressure. The CHARA project must arrive at an enclosure solution which brings the cost considerably below the current typical cost of enclosures for similar size telescopes in the professional astronomy community. The hope to do so is based on the very limited interior space requirement, and the leverage of building multiple copies.

25. PRICING AND PAYMENT

The enclosure contract will be fixed cost.

It is expected that the enclosure work will proceed in phases, with progress payments to be made at the approved completion of each phase. The details will be negotiated after the vendor has been selected.