CHARA TECHNICAL REPORT

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Enclosures and Domes for the CHARA Telescopes

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1. THE CHARA TELESCOPES AND THE DOME REQUIREMENTS

The CHARA telescopes are 1 meter aperture reflecting telescopes with altitude-azimuth mounts. The telescope tubes are approximately 2.5 meters long, and the altitude axis is near the mid-point of the tube. Therefore the required clear radius of the dome interior is somewhat greater than 1.25 meters. In fact a clear radius of 1.7 meters or 5.7 feet is about the minimum possible.

The telescope aperture of 1 meter will require a dome aperture width greater than 1 meter. Pointing toward the celestial equator, in 20 minutes the telescopes will track 5 degrees. For a nominal dome radius of 2 meters, this corresponds to 17 cm. If in addition we require a minimum clearance of 10 cm on all sides, then the dome aperture must be at least 1.37 meters (55 inches). A slightly larger width would be desirable in order to allow longer observations (dome rotation is expected to disturb fringe coherence).

A goal of the Array project is to observe as far south as the galactic center at declination $-28°$ (zenith distance $60°$, altitude $30°$). If the telescope is mounted with the intersection of the altitude and azimuth axes in the center of curvature of the dome, then the aperture must be clear down to within 40 cm of the horizontal plane through the center of curvature.

A preliminary overview of telescope enclosure requirements was reported in CHARA Technical Report No. 8. The telescope geometry considered in that report was different from the one finally selected, but otherwise the requirements are reasonably current.

1.1. Building Code Issues

The CHARA facilities on Mt. Wilson are being built under applicable codes of Los Angeles County. Buildings which are designed by a California licensed architect follow a clear if tedious path through the local permitting process. Some of the following concepts are based on products which have definitely not or possibly not been constructed under LA building code. This raises issues which will not be addressed here.

In any event, we do know that the LA county code requires CHARA buildings be constructed to withstand winds gust to 100 mph, carry snow loads up to 75 pounds/square foot, and satisfy code requirements for seismic zone 4 (the worst).

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2. TELESCOPE ENCLOSURE CONCEPTS

In the course of preparing budgets and plans, quite a number of telescope enclosure concepts have been considered. These include adaptation of industrial storage tank and silo designs, duplication of existing telescope buildings, and design of a new concept from scratch.

2.1. Industrial Storage Tank and Silo Style Enclosure

A novel approach to telescope enclosure design would be to purchase prefabricated structures based on steel tank technology. These tanks are usually built to house chemicals, often corrosive, often under pressure, and they are definitely built to last.

We corresponded with Steel Stuctures, Inc. (P.O. Box 1170, Madera, CA 93639, 209-673-8021). They proposed a steel drum 16 feet in diameter and 18 feet high, with 1/4 inch walls, appropriate bolt circles on bottom and top for footings and dome, two internal platforms (ie floors), external spiral stairway and doors to each level. The price estimates (September 1995) per unit were as follows. Since it has been subsequently determined that a building size of 12 feet diameter and 15 feet height will siffice, a second estimate has been obtained for this smaller building by just adjusting the tank and platform costs appropriately to the scale change, leaving other costs the same.

Component	$16' \times 18'$	$12' \times 15'$
Tank	\$17000	\$10625
Platforms (2)	\$12000	\$6750
Stairway	\$8000	\$8000
Freight	\$5000	\$5000
Erection	\$8000	\$8000
Total	\$50000	\$38375

The tank/platform structures would be assembled at the factory and shipped on a truck to the site for erection.

2.2. Conventional Telescope Enclosures

We considered modeling the CHARA telescope enclosure on other recent telescope installations. We identified two of approximately suitable size for the CHARA telescopes.

One reference point was obtained from New Mexico State University, which contracted for a 1 meter telescope at Sacremento Peak in New Mexico. The enclosure was designed, and construction supervised, by M3 Engineering. The enclosure, about 20 feet above the natural grade, cost approximately \$130K, including a 16.5 foot Ash dome.

A new dome was built at the Kitt Peak National Observatory visitor center to house a 16 inch telescope, but oversize to allow for visiting public. This telescope has the dome floor about 10 feet above natural grade. The cost was about \$125K. In order to scale this experience more directly to CHARA, Jeff Barr of NOAO carried out a detailed costing for a CHARA telescope enclosure, scaling costs from his recent experience with the Kitt Peak telescope, and also his familiarity with the recently constructed SARA telescope on Kitt Peak. The analysis was based on a circular building, elevated 3.5 feet off the natural grade, supporting a 16.5 foot Ash dome. This exercise is fully reported in CHARA Technical Report No. 22. Jeff's estimate for the CHARA enclosure was $98K, including $20K for the dome, but assuming a significant contribution to the site preparation and concrete work from observatory staff.

Jeff estimated the total for the steel structure and siding costs at $29K. This number compares well (square foot costs) with the KPNO and SARA projects. It is also the number to compare to the steel tank option described above.

2.3. Developing a New Enclosure Concept

There are a number of engineering/architectural groups which have established a reputation for design of telescope enclosures, often for unusual requirements in fairly remote locations. M3 Engineeering (2440 W. Ruthrauf Rd., Bldg. 2470, Tucson, AZ 85705, 520-690-8209) has recently designed the WIYN telesope building and dome, the Infrared Optical Telescope Array transportable telescope shelters, and the 2MASS 1.3 meter telescope enclosures.

Leo A. Daly Company (Los Angeles, Washington, Houston, and other cities) worked on the IRTF, SUBURU, and Keck II telescope enclosures, among many.

CHARA has not at this time undertaken a design effort with groups like this, in hopes that the CHARA requirements could be satisfied with an absolute minimum of new design and engineering.

3. TELESCOPE DOME CONCEPTS

We have explored a number of dome concepts, including three brands of commercial domes, a custom dome based on fiberglass panel technology used in Radomes and similar structures, and a fabric membrane convertible style dome.

3.1. Ash Domes

Ash Manufacturing Company (Box 312, Plainfield, Illinois 60544, 815-436-9403) manufactures a line of domes which have been in use at professional and amateur observatories for decades. The rib sections and roof panels are Galvalume (an aluminum zinc alloy processed for corrosion resistance, which can be exposed indefinitely to the elements without paint).

The smallest standard Ash dome which has a clear internal radius large enough for the CHARA telescope is the 14.5 foot model. The wide aperture option (54 inches) would be required.

The Ash Dome solves the sky access problem with a two-section shutter. One section is cranked up and over the dome top, opening a rectangular slit which extends from a middle elevation up and over zenith. A lower shutter section obscures the lower elevations. There are two options for this shutter. In the A model, it can optionally be attached to and raised with the main shutter, obscuring the zenith but opening access to the horizon. In the B model the shutter is hinged at the base and can be tilted outward to gain access to the horizon.

Automation is available for the dome rotation and main shutter, and a shaft can be installed for a dome encoder. At present, no automation scheme is available for the lower shutter section.

For the CHARA telescope, the lower shutter begins to vignette at an elevation of 50°. One possible option would be to request a different shutter length which would occult at zenith (the CHARA altitute-azimuth telescopes will have a small zenith "hole" anyway) and allow a lower horizon. The standard length of the lower shutter is 54 inches. If the length were changed to 20 inches, and the remaining 24 inches added to the main shutter, the main shuter would then occult approximately at the zenith.

An estimate for the cost of five 14.5 foot Ash domes for the CHARA array follows. Numbers annotated with an asterix are CHARA's estimates.

Component	Cost
Domes	$63550
Wide Aperture	4925
Remote Operation	12500
Engineering*	5000
Shipping*	5000
Assembly	5000
Total	$95975
Total each	$19195

This table does not take into account any possible quantity discount. The estimate for engineering is based on a possible requirement to have an independent structural analysis done by a California licensed engineer.

The major disadvantages are the unsolved problem of access to larger zenith distances, and the uncertain problems with certification and permitting for these structures.

3.2. ObservaDome

ObservaDome Laboratories, Inc. (371 Commerce Park Drive, Jackson, MS 39213, 800-647-5364) fabricates a line of all-aluminum domes. These domes use a bi-parting shutter system which avoids horizon occulting complications. The smallest standard dome size which satisfies the CHARA requirement is the 4 meter version. This has a clear internal radius of 78 inches, which is comfortably oversize.

The standard aperture width of 42 inches is too small, but a selected larger size can be obtained for addtional cost.

An estimate for the cost of five 4 meter ObservaDome domes for the CHARA array follows. Numbers annotated with an asterix are CHARA's estimates.

This table does not take into account any possible quantity discount. The estimate for engineering is based on a possible requirement to have an independent structural analysis done by a California licensed engineer. ObservaDome currently has a 9-12 month back-log of orders, which could be significant with respect to the CHARA telescope enclosure construction schedule.

Component	Cost
Domes	$70900
Wide Aperture*	3500
Remote Operation	25000
Engineering*	5000
Shipping*	5000
Assembly	10000
Total	$119400
Total each	$23880

3.3. Pro-Dome

Technical Innovations, Inc. (22500 Old Hundred Road, Barnesville, MD 20838, 301-972-8040) manufactures a line of all-fiberglass domes. The largest, the Pro-Dome, is a 15 foot diameter dome which is large enough for the CHARA telescopes. The shutter is a two-section, up and over style, and the two sections telescope to give a zenith to horizon aperture. The slit width is only 48 inches. A wider slit would require a new fiberglass mold. The standard package includes electric shutter and dome drives.

An estimate for the cost of five 15 foot Pro-Dome domes for the CHARA array follows. Numbers annotated with an asterix are CHARA's estimates.

Component	Cost
Domes	$54500
Remote Operation	1000
Engineering*	5000
Preassembly	8175
Packing	2625
Shipping*	2500
Assembly*	5000
Total	$78800
Total each	$15760

The question of engineering and code approvals are particularly uncertain here, since the previous use of the dome has been primarily in moderate climates. We contacted one professional group (at Sacramento Peak Observatory) which has used a Technical Innovations 10 foot dome. They reported that the dome functioned adequately for intermittent or casual use, but that some redesign would be required for regular, automated operation. The motorized aperture mechanism has not operated reliably, and the dome rotation wheels have worn rapidly. The non-metallic dome will not offer any Faraday cage protection from lightning, or from Radio Frequency Interference such as produced in the nearby commercial radio and television transmitters.

3.4. Composite Domes

Ratech Industries (855 E. Gregg St., #103, Sparks, Nevada 89431, 702-827-2222) builds communications towers and related facilties, often on remote mountain sites. They use a technology incorporating custom designed and prefabricated composite panels. Each panel consists of a PVC core of optional thickness, surrounded by layers of fiberglass cloth in polyester resin. The panels bolt together with gaskets. The resulting enclosure is insulated and weather tight.

Ratech prepared an unsolicited proposal for the CHARA domes based on this concept. They proposed a 20 foot diameter spherical enclosure, constituting approximately 80% of a sphere, instead of the hemisphere normally understood by "dome". The dome, with shutter, drive motors, shipping and installation was estimated at $65000 each. In addition, there would be $12000 in engineering costs and $8500 in tooling costs, for a final unit price of $69100 each in quantity of five.

This would be custom designed by a company which is licensed in California, hence permitting problems might be minimized. The insulated dome is attractive in view of the fact that CHARA hopes to cool the dome interior to the night-time temperature. The panels as described do not provide any Faraday cage protection.

3.5. The Fabric Dome

A.O.S., Inc. (P.O. Box 387, Monmouth Maine 04259, 207-933-4100) builds inflatable fabric structures. Of several such companies contacted, they are the only one to take an interest in the CHARA dome design.

The A.O.S. engineeering staff has proposed a concept based on a fabric covered steel rib structure. The domes would open convertible style, that is, the fabric hemisphere would fold open with the entire cover and the ribs piled to one side, and the telescope completely exposed. The fabric and ribs would form a pile 21 inches high over 180 degrees of azimuth. The fabric would be clamped permanently to a lip on the stationary side. On the side of the opening, the dome lip would engage the base lip with an auto-dogging system.

The fabric is warrantied for ten years, and has been in continuous use for 15 years in Florida, retaining at least 80% of its original strength.

When closed the fabric dome will resist mountain top conditions. An area of concern is at what wind speed the dome can be successfully closed. At present only the engineers' instincts reassure us that it could be closed safely at wind speeds up to 30-40 mph. At some wind speed, closure closure would be impossible.

The option of a completely open dome is interesting for CHARA on Mt. Wilson. On one hand, Mt. Wilson is known for relatively mild wind conditions, and an open dome could be an important asset in promoting thermalization. On the other hand, wind is clearly an enemy of interferometry, and a modest wind may be sufficient to force a halt to interferometric operation.