CHARA TECHNICAL REPORT

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Building Requirements for the CHARA Array

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1. INTRODUCTION TO THE CHARA ARRAY PROJECT

The Center for High Angular Resolution Astronomy (CHARA) of Georgia State University will build a facility for optical/infrared multi-telescope interferometry, called the CHARA Array. This array will consist of initially five (with a goal of seven) telescopes distributed over an area approximately 350 m across. The light beams from the individual telescopes will be transported through evacuated pipes to a central laboratory, which 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, and will be located at the Mount Wilson Observatory in southern California. The CHARA Array is funded by Georgia State University and the National Science Foundation.

2. OVERVIEW OF THE CHARA FACILITY REQUIREMENTS

The fundamental technical requirement of the CHARA Array, to achieve its science goals, is to place a number of telescopes in carefully selected locations and to convey the light from each telescope to a large, central building called the Beam Synthesis Facility (BSF). There, the light will pass through the Optical Path Length Equalizer (OPLE) section. The OPLE is basically a large instrument, approximately 250 feet long. The light beams are then transferred to the Beam Combination (BC) area, where the light beams will be combined and detected. The relative locations of the telescopes, light pipes, OPLE and BC are strongly constrained by technical issues. The BSF will house the Control Room and Office areas and supporting equipment. Several small auxiliary structures will house electronic and mechanical equipment. Elsewhere on the mountain, a number of additional office units may be constructed for permanent staff and visiting scientists.

3. THE CHARA PROJECT TEAM AND PROPOSAL

The Center for High Angular Resolution Astronomy (CHARA) is a research center within the College of Arts and Sciences at Georgia State University comprised of faculty and staff from the Department of Physics and Astronomy. The CHARA staff presently consists of five

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senior members, including the CHARA Director, with extensive experience in high angular resolution astronomy and related instrumentation. The staff also has two Post-Doctoral Research Associates, a number of Graduate Research Assistants who expect to complete doctoral dissertations involving aspects of the Array project, and a full-time Business Manager. The CHARA group is supported by the extensive mechanical shop facilities and staff of the Georgia State University College of Arts and Sciences. Additional technical positions will be created as the CHARA Array goes into construction and operation.

The design of the CHARA Array is based on scientific and technical studies carried out over a period of ten years. The project was initially funded through a "Phase A" feasibility study by the National Science Foundation (NSF) during 1985 through 1988 which led to a "Phase B" preliminary engineering design analysis during 1990 through 1993. These activities culminated in an extensive proposal to the NSF in 1994 which led to a major award announced by Georgia Senator Sam Nunn in October 1994. The complete proposal, along with more recent supporting documents, is accessible on the World Wide Web as noted in the footnote on the first page of this report.

4. PROJECT FUNDING

The CHARA Array proposal anticipated cost sharing between GSU and the National Science Foundation. As approved by both parties, the total funding for the construction phase of the project is $11,390,681. This will be shared by GSU and the NSF in an approximate ratio of 51:49. Most of this budget is for scientific equipment. The budget for construction has not been determined as of this writing, and will depend on an iteration of the requirements with preliminary cost estimates, but is expected to be in excess of $1M.

The original proposal to the NSF would have funded an array of seven telescopes, with supporting instrumentation to provide an extensive visible and infrared imaging capability. The funding requested in that proposal was $16M, with major cost-sharing by GSU. Due to limited resources, the NSF approved funding at the reduced rate mentioned above, and the scope was decreased consistent with the actual funding level. CHARA and GSU will continue to seek funding augmentations to extend the Array to its original proposed performance level, but the current program plan is compatible with an $11.39M project cost. The facility will be designed such that the addition of telescopes will not require major renovation or additional construction beyond the additional telescopes themselves.

The Array facilities will be the property of the Georgia State University Research Foundation, Inc., and GSU will support the basic operational costs of the Array. Partial support for scientific activities at the Array will be sought in competitive, peer-reviewed programs.

5. SITE SELECTION

During the planning phase, numerous possible sites for the CHARA Array were studied. The Mt. Wilson site was selected based on a balance of specific considerations, as summarized in CHARA Technical Reports 11 and 13. Significant factors relevant to the construction of the Array are the well-developed infrastructure at Mt. Wilson and the proximity to a major metropolitan area. A significant limitation of the Mt. Wilson site, with regard to planning for the CHARA Array, is the irregular topography and numerous existing facilities, which limit the options for the new Array.

6. HISTORY OF MT. WILSON OBSERVATORY

Mt. Wilson is a 5,650-ft peak in the San Gabriel Mountains north of Los Angeles. The Mt. Wilson Observatory has a long history of major contributions to science. These include classic physics experiments undertaken by Albert Michelson, one of the greatest American scientists, near the turn of the century. It is accurate to state that optical interferometry was born here, and Michelson and his colleagues made use of the 100-inch telescope, dedicated in 1917, for pioneering interferometric observations involving the measurement of the diameters of stars and the detection of the individual components of binary stars not previously seen as doubles.

Although Michelson worked here for access to the world's largest telescope, which the 100-inch remained until the dedication of the Mt. Palomar 200-inch reflector in 1948, it is now understood that Mt. Wilson is an outstanding site, possibly the premiere site in the world, for the very difficult interferometric measurements. These measurements require excellent image quality afforded through very stable, laminar air flow over the site. The close proximity of Mt. Wilson to the marine flow off the Pacific Ocean often gives rise to exceptional conditions found more typically at high elevation island sites such as Mauna Kea, Hawaii.

These qualities have brought two major interferometer programs to Mt. Wilson in the last decade, both initially sponsored by the Naval Research Laboratory. One of these projects, the Mark III interferometer, served as a prototype for an instrument constructed by the U.S. Naval Observatory in northern Arizona, while the other, the Infrared Spatial Interferometer operated by the University of California at Berkeley, is undergoing an expansion to a third telescope funded by the NSF. Other NSF-supported projects underway at Mt. Wilson include the laser-guidestar adaptive optics program of the University of Illinois and the binary star speckle interferometry program of CHARA. Both of these activities involve regular access to the 100-inch telescope. The Mt. Wilson Institute has privately funded an adaptive optics system for the 100-inch. These programs now in progress are bringing modern high-resolution capabilities to the venerable 100-inch telescope, once again putting this instrument at the frontier of current astronomical technique.

These programs, combined with the CHARA Array, constitute a rebirth of the scientific facilities at Mt. Wilson, and ensure a healthy and productive observatory into the coming decades.

7. SITE OWNERSHIP AND LEASES

The Mt. Wilson Observatory is located on land managed by the U.S. Forest Service (USFS) as a part of the Angeles National Forest, although the first astronomical facilities at Mt. Wilson actually predate the National Forest system by many decades. The property is managed by the Mt. Wilson Institute (MWI) under a sub-lease from the Carnegie Institution of Washington, the actual owner of the existing facilities on the site. The present 99-year lease expires on 31 December 2003 and may be extended at the option of the Carnegie Institution for another 99 years. If Carnegie chooses not to extend the leasehold itself, this right is passed along to the MWI which also has the authority to host other research projects on the mountain. In this regard, GSU signed a Memorandum of Understanding with MWI on 30 October 1995 which formally designates Mt. Wilson as the site for the CHARA Array.

8. ENVIRONMENTAL ASSESSMENT

Mt. Wilson and adjacent terrain in the front range of the San Gabriel Mountains has a long history of development and exploitation, including resort, recreation, logging, skiing and other commercial uses.

At present, the Mt. Wilson Observatory site is heavily wooded, in part with non-native species. Numerous telescope and support buildings are distributed over the site. The abundant pine trees on the site are much higher than the conventional buildings. Only the telescope domes rise above the tree line. An extensive array of radio and television transmission antennas adjacent to the observatory (but not on the observatory grounds) are prominent on the Pasadena skyline. Owing to the history of extensive use, the CHARA Array project is not expected to raise major environmental issues.

Because federal funds are being used for construction purposes, the National Environmental Policy Act requires an assessment of the potential environmental impact of the Array. Furthermore, the responsibility for reaching a finding regarding this impact lies with the funding agency, in this case the NSF. The fact that the land is managed by the USFS does not mean that the Forest Service has the responsibility for the environmental assessment (EA). Instead, the USFS will serve as a "cooperating agency" with the NSF. If the EA process results in a "finding of no significant impact," the USFS will issue a signed "decision notice" concurring with the results of the NSF-managed EA. A "special use permit" to CHARA is not required under the terms of the existing lease. In order to complete the EA in a timely manner, CHARA, with the approval of the NSF, has contracted with Woodward-Clyde Consultants of Santa Ana, California, to undertake the EA with an expected completion date of 29 April 1996.

9. NATURE OF THE CONSTRUCTION

The facilities to be constructed which together comprise the CHARA Array fall into three categories: telescope enclosures; vacuum light pipes and associated support piers; and the central Beam Synthesis Facility. CHARA may choose to bid each of these as separate subsystems or combine them into a single bid package.

The designed life expectancy of astronomical telescopes is typically 20 years, although, as the 100-inch telescope on Mt. Wilson clearly demonstrates, much longer lifetimes are common due to occasional upgrades and refurbishments. The CHARA Array design lifetime without major renovation is also 20 years. It is possible that the entire Array could at some time in the future be moved to another site, should a better site be identified. Therefore, much of the facility will be relocatable. This will include the telescopes, substantial parts of the telescope enclosures, the beam pipes, and most of the central facilities.

10. TOPOGRAPHICAL SURVEY

A topographical survey of the planned Array site was commissioned by CHARA and executed by Pafford Associates (PA) of Los Angeles. PA conducted an aerial photographic survey, producing images both for reconnaissance and topographical analysis. They also carried out ground measurements to support the computer aided analysis. This effort resulted in topography with 2-ft contour intervals and is available in several forms, including hard copy topographical maps, CAD compatible maps, and computer readable tables of raw terrain coordinates. This map is the basis for planning and is illustrated in the figures which accompany this report.

Figure 1 shows the portion of the Mt. Wilson Observatory grounds where the proposed Array will be located. This map shows the structures and roads currently in place. The contour interval in this figure is 10 feet. The large circular structure nearest the center of the map is the 100-inch telescope building, the smaller circle just to the southeast of the 100-inch building is a 500,000 gallon water tank for fire fighting, and the smallest circle at the south end of the map is the 60-inch telescope building. Existing roads are shown with dashed portions indicating road boundaries obscured by trees in the survey aerial photography and not drawn on the original PA map but subsequently inserted by CHARA staff. An aerial photograph of the Mt. Wilson Observatory is attached at the end of this Technical Report.

11. DEMOLITION AND RELOCATION

One existing structure, a 4-bay concrete block garage located just to the northeast of the 100-inch telescope building, will be razed to provide additional space required by the central Beam Synthesis Facility. No other existing structures will be removed nor will the historically important telescope buildings be disturbed.

Underground electrical utilities near the 100-inch telescope building, and water pipes near the existing 60-inch telescope, may be relocated or modified to allow Array construction.

12. WIND SPEED PROPERTIES

Typical winds on Mt. Wilson range from dead calm to a moderate breeze with maritime generated winds from a southerly direction. For planning and design purposes, we propose designing facilities to withstand 120 mph winds to provide a margin of safety over what might be encountered as the result of very rare storm conditions.

13. ARRAY LAYOUT

The central concept of the CHARA Array requires a carefully planned distribution of the telescopes over a roughly circular area approximately 0.3 miles in diameter. The telescope locations must satisfy several criteria. In approximate order of importance, these are:

- Maximization of a technical quantity derived from the spatial and angular separations of the telescopes, the so-called "UV-plane coverage."
- Placement of the telescopes on sites with orographic characteristics which will provide acceptable image quality. Generally, these sites are somewhat higher than the nearby terrain, with minimal obstructions to wind flow in the windward direction.
- Suitable topography to allow line-of-sight beam transmittal from each telescope to the central Beam Synthesis Facility, with the beam pipes at convenient heights with respect to the local terrain. In addition, the sequence of reflections employed in the

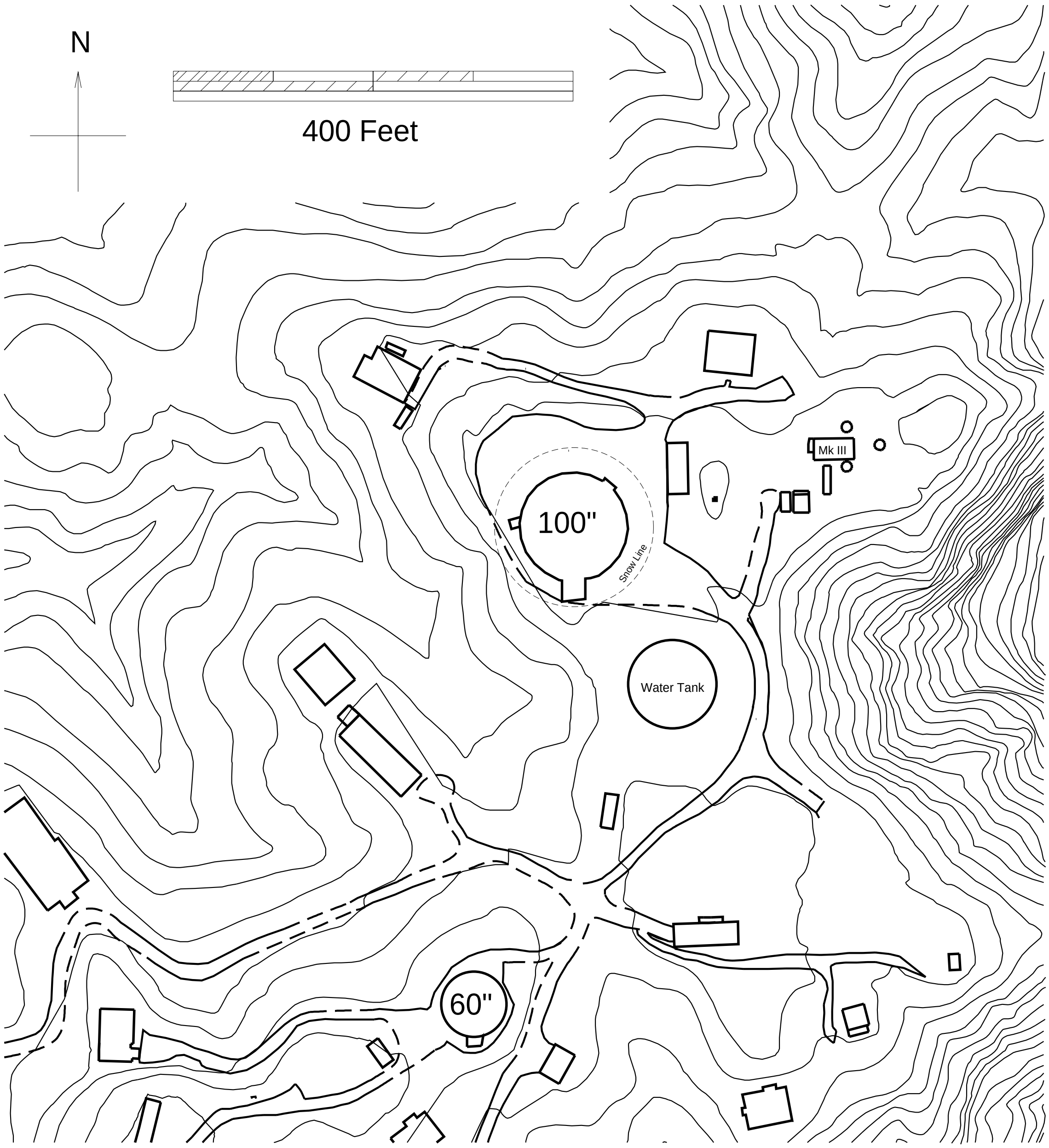

FIGURE 1. The Mt. Wilson Observatory with existing structures and 10-ft contour intervals is shown. The large circular building in the center is the 100-inch telescope building.

beam transmittal must conserve a technical characteristic of the light, the polarization. This requires that the beams follow a precise series of reflections according to prescribed angles.

Following an extensive study of the Mt. Wilson site, including the topographic and meteorological characteristics, an Array layout has been found which satisfies these requirements. The layout is shown in Figure 2. The locations of the telescopes are constrained rather strongly by the considerations listed above. The layout of the Beam Synthesis Facility is also strongly constrained by existing buildings and beam pipe clearances and elevations.

Most of the telescopes are on or near existing roads and structures. Several locations are on ridges which extend west and north from the currently developed core of the site. All are within the boundaries of the land set aside for astronomical activity.

The Beam Synthesis Facility (BSF) is planned for construction on the only centrally located, flat space with sufficient room for extensive instrumentation required at the central location of the Array. The location, orientation and relative locations of the OPLE and BC areas are very strongly constrained by the considerations mentioned above, leaving flexibility for only small adjustments during the detailed design. Snow dumping from the 100-inch telescope building prohibits locating any unprotected construction closer than 25 ft to the 100-inch dome, and we plan on avoiding that zone with our proposed buildings.

A control and office facility is a part of the central BSF so that electronic data and control communications to the BC and OPLE are appropriately short and protected.

14. TELESCOPES AND THEIR ENCLOSURES

The telescopes are discussed extensively in CHARA Technical Report No. 8 while Reports 10 and 22 discuss detailed technical requirements and present concepts for the telescope enclosures.

The telescopes are designed for remote operation. They are 1-meter aperture reflecting telescopes on altitude-azimuth mounts. The total weight of telescope and mount will be approximately 7000 pounds.

In order to operate correctly, the telescopes must be protected from vibration, from wind and from rapid thermal fluctuations. No sources of heat may be permitted near the telescope. Therefore, the telescope enclosures must have low thermal mass.

In order to raise the telescope above disturbing air currents near the ground, the telescopes will be raised above the ground on a pier.

In order to isolate the telescope from wind disturbances, the telescope enclosure will have footings which are independent and isolated from the telescope pier.

Each telescope will have a small control computer and auxiliary control electronics. These will be protected with a small Uninterruptible Power Supply (UPS).

There will be no heating system for the telescope enclosures. There will be a ventilation and air conditioning system (VAC) to maintain the interior of the enclosures at the nighttime temperature. The AC will operate during the day while the enclosure is closed. Note that this AC will operate even in winter. At night when the enclosure is open, the AC will be shut off, louvered ventilation ports will be opened, and a ventilation system will draw outside air through the enclosure.

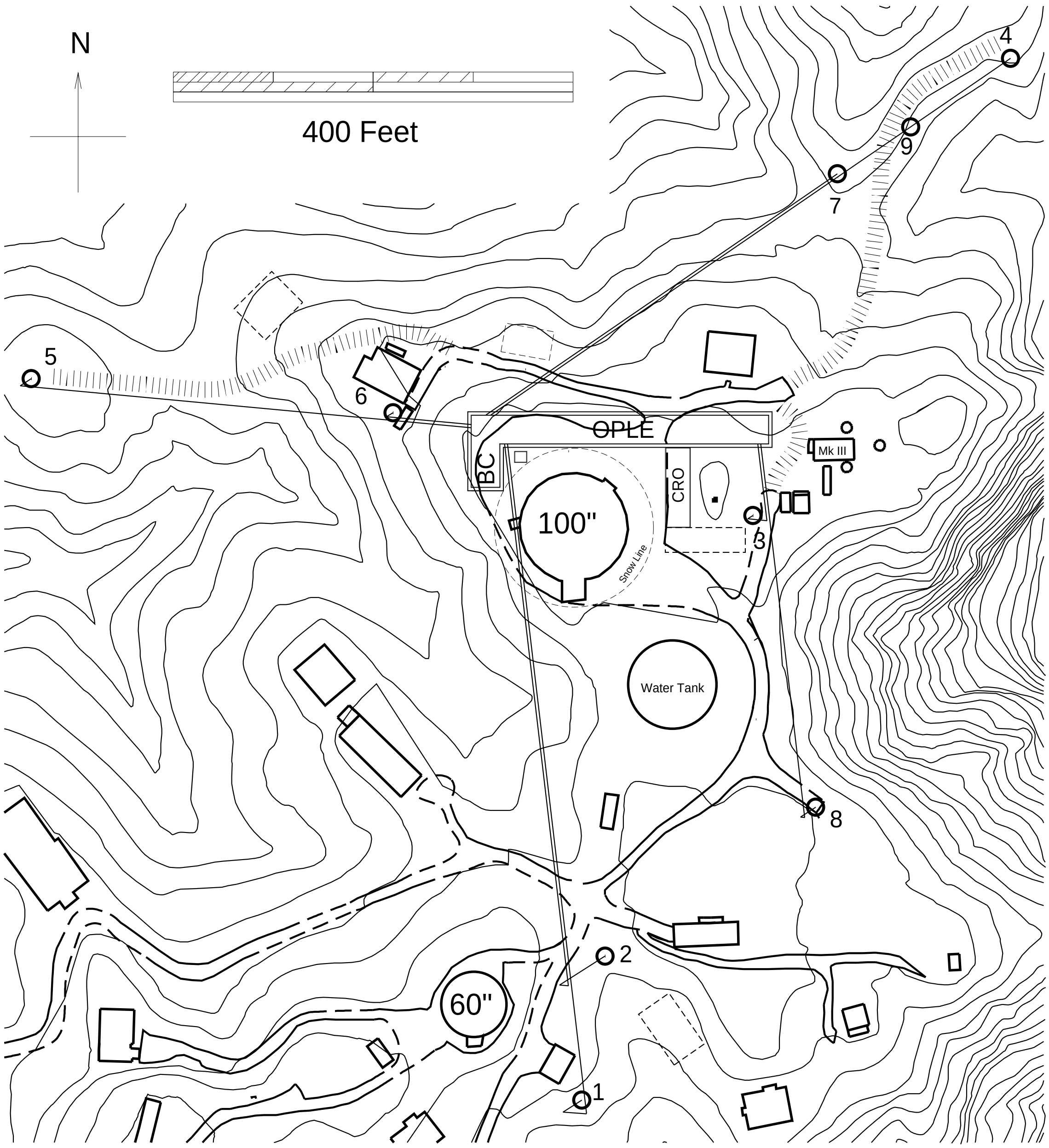

FIGURE 2. The layout of the planned CHARA Array. This figure differs from Figure 1 by the deletion of an existing garage, and the superposition of the new Array construction. Telescopes 1–5 are proposed for construction under the currently approved budget. Telescopes 6 & 7 are proposed for construction with requested additional funds. Telescopes 8 & 9 are possible locations for additional future expansion, not currently planned. The proposed buildings are all drawn to scale. New road sections required to provide access to the telescopes on the NE and W arms are shown as a series of hatch marks. The dashed rectangle adjoining the CRO area shows the potential location of an office/shop area while future potential sites for offices are shown as dashed rectangles just to the northwest and northeast of telescope 6 and to the northeast of telescope 1.

In order to avoid vibrations and undesired thermal effects, the ventilation equipment, computer, UPS, and other electronics will be located in a small, separate enclosure on an isolated slab separate from the telescope enclosure. This isolated enclosure will include a small heating unit in addition to the VAC in order to keep the computer equipment within the proper operating temperature regime.

These telescopes differ from many conventional telescopes. They will be operated strictly be remote control. The enclosures will only be accessed rarely by staff for installation or repair of equipment. The enclosure footprint dimensions will be kept minimal.

The design of the enclosures has not yet been settled, but several concepts have been subjected to preliminary investigation. Generally, the favored concept involves a massive pier to support the telescope at a suitable height above the ground (top of the telescope about 30-40 feet above ground level). The enclosure is likely to be supported on posts, with no slab (which would provide an undesired thermal mass). The height of the enclosure, as determined by the length of the supporting posts and the height of the telescope pier, may differ from telescope to telescope, depending on local topography. The lengths of supporting posts will be in the range 3–12 feet. The diameter of the enclosure will be approximately 16.5 ft. Figures 3 and 4 show a concept for the enclosure.

It will be necessary to trim or remove a number of trees near each telescope. Scientific operation will begin at 30 degrees above the horizon. As some of the trees on the observatory grounds are considerably taller than the CHARA telescopes, those which are quite close to the telescopes may be trimmed or topped to allow the telescopes to operate over the sky. We understand that the present tree density on the observatory grounds represents an all-time record growth that may exacerbate the hazard of fire and that MWI is presently studying the situation. Trees also tend to adversely affect astronomical seeing conditions. Nevertheless, we recognize that trees contribute to the natural beauty of the site and provide habitat for birds and small mammals, and we wish to have the least possible impact on tree density consistent with successful achievement of the scientific goals of the Array project.

15. LIGHT BEAM PIPES

The light from the telescopes will be carried through evacuated 8-in diameter aluminum pipe to the central Beam Synthesis Facility. The Array layout has been arranged to locate the beam pipe at an accessible height at all locations. The height will range from slightly below ground level, to a maximum in excess of 30 feet above the ground over several short stretches. The greatest height occurs on the west arm of the Array, and we note that a relatively minor clockwise rotation of the west light pipe about telescope position number 6 can significantly reduce the maximum height on that arm.

Figure 5 shows the approximate elevation above local terrain of the beam pipe paths shown in the facility layout. These elevations are based upon our analysis of topographic data from the Pafford Associates survey.

The pipe will be installed typically in 20-foot sections, with a support pier at each section junction. Longer sections may be used in some locations to save construction costs, simplify installation, and/or reduce environmental impact. In order to allow for thermal expansion, there will be a gap between pipes with a flexible no-hub connector. The connector will be air tight to preserve the low pressure condition in the pipes. The pipes must be aligned to within approximately 0.5 inch. The pipe supports will allow sufficient adjustment in the pipe positions to align them accurately. Figure 6 shows a concept for a pipe support pier.

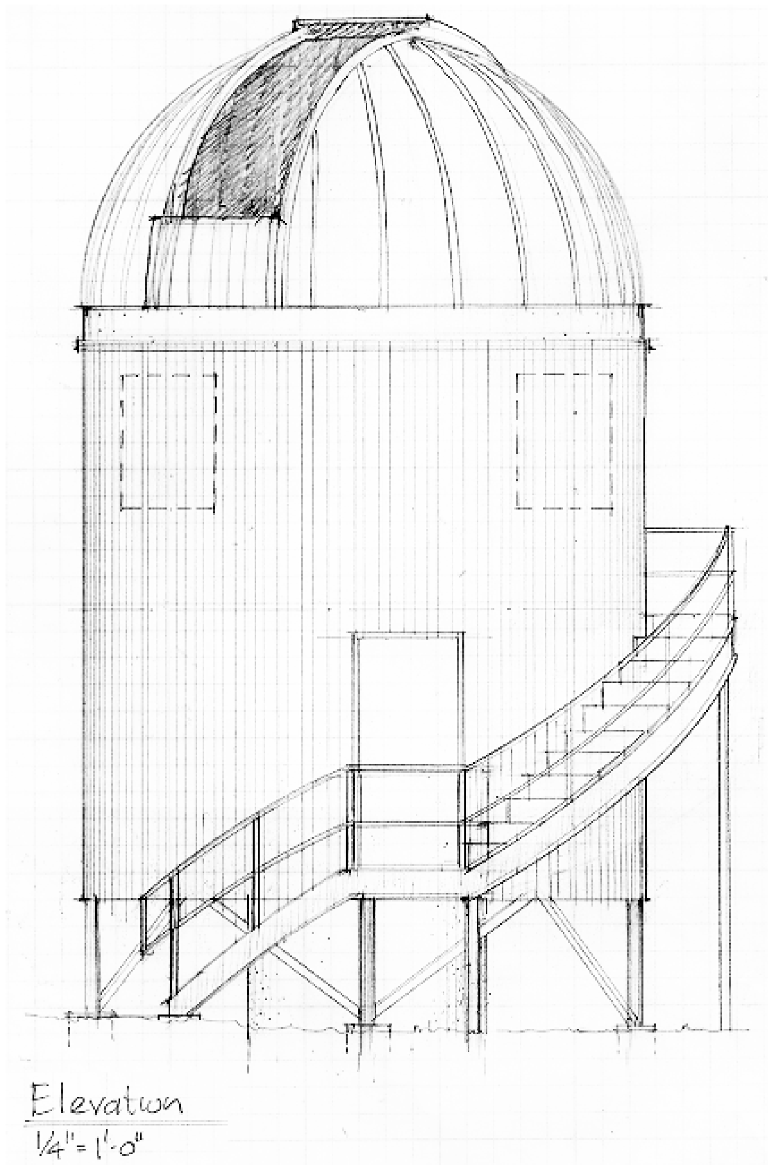

FIGURE 3. A conventional concept for the telescope enclosure, based on a cylindrical or square building with a hemispherical dome.

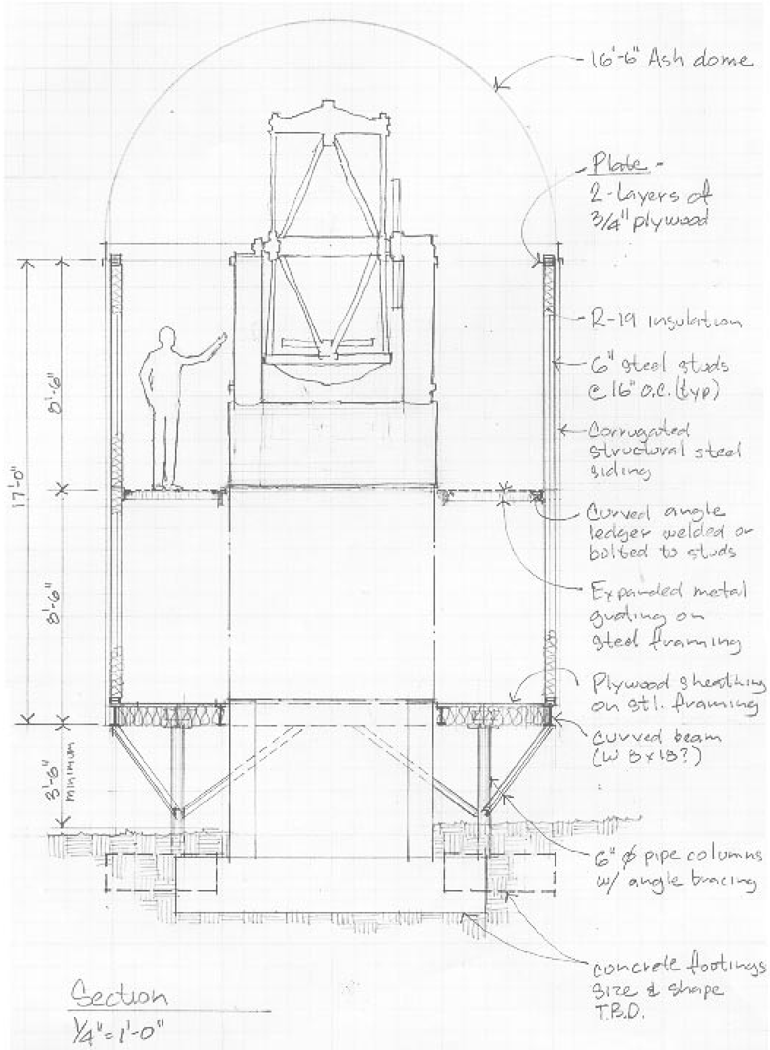

FIGURE 4. Cross section of a telescope concept showing a possible structural configuration.

Pipe below ground level will be located in a backfilled or covered trench. Where the pipe is above ground level at a readily accessible height, it will be protected with chain link fence. Where the pipe is well above ground level, the support piers will be individually protected to discourage tampering.

There will be some flexibility in the precise location of the beam pipes, and this will be employed to adjust the beam line to minimize tree removal along the beam path. Some trimming of vegetation will be needed to allow passage of the beam pipe.

16. THE BEAM SYNTHESIS FACILITY

The Beam Synthesis Facility (BSF), located at the central convergence of the light beam pipes, contains the core equipment which allows the Array to function. The BSF consists of

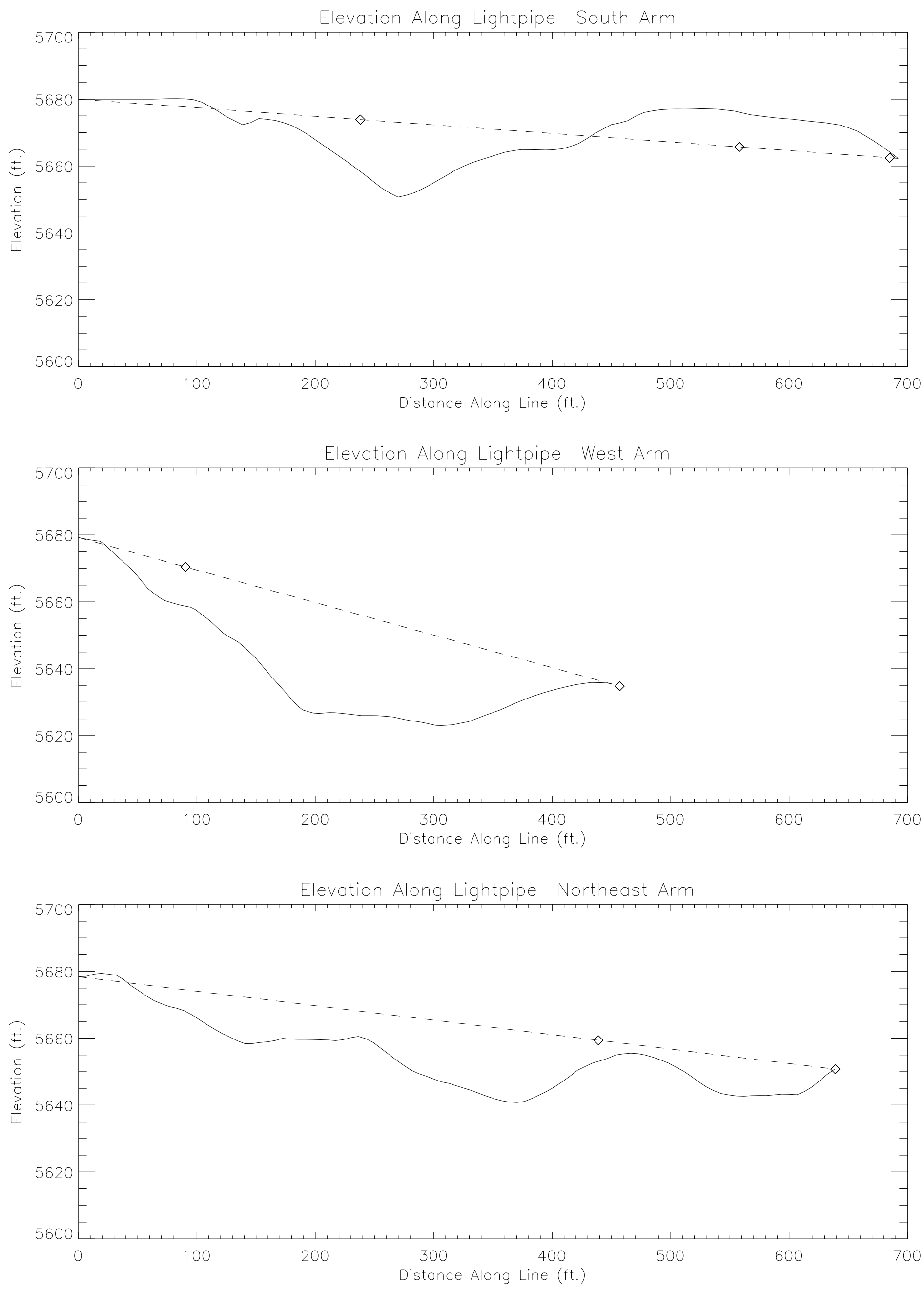

FIGURE 5. Profiles of the relative height of the beam pipes above the local ground level. (a) The South Arm. (b) The West Arm. (c) The North-East Arm. In these diagrams, the zero point of each horizontal coordinate indicates the center of the Array; telescope locations along each arm are indicated by diamonds.

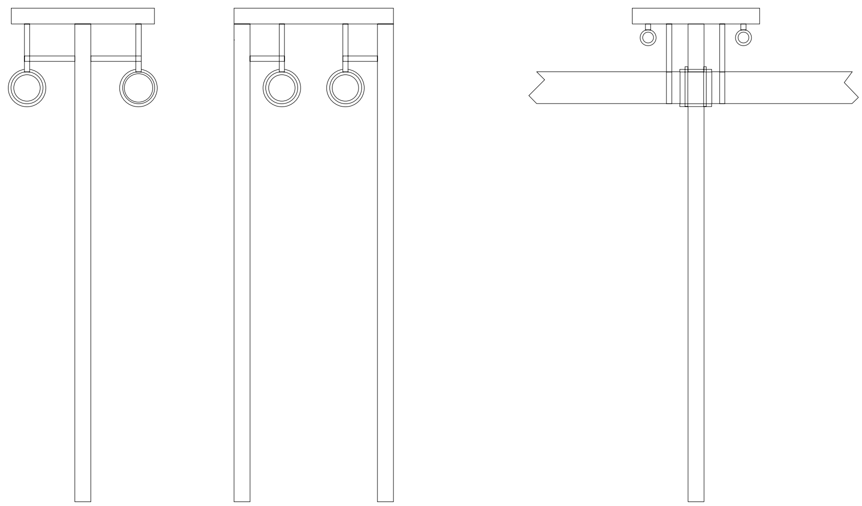

FIGURE 6. Two concepts for the pipe support pier. In this example the height is 15 feet. The actual height will be adapted to the local terrain to maintain a correct line-of-sight.

three parts: the Optical Path Length Equalizer (OPLE); the Beam Combination (BC) area; and the Control Room/Office (CRO) area. A small separate structure housing the vacuum pump system for the light beam pipes and heat-producing electronics may be constructed just outside the interior corner of the OPLE and BC areas.

The BSF can only function properly if the OPLE and BC are very carefully protected from vibration and temperature variations as well as from light sources. Air circulation must also be suppressed. The concept for the OPLE/BC housing provides for a double enclosure. The outer enclosure will be well sealed and insulated to R-20 or R-30 (value to be selected during the design optimization). The inner enclosure will also be well sealed with insulation of similar R-value. This double-walled enclosure is intended to provide for a very stable interior volume within which air currents and convective circulation will be minimized. Such effects have an adverse influence on the light beams passing through the long OPLE paths.

These structures do not provide habitable space and will be entered only for installation or repair of the OPLE/BC. The inner and outer enclosures will have no windows. HVAC will be provided to the space between the two enclosures. This space will be temperature stabilized for optimal interferometric function rather than for human comfort. The inner enclosure will have no HVAC connection, as the air circulation, rapid temperature fluctuation and vibrations would disrupt the optical phase which must be preserved in the OPLE/BC. Provision will be made to occasionally flush stale air from the inner enclosed OPLE and BC areas using fans. When not in use, the fans will be covered with insulated doors to maintain the integrity of the stabilized air in these areas. The temperature of the inner space will be extremely stable, with only very slow drifts, due to the temperature stability between enclosures and the thermal mass and heavy insulation of the inner enclosure.

Several additional steps will be taken to minimize disturbance of the OPLE/BC. The slab within the inner enclosure will be independent and partially isolated from the outer slab and the footings. The HVAC equipment will be located on an isolated slab which is outside the outer OPLE/BC enclosure. All ducts will be connected to the outer enclosure and not to the inner enclosure.

A conceptual layout for the Beam Synthesis Facility is shown in Figure 7. At the east end of the OPLE, and at the south end of the BC, 14-ft wide overhead doors give access to the facility for initial installation of equipment. The corresponding end walls of the inner enclosure facing the outer overhead doors will be left open initially. At the completion of construction and after installation of equipment, these openings will be closed with semi-permanent walls. These walls would only be reopened for removal of equipment following termination of scientific operations. Single hung doors, not shown in Figure 7, will provide access to personnel for occasional maintenance or repair.

16.1. The Optical Path Length Equalizer (OPLE) Area

The OPLE is a set of optical devices which adjust the optical path length of the beams from the telescopes. The length of the OPLE is determined by the magnitude of the required adjustments. The optical equipment in the OPLE will consist of two types: the fixed delay segments and the variable delay. The fixed delay segments will consist of a number of remotely actuated mirrors in long pipe sections. The pipe will be evacuated. The variable delay will consist of a number of mirrors mounted on movable stages, which will be translated along fixed rails, under remote control. The variable delay paths will be in air rather than in vacuum. The technical plan for the OPLE optics will be given in detail in a future CHARA Technical Report.

16.2. The Beam Combination (BC) Area

As with the OPLE, the correct function of the equipment in the BC area requires complete isolation from rapid thermal drifts, air movement, and vibration. Therefore, the BC area will be located within the same double-walled environment. Figure 7 includes the conceptual layout of the optical equipment tables in the BC area.

16.3. HVAC for the OPLE/BC

In order to maintain the inner OPLE/BC enclosure at a constant temperature, the air-space between the inner and outer enclosures will be carefully conditioned, including air conditioning and heating, as necessary. There will also be provision for humidification, dehumidification and filtering to remove dust.

Provisionally, the HVAC will be located in the Control Room wing of the BSF. It will be mounted on an isolated slab to minimize vibration transfer to the OPLE area. The OPLE ducts will be sized to operate with low velocity air circulation in order to limit duct vibration. The ducts will be fixed to the outer enclosure and/or slab, and will provide sufficiently uniform distribution to minimize the formation of hot or cold spots within the inside enclosure. The ducts to the OPLE/BC will be partially isolated mechanically from the HVAC equipment with flexible sections of duct.

16.4. Electrical Equipment in the OPLE/BC

As the OPLE/BC will operate under remote control, there will be some automation. The control systems are to be housed in the Control Room/Office (CRO) area, and control signals will be carried via optical fiber. The maximum instantaneous total power load for this equipment is estimated to be considerably less than 10KW.

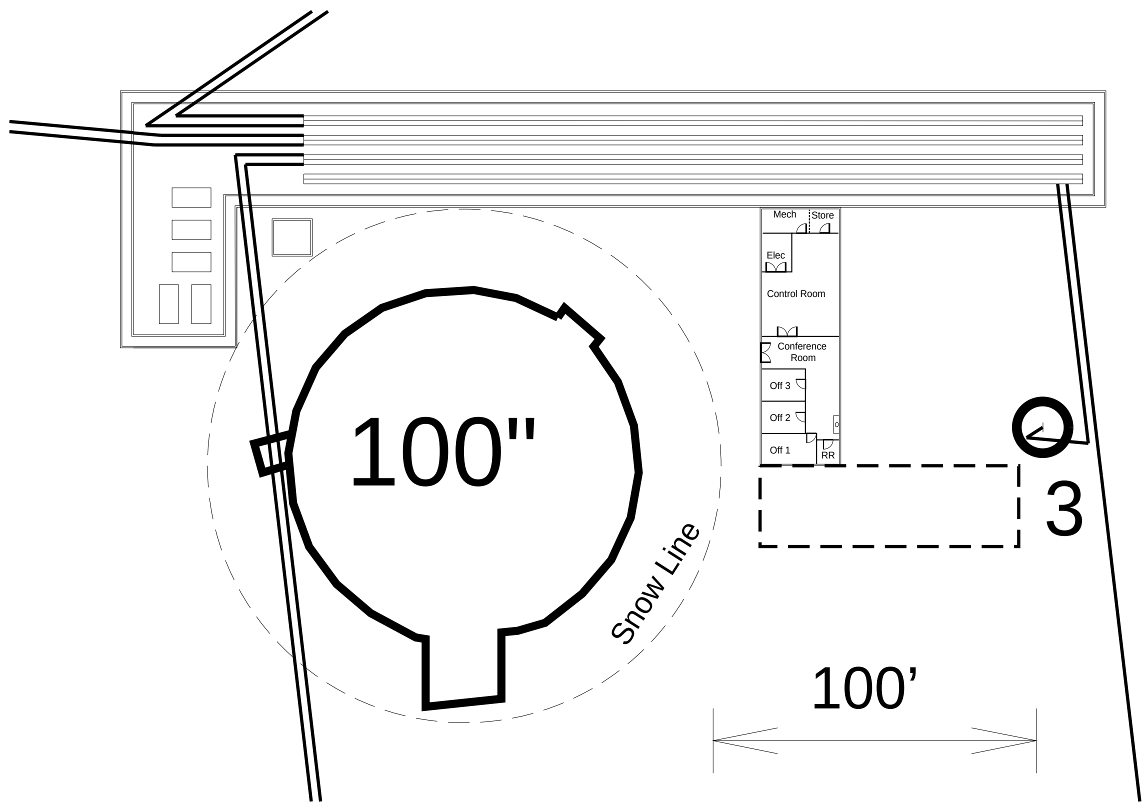

FIGURE 7. The layout of the Beam Synthesis Facility (BSF) is shown above, indicating the interior double wall, the placement of some optical equipment support structures and tables, and the intersection of the light beam pipe system with the BSF. A potential location for an additional office/shop facility is shown as a dashed rectangle. The small square just outside the interior corner of the BC and OPLE areas represents a building for mechanically and thermally isolating the light pipe vacuum system and electronics racks serving equipment in the BC and OPLE areas. The light beam pipes running within the "snow line" of the 100-in telescope will be protected from falling snow, most probably by trenching so as to be just below grade.

16.5. Beam Access to the OPLE/BC

The optical beams from the telescopes will be conducted to the OPLE through beam pipes as discussed above. Most of these pipes will enter the OPLE at the west end, following precise geometric orientations. One will enter the east end of the OPLE. These pipes will pass through the outer and inner enclosure walls to the optical equipment within. After processing in the OPLE, the beams will leave the OPLE at the west end, and pass south into the BC.

16.6. OPLE/BC Slab

The terrain at the OPLE/BC site is generally flat, with some required excavation at the east end, and some fill, stem wall and possibly a retaining wall at the west end.

In order to isolate the OPLE/BC from wind disturbances of the outer building, the inner building slab will be separate and partially isolated from the outer building slab.

The OPLE/BC equipment will be very precisely aligned, to approximately 1 arcsec. Drifts due to settling of the slab must be minimized by thorough compacting of the soil. In the detailed design, the inner slab will be poured in a number of sections, each suitably reinforced to minimize warpage.

Because the beam pipes will be evacuated, at any point where a pipe ends or bends there will be a force on the pipe equal to atmospheric pressure over the pipe cross-sectional area. For a pipe diameter of 8 inches (as for the outside pipes and at the OPLE entrance) this pressure will be approximately 800 pounds. For a 12-inch pipe (as for the fixed delay segments in the OPLE) the force will be approximately 1800 pounds. The slabs beneath these points will be designed with suitable reinforcement and anchor bolts to hold the pipe mounting fixtures and withstand these forces.

16.7. The Control Room/Office (CRO) Area

All functional aspects of the CHARA Array will be controlled and monitored from the CRO which will have space for computers and other electronics and control equipment required for operation of the telescopes, OPLE, and equipment in the BC area. The building structure does not present any special requirements, other than good insulation in order to minimize thermal plumes which can disturb astronomical operation. Due to the proximity of the CRO to the OPLE, it may be convenient to house the OPLE HVAC in the CRO area.

Figure 7 shows a nominal floor plan for the CRO area consisting of a control room, with working space for up to 4 persons, adjacent conference and office space, and a restroom. It may be possible to tie the rest room into the waste water septic tank and leach field now serving the 100-inch telescope building as these lines are located on the eastern side of that building.

Electronic communication to the OPLE and BC equipment will be via wires and optical fibers distributed through the BSF in cable carriers. Communication to and from the telescopes will include control, data, and images, and will be passed via wire and optical fibers distributed to the telescope enclosures in cable carrying pipes suspended with the beam pipes.

17. ADDITIONAL OFFICE FACILITIES

Additional office space may be provided, budget permitting, for use by CHARA staff and visiting scientists. It may be possible to adapt existing observatory buildings to this purpose, should they become available. Otherwise, one or two additional small office buildings may be constructed. Several possible locations are shown in footprint on the site layout (Figure 2). A total floor space of approximately 2000 sq-ft will be required.

18. BUILDING COLORS AND FINISHES

Wherever possible, building finishes will be white in order to match the predominant color used on the existing astronomical facilities on Mt. Wilson. "Observatory white" has very good thermal properties that prevent building walls from heating up in direct sunlight. The use of factory supplied finishes to exterior walls is desirable from the perspective of durability and lifetime. The domes atop the telescope enclosures will be an unpainted aluminum finish possessing favorable thermal reflectance properties. The light beam pipes will be unpainted, weathered aluminum and their support piers will be treated steel.

19. SUMMARY OF NEW STRUCTURES

A summary of the properties of the new structures is shown in Table 1.

TABLE 1. Characteristics of Proposed Construction

Building or Auxiliary	*Number*	*Size*	*Power*
Telescope Enclosure	5	200 SF	5.0 kva
Telescope VAC/Computer	5	100 SF	6.5 kva
BSF	1	10000 SF	60.0 kva
Electronics/Pump Room	1	TBD	10.0 kva
Beam Pipes	3	700 LF	0
Beam Piers	100	10 SF	0
Future Offices	2	2000 SF	15.0 kva

20. RADIO FREQUENCY (RF) INTERFERENCE AND LIGHTNING

Mt. Wilson has a large complement of radio and television transmitters. These transmissions can severely impact sensitive electronics which will be present throughout the Array facility. In order to shield this equipment, the Array will use the concept of the "Faraday cage." That is, each critical structure, including the telescope enclosures and the entire Beam Synthesis Facility, will be sheathed in a conducting material. Most likely, this will be achieved simply by selection of a standard metal sheathing for the exterior of the outer enclosures. This could also be accomplished with metal sheathing or wire mesh installed within the walls or on the interior surface of the walls.

Conventional lightning protection will be required for all facilities, and will also be implemented on the beam pipe support piers, in order to reduce the likelihood of damage to the pipes and their connectors.

21. ROADS AND ACCESS

Most of the Array facilities will be located on or near existing paved roads. Access to the west and north-east Array arms will require road extensions totaling about 1000 feet. The proposed routes are shown in Figure 2. These roads will have inclines up to about 25% and will be intended solely for passage of construction vehicles and for repair and maintenance requirements. The local soil, graded and untreated, with a protective layer of gravel, will serve as a suitable roadbed for these purposes.

In one place, a new road section will cross a minor drainage area, approximately 500 feet northeast from the Beam Synthesis Facility. This may reasonably be stabilized with a grade level crossing.

The beam tubes will have support piers at intervals of 20 feet, with possibly longer sections in places. Some of these piers will be on slopes and at some distance from roads. There is no plan to grade roads to these locations, though limited clearing of brush may be required to allow passage of personnel and light equipment, concrete pumping equipment, piers, and beam pipes. Access by foot will be sufficient for subsequent maintenance or repair.

22. USE PROFILE

The CHARA Array will have a permanent staff of approximately 3 FTE. Some of these staff may reside in existing buildings on the observatory grounds while others may commute from a nearby community. In addition, there will be a regular flow of visiting scientists and graduate students who will be lodged on the observatory grounds in the existing dormitory facilities known as the "Monastery."

There will be regular activity at the Array on nearly a 24-hour schedule, including support work on a normal business schedule, 5 days per week, and scientific work at the telescopes during the nighttime hours. In addition, there will be daily scientific work in the offices at an irregular schedule.

23. SECURITY, SAFETY AND FIRE PREVENTION/PROTECTION

Most of the telescopes and other buildings and structures will be located near the central, extensively developed part of the observatory grounds. The roads which access the few more distant telescopes will be designated "off limits" to visitors.

The buildings and other enclosures will not offer any special hazards, and will be closed and locked securely to protect equipment. Alarm systems will be installed to alert staff to unauthorized entry and to warn away intruders. Smoke detection will be provided in all structures. The incorporation of a sprinkler system will be considered. We note the close proximity of the BSF to the primary fire fighting water supply on Mt. Wilson.

In addition, all telescope enclosures, the OPLE and the BC areas will have provision for remote TV monitoring. This will be provided in any event for operator convenience during remote operation, and will also be useful for centralized security control.

The beam pipe could be damaged by vandalism or accidental mistreatment. Where the pipe is above ground level at an accessible height, it will be protected with chain link fence and posted. Where the pipe is well above ground level, the support piers will be individually protected and posted to discourage casual access.

24. PERMITTING

The CHARA Array will be planned and built in accordance with all applicable federal, state, and county regulations. The issue of environmental assessment has been discussed above. The CHARA funding agencies do explicitly require that all construction shall satisfy local building codes. CHARA will initiate the permitting procedures in parallel with the environmental assessment process as soon as sufficient architectural details are available.