CHARA TECHNICAL REPORT

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Beam Synthesis Facility Design Considerations

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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. SCOPE OF THIS REPORT

This Technical Report provides additional information about the BSF beyond the overview in TR 23 which should be consulted for information of a more general nature not discussed herein. This report differs primarily in providing additional information about the underlying reasons for requirements described in TR 23, and explaining the scientific equipment which will be installed. More details of the baseline concept and some of the options which have been considered during the conceptual planning are also presented here.

The interfaces between the building and the scientific equipment still require additional study and documentation will be described explicitly below. There are a few known differences between TR 23 and this report. These will be called out specifically where they are recognized.

3. BEAM SYNTHESIS FACILITY OVERVIEW

The central Beam Synthesis Facility (BSF) contains the core equipment which allows the Array to function. It consists of five parts: the Optical Path Length Equalizer (OPLE), the

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FIGURE 1. The Beam Synthesis Facility is shown above, identifying the OPLE, BC, BPJ areas (which together constitute the Optics Enclosure), the CRO section, and the VPES.

Beam Combining Area (BC), the Beam Pipe Junction (BPJ) area, the Control Room and Office (CRO) area, and the Vacuum Pump and Electronics Shelter (VPES).

The OPLE/BC/BPJ areas constitute a unified environment of isolated and protected equipment space. This combined area will be referred to as the Optics Enclosure. The CRO area is virtually a separate building, adjacent to the OPLE/BC for convenience of electronic communications. The VPES is a small shelter near the BSF where vibrating and heat producing equipment will be housed.

This terminology is clarified in Figure 1, which also presents a conceptual layout for the BSF. Note that in this figure, the BCO area is shown as a separate structure, whereas in TR23 the structures appear joined. The structural separation is probably required by the desire to protect the Optics Enclosure areas from vibrations in the CRO area.

The CHARA Array can only function properly if the equipment in the Optics Enclosure is protected from vibration and temperature variations as well as from light sources. Air circulation must also be suppressed. The concept for the Optics Enclosure provides for a double enclosure. These structures do not provide habitable space, and will be entered only for installation or repair of the OPLE/BC/BPJ equipment. 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 to a temperature optimized for the interferometric function. 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. The temperature of the inner space will be stable, with only slow drifts. This will be achieved without active HVAC in the interior due to the temperature stability between enclosures, and the thermal mass and heavy insulation of the inner enclosure.

The double enclosure concept has been validated in three similar facilities, one at Mt. Palomar, one at Anderson Mesa in Flagstaff, and one in Australia.

Several additional steps will be taken to minimize disturbance of the Optics Enclosure. 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 outside the outer enclosure. All ducts will be connected to the outer enclosure and not to the inner enclosure.

The Control Room/Office area will provide space for the Array operator and visiting astronomers. Here they will control the Array through a computer/electronic interface.

4. THE STRATEGY FOR FACILITY REQUIREMENTS

It might be assumed that a scientific project such as the CHARA Array would have precisely defined technical requirements which would lead to exact facility requirements. This is generally not the case.

The CHARA Array is a new type of facility, which will offer a research capability which will depend on the quality of the facility. This quality will be limited by the project budget (which is fixed) and by our ingenuity in dispensing project funds effectively.

At each stage in the project, and in countless decisions in the facility design, tradeoffs must be made to determine the most cost-effective allocation of limited funds. Some of these tradeoffs have been made in an early planning phase. The telescopes will have an aperture of 1 meter (39 inches). The size of the array will be approximately 1200 feet. However, many tradeoffs remain to be made. Some of these will be discussed below.

In general, it is expected that cost-effective allocation of funds will result from using standard design and construction practices. If cost-conscious implementation of the preliminary concept leads to budget difficulties, it will be necessary to identify the most reasonable reductions in cost.

5. THE LIGHT PATH THROUGH THE BSF

As an aid to understanding the building configuration, the path of the light beams through the BSF will be described. The beams are transmitted from the outlying telescopes to the BSF through 8-in diameter vacuum pipes.

In most cases, the light pipes will enter the building from the north-west corner, into the BPJ area. In the BPJ area, the beams will be reflected a number of times, as required by technical optics considerations. The beams will be sent down the BSF from west to east in 12 inch diameter vacuum pipes. At some point along the way, a flip-in mirror will reflect each beam back to the BPJ area. There, the light beams will leave the vacuum pipes through windows, and henceforth be transmitted in air. An optical network will send each beam again to the east in the OPLE unit, which will return the beam to the west end. In the BPJ area, the beams will then be passed through beam compressors (reduction in beam diameter), and reflected south into the BC area.

6. THE OPTICS ENCLOSURE AREAS

The OPLE/BC areas have a common requirement for protection from vibration, air motions, and rapid thermal variations. In order to achieve this protection, the OPLE/BC areas will be built on an independent slab and enclosed completely (building within a building). During operation, there will be no heating, ventilation or lighting in this area. This condition

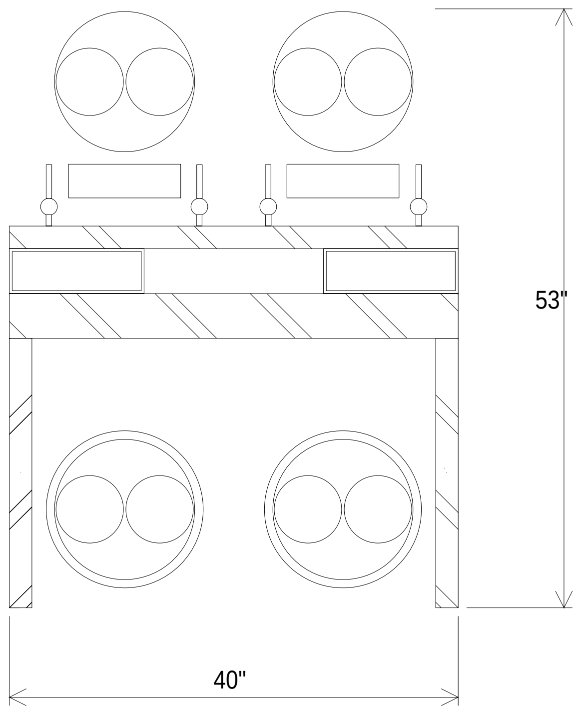

FIGURE 2. A conceptual cross-section for one OPLE pair. Two parallel beam pipes are shown in the lower section; two OPLE units, with rails and supporting structure, above.

is required for the operation of the instrument. This instrument area is not a habitable space, and will be entered only for installation and maintenance.

6.1. Size of the OPLE/BC Areas

A long OPLE area is desired in order to maximize the efficiency of the Array operation. In the current concept it is set to the maximum length that will readily fit on the site (about 300 ft). However, this length is subject to adjustment (reduction) as the cost estimates are improved should they exceed available resources. Specifically, implementation of the full length OPLE area will provide a research capability which is optimally efficient. A reduction on OPLE length will reduce the efficiency of the Array. This is not desirable, but may be considered.

The width of the OPLE area is determined by the requirement to fit eight beam pipes and OPLE's into the space, with access for installation and maintenance, plus the space required between inner and outer walls. Several concepts show that the two beam pipes and two OPLE units can be contained in a rectangular cross-section 40 inches wide and 60 inches high. Installation in pairs is proposed as shown in Figure 2, since convenient access to each will be required for initial alignment and any subsequent realignment.

In the current concept, the space between OPLE units is 2.5 ft. This is considered to be a minimum for access, including initial installation and eventual removal for maintenance of the vacuum pipes and the OPLE rails and rail supports.

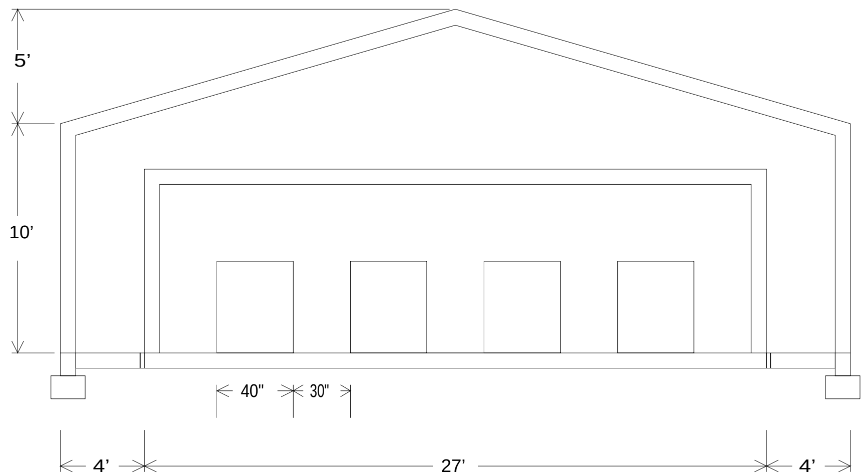

FIGURE 3. A concept cross-section of the OPLE area. The beam pipes and OPLE units are assumed contained within the rectangular spaces - two in each - as shown in Figure 2. The figure has been accurately drawn, with 40 in wide OPLE unit sections, 30 in spaces, 36 in between enclosures, and 8 in enclosure walls, but dimensions given in feet have been rounded to the nearest foot. The wall and overhead profiles are only suggestions.

In the concept, the space between inner and outer enclosure walls is 3 ft. This is based on the assumption that 3 ft is approximately the minimum space allowing access during erection, insulation, sealing, etc, and subsequent repair and maintenance. However, a construction concept which did not require this access could be considered. Adequate space must also be allowed for air circulation throughout this inter-wall volume.

Figure 3 shows a nominal cross-section of the OPLE area, based on these dimensions, and with an inner and outer wall thickness of 8 in. This gives a full width of the OPLE area inner enclosure of about 28 ft, and the OPLE area outer enclosure of about 34 ft. This width is subject to adjustment depending on design and code requirements. Generally it is certainly desired to keep this width to a minimum consistent with the required functionality. We have looked at the possibility of stacking the pipes and OPLE units in higher tiers (eg two deep), and find that unfortunately this is not compatible with the optical requirements for sequence of reflections and reflection angles.

The size of the BC area as shown in the concept is determined from the minimum space which will suffice for the first generation optical detection system. It is desired to keep the area at least as large as in the concept, and a somewhat larger area would be preferred to allow for a possible future expansion. In developing the concept, it appeared that a larger area would be difficult to achieve given the site constraints. If a larger area proves possible at moderate cost, it will be seriously considered. However, in considering an increase in size, the constraints on the BSF size and location, described below, must be respected.

Figure 4 shows the overall dimensions of the BSF concept, based on the functional requirements and site limitations. These are approximate and subject to adjustment during the preliminary design.

FIGURE 4. Dimensions of the conceptual Beam Synthesis Facility.

6.2. Protection from Vibration and Instrumental Drifts

The optical equipment in the BSF must be accurately aligned. When the alignment drifts, it must be realigned. At the alignment tolerance (about 1 arc-second) drifts will occur due to settling, thermal changes and mechanical relaxation. The optical equipment will include a considerable complement of remotely actuated devices for rapid and partially automated realignment. Nevertheless, frequent realignment will reduce the efficiency of operation. Therefore, the goal of the facility design is to ensure that these drifts are reduced to the extent possible, and that they are as slow as possible. The strategy proposed is to use thermal isolation, thermal mass, and limited temperature stabilization of the surrounding environment.

It is also important to limit the amplitude of vibrations of the optical equipment. From previous experience at seismically active sites, including Mt. Wilson and Mauna Kea, Hawaii, it is clear that the vibrations of concern are not natural tremors, but human activity. The strategy here is to use a partially isolated slab and to limit the input of equipment vibrations to the facility.

6.3. OPLE/BC/BPJ Area Slab and Vacuum Pipe Anchors

The Optics Enclosure areas will have an independent slab. The purpose is to reduce coupling of vibrations and thermal flow from the outside and from the outer BSF building walls and the inter-wall space. Obviously this decoupling will be only partial and the goal is to do as well as possible with limited resources.

At the least, the Optics Enclosure instrument area slab should be separated from the outer slab. The separation material should be of minimal rigidity. Some kind of insulation would serve the additional function of reducing heat flow through the slab. In the concept, we assume a 2-in layer of polystyrene or similar insulation.

We have not studied the utility of an insulation layer under the slab in order to reduce heat flow across the temperature difference between ground and building. This could be included if it would significantly improve the thermal isolation. We tentatively propose a

2-in layer of polystyrene or similar insulation beneath the inner slab.

The optical equipment will be supported on piers. It has not been determined if these will be supported on the slab, or on separate footings. The major consideration is probably the settling (with age) and the differential expansion of materials with temperature. The OPLE unit will have steel rails extending nearly the full length of the OPLE area. These rails will be assembled from butted rail sections. The alignment of these rails must be maintained accurately, and drifts of 0.10 inch will require realignment. The objective of the pier construction will be to minimize systematic drift (aging of concrete, settling of soils), and also to be tolerant of slow thermal drifts (differential expansion). The mechanical design of the rail/pipe supports has not been addressed in detail, and will have some impact on the detailed configuration of the slab.

For the present, it is proposed to cast the interior slab in discrete sections, perhaps 20-ft long to match the likely length of the beam pipe sections, and the full width of the OPLE interior enclosure (about 27 ft). Steel reinforcement will be employed to reduce the likelihood of sudden settling. The slab can be thicker than normal if this is an advantage and cost effective. It is desirable for the slab coefficient of thermal expansion to be the same as the steel in the rail assemblies, if this can be controlled by design and selection of materials.

The vacuum pipe optical system will have several components. A number of mirrors will direct the optical beams from place to place. These mirrors will be located inside vacuum housings, which in turn will be fastened securely to the slab or piers. Some of these housings will have atmospheric pressure forces on them of order 700-1000 pounds. Suitable bolts will be required in the slab/pier.

It will be the responsibility of CHARA to provide an accurate map of the required bolt characteristics and locations. This work has not yet been carried out. A deadline for this work should be established.

Between the mirror housings, the optical beams will travel through vacuum pipes. These pipes will be either 8 inch diameter (entering the OPLE) or 12 inch diameter (extending the length of the BSF). The pipes will be connected to the mirror housings and to each other with no-hub type connectors. The pipes will require physical support, with some adjustment for alignment, but the tolerances are not tight and there will be no forces other than gravity. The no-hub connectors will allow a gap between pipes which will accommodate expansion and contraction with thermal fluctuations.

The optical beams and surrounding vacuum pipes will be near floor level in the OPLE area, the exact height depending on whether the flip-in mirror housings extend above or below the pipes.

6.4. The Beam Junction Area

The north-west corner of the BSF building will serve primarily as a location for the entry and redirection of the optical beams. At this point the beams will be in vacuum pipes, so the area will contain mirror housings and vacuum pipes.

The returning beams from the BSF east end will leave the vacuum pipes here and be reflected back to the east. In this return to the east, the beams will be at a nominal height above the floor of 48 in. This height leaves space for the OPLE rails and rail supports.

In order to complete the detailed design of the BSF, specifications will be required for the entrance points of the vacuum pipes. These are known approximately at this time. The positions may be adjusted slightly during the detailed design of the telescopes, which will not commence until the BSF design is complete.

The proposed solution is to locate the pipe entrance points to within a tolerance of about 6 inches. Then, at each entrance point, a "knockout" aperture will be provided with a size of about 2 ft square or round. When the pipes are installed, the knockouts will be removed and replaced with custom closures.

Note that the beam from telescope number 3 will enter the BSF from the east end. The reflections will differ in detail from the other telescopes, but not in a way as to constitute a major change in concept.

6.5. Outer Enclosure

The outer enclosure of the OPLE/BSF is expected to be a conventional structure, possibly a pre-engineered building system suited for installation at moderate cost on Mt. Wilson. Several specific options considered in conceptual design will be mentioned in an Appendix.

As described in TR 23, the building should provide a Faraday cage protection from radio transmissions. An external steel, aluminum or other metal sheathing on walls and roof should serve this purpose, provided the individual sheets are physically contacted to provide a low-resistance path between any two points. If walls and/or roof were not metal sheathed, it would be necessary to provide additional metal screening. A detailed design of the Faraday cage effect is not planned, since experience has shown the efficacy of this technique.

The outer building should be well sealed against infiltration and well insulated. This is both to stabilize the interior conditions and also to control operating costs. A specification has not been set, but insulation in the range R=20–30 is expected to be appropriate. This number is suggested on the basis that it can be achieved with inexpensive materials and a wall of modest thickness.

6.6. The Inner Enclosure

The inner enclosure must be well sealed to prevent circulation of air currents. Ideally, it should also be well insulated. Again, an R value in the range 20-30 is thought to be appropriate. Here also, a number of pre-engineered building systems may be considered. However, since a relatively simple structure could be satisfactory, there may be more cost effective alternatives. Depending on construction costs, a wood stud and sheetrock structure might be favored, particularly since detailed finishing of the surfaces would not be required.

The major structural issue in the inner enclosure is perhaps the span of the roof, which is nearly 30 feet in the concept. Depending on live load requirements (probably driven by access for installation and maintenance of the HVAC), this might be supported with trusses, or with columns inside the OPLE/BC areas. Trusses are preferred, as columns would be an inconvenience, and would have to be located in specific locations across the width of the BSF.

Note that the roof/ceiling of the inner enclosure should not be hung from the outer enclosure, since this would transmit vibrations, eg. from wind or sound.

FIGURE 5. A concept for access to the Optics Enclosure area (OPLE, BPJ, BC), showing the configuration during equipment installation, with end walls on the inner enclosure left open.

6.7. Access to the OPLE/BPJ/BC Areas

In order to install the vacuum pipes, OPLE rails, optical support platforms, and associated piers and structure, it will be necessary to have access to the interior of the Optics Enclosure after construction of the BSF. However, this access should not result in compromise of the seal and insulation of the interior areas.

The proposed solution is to provide the ends of the BSF with 12–14 ft insulated overhead doors, and to leave the corresponding end walls of the interior enclosure completely open. This will allow convenient access to the interior, including access with a fork lift or other light equipment. Ventilation of the interior, while extensive work is underway, will also be facilitated. Upon completion of the equipment installation, the interior end walls will be finished and sealed, including access doors. If the exterior overhead doors are adequately insulated and sealed, they will be left in place. For obvious reasons, no windows are planned for the OPLE/BC areas.

For normal access (inspection, maintenance, safety) a number of single hung doors will be provided in exterior and interior walls. Figure 5 shows the doors which are proposed for operational access. Additional doors (eg code requirement for safety) should be kept to required minimum since each will likely be an area of reduced insulation and increased infiltration.

6.8. Heating, Ventilation, Air Conditioning

The primary objective of the HVAC is to protect the interior of the Optics Enclosure area from thermal disturbances, and to do so without introducing air currents. The method proposed is isolation of the interior space and conditioning of the air space between inner and outer enclosures. Note that it is not required to stabilize the temperature to a specific value. In fact, the most convenient value may vary with season, probably higher in the summer and lower in the winter. Keeping the temperature at a comfortable level for personnel is a secondary consideration, since access will be limited.

In order to maintain a relatively uniform temperature throughout the inter-structural space, and to avoid the formation of hot or cold spots, it is proposed to operate the ventilation system continuously. The ventilation fans should be outside the OPLE/BC/BPJ areas to avoid vibrations. Heating or cooling would be applied as required. The optimum type of heating is not known. However, electricity is quite expensive on Mt. Wilson, and most heating there is based on propane. The tolerance for temperature variations is not specifically set, as the objective is to do as well as possible at moderate cost. For the same reason, no detailed thermal modeling of the structure has been carried out or planned.

While it is desired to avoid unusually high or low humidity, it is not necessary to achieve a specific humidity level. A goal is to keep the humidity generally above 20% (to reduce static hazards to electronics) and below 70% (to limit deterioration of moisture sensitive optical and steel instruments. These are also not hard specifications, but are considered reasonable with moderate effort and cost.

Several ideas are proposed in the design concept to limit the HVAC disturbances to the OPLE/BC. All HVAC motors will be located outside the exterior wall of the OPLE/BC sections. All ducts will be connected to the exterior enclosure or associated slab, and not to the interior enclosure or slab. In the concept, the HVAC motors are assumed to be located in the Control Room/Office area, as discussed below. The air circulation will be designed for low velocity circulation to avoid generating excessive vibrations in the ducts. The ducts will have a flexible section to decouple the exterior equipment vibrations from the Optics Enclosure areas. These ideas for minimizing disturbances are proposed in the belief that they will be helpful and low cost. Additional or different strategies may certainly be considered.

Although the Optics Enclosure interior will be well sealed and not ventilated during operation, it will be desired to ventilate the space during installation or extensive maintenance. It is suggested to locate fans on each end of the inner enclosure to exchange air between the inner enclosure and the inter-enclosure space. These should have closures which provide adequate seal and insulation when not in use.

6.9. Lighting

In normal operation, the interior will not be illuminated. If safety considerations specify a minimum illumination level, we will want to apply this to the inter-wall space, not to the OPLE/BC areas, where any illumination during operation, even very low level, will saturate the sensitive cameras.

For maintenance inside the OPLE area, we prefer to plan on a low level of permanently installed illumination, with additional portable illumination for specific purposes. An extensive complement of installed light fixtures would entail unnecessary costs for the fixtures and installation, and also impose an artificially high power requirement, since in practice work will be carried out in only local areas within the interior. Similar considerations apply to the inter-wall space.

In the BC area, installed fixtures to provide a standard office illumination level is proposed, since the BC area will be accessed with greater frequency, and the instruments are more nearly contiguous. Emergency (power failure) lighting should be provided throughout the OPLE/BC interior and inter-wall spaces.

FIGURE 6. Possible electrical layout to provide for both fixed electronic equipment, and for maintenance use. Each heavy line is intended to suggest one circuit. In this layout, it is assumed that outlets are spaced at 10-20 foot intervals.

6.10. Power

The power requirements for the optical equipment have not been fully defined but are known to be modest. One reason for this is that surplus heat generated by virtually all electrical and electronic equipment would disturb the optical beams. Such equipment will be preferentially located in the CRO area and in the Electronics Shelter. Another factor is the increasing efficiency of optical detection and computer electronics.

Power requirements during construction, installation, and maintenance will be significantly higher, including lighting, electronic test equipment, and small power tools.

The layout of pipes and other equipment in the OPLE area effectively creates east-west barriers. As a result, outlets on the long walls would not be very useful in the interior. Instead, for use as “convenience” outlets, we recommend locating outlets on the ceiling over the OPLE units. The inner enclosure walls should have an array of convenience outlets on both sides, primarily for use in maintenance.

Since the BSF is rather large, it will be a convenience to have a relatively large number of outlets. However, the number of circuits required does not need to be proportionately large. One possibility is to install a moderate number of circuits with a sufficient density of outlets to have several circuits available from any location. Figure 6 shows a suggestion of how this might be accomplished.

6.11. Sprinkler System and Smoke Alarms

Smoke alarms should be installed throughout both the interior space and the inter-enclosure space. The most likely source of smoke, electronic equipment, will be concentrated in the east and west ends of the OPLE area, and in the BC area.

The equipment in the inner enclosure will be delicate and subject to serious loss in the event of sprinkler system leaks, which might go undetected for some time. If a sprinkler system is used, there should be some consideration to installing it only in the space between enclosures.

7. CONTROL ROOM/OFFICE SECTION

The CRO section of the building is relatively simple and straight-forward. In the concept, it is virtually a separate building (a change from TR 23), with the north end near the mid-point of the OPLE area. A structural gap (footings, slab, walls and roof) is planned in order to prevent transmission of vibrations due to human activity in the CRO area into the Optics Enclosure areas.

In the concept, the HVAC for the complete BSF is placed in the north end of the CRO area. This is based on the assumption that the vibrations of the HVAC equipment can be limited, probably with an isolated base for motorized equipment. The HVAC ducting would then cross the partially exposed space between CRO and Optics Enclosure.

Also in the north end of the CRO, there is a designated computer room. This does not imply an elaborate computer requirement. The computers employed will be desk top workstations and single board computers. The computer room will contain a number of electronics racks with various computer and control components. An electrical requirement of 10 kW is expected for the CRO computer room. The relatively large allocated space is for convenience of access to front and back of equipment and for access to cables.

The remainder of the CRO area can be treated as conventional office space and designed accordingly. Additional computer requirements (mainly terminals) in this area can be readily supported from standard convenience outlets. At this writing, the interior layout of the CRO is provisional and may be revised.

8. POSSIBLE FUTURE EXTENSION

In the Environmental Assessment, the CHARA plan describes a possible future extension or addition to the BSF, in the form of additional office/shop space extending east from the south end of the CRO area. This extension is not an integral part of the CHARA Array plan, is not mentioned in TR 23, and should not be included in the planning for the BSF.

9. VACUUM PUMP, ELECTRONICS SHELTER

A Vacuum Pump, Electronics Shelter (VPES) is planned near the BC section of the BSF. The purpose is to provide a location for several items of equipment which generate too much heat and/or vibration for location inside the BSF. The shelter will have a pump room and an electronics room. A prefabricated or semi-portable structure may be suitable for the shelter.

A vacuum pump, possibly with a backup unit, will be located in the pump room. The pump(s) will be placed on an isolated or suspended base in order to reduce transmission of vibration into the ground (and hence to the BSF). A vacuum pipe (not shown on the figures) will connect the vacuum pump to the beam pipes in the BPJ area. A diameter of 8 in will be adequate. The routing is not critical.

A number of electronics units will be installed in the electronics room. These will be rack

FIGURE 7. A concept layout for cableways in the Beam Synthesis Facility. Cableways are shown as dashed lines.

mounted. A power requirement of 10 kW is estimated. The electronics area of the shelter will need Faraday cage shielding, provided naturally with a metal sheathed structure. A low level of heating capacity will be required to keep the temperature above freezing, and to raise the temperature at times of high humidity to prevent condensing conditions. If the shelter is well insulated, electrical heating may be acceptable. Forced ventilation of both vacuum and electronics areas will be required to limit temperature during warm weather operation.

10. CABLEWAYS

Cableways will be required for electronic and electro-optic communication between the various sections of the BSF, and also between the CRO area and the individual telescopes. These are for control and communications purposes. They are not intended to supply power. Figure 7 shows a possible layout for cable routes.

Within the BSF interior, standard cable trays are suitable. In places, the cable ways will pass between buildings. Between the CRO area and the OPLE/BC areas there will be a gap between walls. Also, communications are required between the Vacuum/Electronics Shelter and the BSF. In these spaces, the cable ways should be above ground. Metal pipe should be used to resist damage and to protect from ambient electromagnetic disturbances. Aluminum or corrosion resistant steel is acceptable.

For initial planning purposes, the following requirements may be used. Within the CRO, a cable tray of at least 10 sq-inch is required. Between the CRO and the rest of the BSF, and between the VPES and the rest of the BSF, a capacity of at least 24 sq-inch is required. Other cable ways must have a capacity of at least 12 sq-inch. These estimates will be reviewed during the preliminary design.

11. SITE CONSTRAINTS FOR LOCATION OF THE BSF

The BSF conceptual design has been fit into site constraints with some care and not much flexibility remains. At the west end, some fill is required and further extension of the BSF will rapidly require extensive additional fill. At the east end of the BSF, the building stops short of a significant prominence so as to leave necessary space for passage of traffic. Shifting the BSF north would require additional fill, and would begin to block an existing road.

On the south side of the BSF is situated the 100-inch Telescope building. The hemispherical roof of this building collects and dumps snow during the winter. A 25-ft margin between buildings is planned to avoid snow drop onto the BSF. In addition, a low wall may be constructed along the 25-ft line to prevent excessive splash of dumped snow. Observations will be made this winter to judge the requirement.

A final, important constraint concerns the entrance of the beam pipes from the south Array arm. These are planned to pass close to the 100 inch building, close to and parallel to the BC west wall, and enter the BSF near the intersection of the OPLE and BC sections. This beam path was designed on the basis of a primarily aerial survey. Due to the several constraints on this beam path (including a garage at the other end of the pipe), it is necessary to obtain a confirmatory ground survey. This should be scheduled. It is then critical to ensure that the BSF is actually located correctly with respect to that survey. This constrains primarily the east-west location of the interior corner of the BSF at the OPLE/BC area junction.

12. LIGHTNING PROTECTION

General lightning protection should probably be based on a surface mounted system. The installed electronics equipment will probably include the use of small Uninterruptible Power Supply Units (short duration) which will include an additional level of protection from power surge effects due to lightning and other sources. Such UPS units are not included in the facility specification.

13. APPENDIX I. BUILDING SYSTEMS CONSIDERED FOR THE EXTERNAL SHELL

In the course of preparing conceptual designs for the CHARA facilities, and estimating budgets, a number of building systems were considered. The information was obtained at different times in the development of the requirements, and are not all directly comparable. Several of these will be described here with comments on their perceived merits. The inclusion of this material is intended to help clarify the BSF requirements, and is not meant to suggest that any of these building systems are more favorable than others which may be proposed.

13.1. Miracle Truss

Miracle Truss (Waterford Tower, Suite 500, 505 N. Highway 169, Minneapolis, MN 55441-6420, 612-593-1000).

The Miracle Truss system employs manufactured steel frames for a vertical side wall/peaked roof building. The frame units have clips for installation of 2" lumber which serves as roof purlins and side girts. The frame units are spaced to accept standard precut lumber (8'–10'–12') depending on the load requirements.

An advantage is that installation of insulation and sheet rock follows conveniently as in a frame structure. A disadvantage is that the trusses extend into the interior space by more than the likely wall thickness. Pre-manufactured metal panel sheathing is fastened to the wood lumber. Customization and modifications can use normal framing techniques.

A telephone estimate for the manufactured building 200' by 42' (including trusses, lumber, sheathing and fasteners) is $66,900. This package includes a hurricane package (105 mph) and increased live load to 48 psf. Assembly is informally estimated at 4 weeks for a crew of four with no prior experience with this system.

13.2. IBEX International

IBEX International, 701 Travelers BLVD, Suite 535, Summerville, SC 29485, 803-871-4696.

The IBEX building method employs steel sheeting which is folded to serve as both structural material and sheathing. Premanufactured sections are bolted together into arch units which are then tilted upright and joined.

An advantage is that the interior clear width is maximized. A disadvantage is that there is no natural way to install insulation and a tight weather seal. Pins can be glued to the inside of the sheathing to retain insulation.

Customization and modification require special techniques.

Written quotes were obtained for a building 200 feet by 35 feet, in two options. In the standard model (117 MPH, 38 psf ground snow load) the cost is $36,798 (FOB job site). In a heavy duty option (136 mph, 53 PSF ground snow load) the cost is $41,939 FOB jobsite. Assembly is informally estimated at 4 weeks for a crew of four with no prior experience with this system.

13.3. American Buildings Loc-Seam Panel

American Buildings Company, P.O. Box 800, State Docks Road, Eufaula, Alabama, 36027, 205-687-2032.

The Loc-Seam system employs manufactured steel frames in a vertical wall/peaked roof profile. A system of steel purlins supports the Loc-Tite roof panels. The walls are sheathed with a steel panel (Shadow Panel) system.

An advantage is that this system was employed successfully in a similar (though smaller scale) project carried out by JPL several years ago. Disadvantages include the possible difficulty of installing insulation and sealing the interior of the wall. The steel frames protrude somewhat into the interior space.

No cost estimates were obtained for this system.

13.4. Key-Block System

Key Block Building Systems, 11278 Old Baltimore Pike, Beltsville, MD 20705, 301-595-0215.

The Key-Block system employs manufactured modular building blocks of ceramic cement. The modules are assembled with bolt-through steel rods.

An advantage is that the insulation is excellent (R=30-45) and the weather seal is excellent. A disadvantage is that a precision footing system is required, and an experienced asembly crew.

Customization (after manufacture) and modification appears unusually difficult.

Wind and earthquake resistance is excellent. The blocks are unusually fire resistant.

Construction time estimate (shell) is 3 days for 5000 square feet. No specific estimate was obtained.

13.5. Wood Construction

Wood construction (stud walls, truss roof) was also considered because it is easy to insulate and seal, and modifications are easy. Also, it is easy to estimate costs. Our estimates are not repeated since they are probably not sufficiently accurate for the current stage of the project.

14. APPENDIX II. BUILDING SYSTEMS CONSIDERED FOR THE INTERNAL SHELL

Of the building systems described in Appendix I, two could also be considered for the interior shell as well. These are the Key-Block system, and the wood frame.

14.1. Hart Industries

Hart Consolidated Industries, P.O. Box 1206, Hartwell, GA 30643-6206, 706-376-3655.

Hart has a building system specifically for interior enclosures. The normal market is for food processing. The wall panels are pre-manufactured with a pre-painted steel skin and foamed in place polystyrene core. The panels assemble tongue-in-groove, into channels installed at floor and ceiling. The roof is a non-loadbearing ribbed steel deck, and the ceiling is mineral board tile in a suspended steel grid, with bat insulation.

Advantages include a high quality appearance. A disadvantage is the relatively high cost.

Hart quoted on an enclosure 200 feet by 34 feet by 10 feet, with 6 inch thick walls. The cost for materials is $85,000, FOB Maryland Heights, MO.

15. ATTACHMENTS

One copy of this TR includes as attachments a set of literature from the companies mentioned in the Appendices. Extra copies of this material are not available.