CHARA Technical Report

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CHARA Michelson Array Pathfinder: CMAP Site Preparation

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ABSTRACT: In TR117 (Site selection), we discussed the range of site possibilities available for the locations of the CHARA Michelson Array Pathfinder (CMAP) mobile telescope, and we ranked them in order of desirability. We also discussed the configuration of the telescope enclosure and transportation in TR116 (Transport and Enclosure Design). In the first phase, we will be focusing on sites S3 (near existing S1 and S2 telescopes) and S4 (near the Cooke dome) with the possibility of W5 (at the old Channel 13 site) coming later, and now we move on to preparing the locations and their surroundings for accessibility and operations.

1. INTRODUCTION

The purpose of this document is to provide information on the telescope system design and the site considerations for potential contractors who will help locate and prepare the site facilities for the mobile telescope. For each of the two sites, we discuss the location of the telescope pier, concrete support pad, grading and leveling of the site, box location for fiber and power cable storage, road work for site access, tree removal for observational accessibility, and any specific issues for the individual sites. The overall design of the support pads is subject to contractor comment, but this document describes the site features in enough detail to help streamline the building process.

There are two primary sites for the first phase of the mobile telescope operations. The site we call S3 is located to the south east of the current CHARA S2 telescope. It is accessible from a paved road that leads east to Mount Wilson Observatory house number 3. It will form a small triangle with CHARA telescopes S1 and S2 for short baseline observations.

The next site is called S4, and it is located at a far southern location near the Cooke telescope dome of the Mount Wilson Observatory. It is accessible from a spur road that heads west and south from the road leading to the Mount Wilson Observatory Monastery building. The combination of the mobile telescope at S4 with the CHARA E1 and W1 telescopes will enable observations with very long baselines. Both the S3 and S4 sites are located on the Observatory grounds. The space limitations for both sites require that the trailer supporting the telescope will be backed into position; there is no room for a full turn-around of the trailer.

2. LOCATION REFERENCES

We set the locations for the telescope piers using a portable GPS receiver. More accurate coordinates were derived from measurements made with Google Maps and CalTopo.com. In addition to the coordinates, we provide in Table 1 below fixed reference points from buildings, permanent structures, or other landmarks for distance and the compass orientations (based on magnetic north that is oriented 11° 34′E of true north at this time). Each reference point orientation is based from the landmark to the pier location. Aerial images of the S3 and S4 sites and the reference locations are given in Figures 1 and 2, respectively.

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	GPS and Location	D (m)	MB
S3	34° 13′ 28.7″N, 118° 03′ 25.10″W	EL: 1729	
1	Railing near S2 bunker	11.10	155°
2	S2 Cylinder Support	17.65	120°
3	Railing near 60” dome	21.45	104°
4	S1 Lightpipe pier	16.89	36°
5	Driveway post south	15.77	312°
S4	34° 13′ 21.0″N, 118° 03′ 28.6″W	EL: 1716	
1	Stone Box corner	24.48	164°
2	Survey Marker West	12.94	146°
3	Cooke Railing	4.61	3°
4	Concrete Pull Box	4.63	208°

TABLE 1. Reference locations for the S3 and S4 telescope piers. Column 3 gives the distance in meters from the reference position to the pier location, and column 4 gives the magnetic bearing.

FIGURE 1. Aerial view of S3 site with location references. The declination diagram references MN - Magnetic North, TN - True North, GN - Grid North (direction of the plane grid system based on USGS maps).

FIGURE 2. Aerial view of S4 site with location references. The declination diagram references MN - Magnetic North, TN - True North, GN - Grid North

3. PAD AND PIER LOCATION AND ORIENTATION

The heavy load of a movable building, trailer, and telescope will require us to have significant support for long term use and to reduce vibration as much as possible. Each site will host a substantial concrete pier and a pad. When a site is not in use, it is required that the surface is flat, does not obstruct use of the area, and does not create a hazard. For this purpose, the concrete pier is sunken below the road grade and a steel cover plate can be fixed above the pier. The pier will be a concrete cylinder (Outside diameter of 72in) poured below ground level to the depth required to provide stability with the top face height at the level

of the reinforced pad. The exact depth may vary with the location, soil and subterranean conditions of the decomposed granite substrate but should be at least 6ft in depth with rebar further inserted to protect against lateral and horizontal motion and tipping. This concrete pier will support the steel pier of the telescope in a 6in deep inset, 48in in diameter.

Embedded in the concrete pier, steel sleeves with 1 inch female threaded holes serve as attachment points for threaded rods or bolts that hold the accepter plate in place. Above this plate will rest the bottom two sections of the removable pier for the telescope. The accepter plate will also support the cover for the inset when the telescope and enclosure are moved to another site. The cover weighs 500 lbs and will be moved with a crane or Bobcat. The pad and concrete pier will need to have adequate drainage. The threaded rods and accepter plate allows for telescope leveling while allowing the concrete pad to have a minimal slope for runoff. The enclosure will also have lift jacks on the corners to keep the enclosure and dome level.

The surrounding, but isolated, pad will support the trailer and enclosure. There will be vibration reducing fill material in the gap between the concrete pier and the pad and at the locations for the trailer support jacks. The pad will need at least one trough for fiber, data, and power cable routing from the perimeter of the pad to the pier at the location for best access. It might be necessary to have two troughs from the perimeter to the center to separate the power cable from the science and data fibers. This will depend on placement and size of the transformer and access to electrical power which is better determined by the contractor completing this bid. A site survey will be required to ascertain the location of underground wires and pipes in the ground under the proposed sites. Pad and pier size, position, and orientation, may need to be adjusted following the results of the exploratory survey. A diagram of a potential design for the telescope pad and pier is shown in Figure 3. The pad thickness needed to support the weight of the trailer, telescope, and enclosure (approximate total of 10,000lb) needs to be more than 8in thick reinforced with rebar. (To be determined by contractor for engineering design and safety.) While the platform as shown in Figure 3 is symmetrical about the central pier, it may be better to shift the pier along the long axis to allow for the tongue of the enclosure to rest on the reinforced pad. Contractor input is recommended before design is finalized.

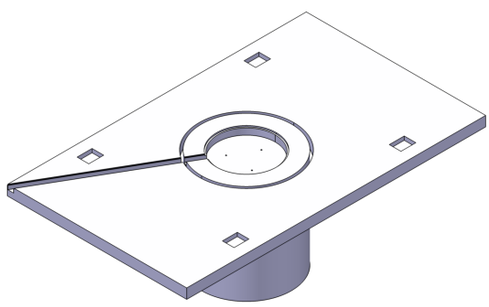

FIGURE 3. Schematic of one version of the pad and pier with a channel needed for power and data cables. The dimensions of the pad will be specific to each site due to terrain differences. Pad should be at least 8 inches thick and 20' long, with the width either 12 or 14 ft depending on the site. The central concrete pier will be 72" in diameter and at least 6 ft deep, with a 48" diameter inset that is 6" deep. Reinforcement pads placed around central pier may not be necessary as the pneumatic or hydraulic supports for the enclosure can incorporate larger padded feet to distribute the weight and damp vibration.

3.1. S3 - Pad and Pier Location and Orientation

The current selected position and orientation of the long dimension (330° from magnetic north) of the pier and pad is shown in Figure 4. As there is a down-slope immediately to the west, it would be ideal to have a drainage pipe inset in the concrete leading southwest for drainage from the central pier inset. This pad will not be on an existing paved surface, so significant grading, leveling, and compression will be needed to insure that the pad can support the mobile enclosure. Furthermore the trailer needs to be driven onto the pad

without excess maneuvering. Thus, the destination pad needs a wide concrete drive for ingress and egress. Figure 4 shows the potential extent of the concrete paving that may be required for the driveway. The exact dimensions of the reinforced pad for this site are currently set to 14ft x 20ft in the images but there is more than enough room for expansion if needed.

FIGURE 4. Aerial view of S3 with trailer size and approximate size of paved and leveled area needed to place the trailer in its intended spot. The central rectangle (red/blue) is approximately the size of the telescope enclosure without the dome, while the other outlined area is the driveway that will need to be paved for access from the road. Orange lines mark the outer edge of the reinforced pad. The line segments are color coded for length. The enclosure rectangle is 10ft wide (red) by 14ft long (blue). Green segments are 8ft, and the single purple segment is 5ft. The white segment represents a drain pipe under the concrete slab.

3.2. S4 - Pad and Pier Location and Orientation

The orientation of the road and therefore long dimension of the pad for S4 is near to the orientation of S3 at 335° relative to magnetic north. Unfortunately the width of the road at 9ft is narrower than we would like. The telescope enclosure is 10 ft wide, so we need a pad

width of approximately 12ft. Consequently we will need to widen the road by excavating into the hill on the east side and by building up a small retaining wall on the west side. In addition, we will need to support and reinforce the west side of the pad where the terrain drops off rather sharply. See Figure 5 for pad orientation and extent. Drainage will be accomplished much like the pad at S3, also to the west side with pipes sunk under the pad from the center of the pillar inset.

FIGURE 5. Cropped S4 aerial view with approximately the position and orientation of the pad with ENF box on North-East corner (orange) with previously identified reference locations. The pad at this location is 20ft long by 12ft wide. White segments are drain pipes for the central pillar and the ENF box.

4. ELECTRICAL AND NETWORK BOXES

The operation of the mobile telescope requires access to electrical power, communications fiber optics, and science fiber optics. The routing of the science fiber optic cables from the

lab to the telescope pads will be discussed further in another Technical Report, but here we consider how to store the connectors for these components safely and as close to the telescope as possible. The exact dimensions, materials, and placement of the boxes are still under discussion, but the general idea is to have a concrete box embedded in the ground at the corner most convenient to the connection. To avoid any loss of signal strength through fiber junctions, we will use a single length of fiber optic cable, and the final 10 m of the cable (to be attached to the telescope) will be stored in the box when the telescope is not at the site. When installing the telescope at that location, we will uncoil the fiber optic cable and feed it through the channel to the central hub and pier, then up through the telescope cable wrap to the Adaptive Optics Bench (AOB). This will be reversed when it is time for the telescope and trailer to move to another location. A generalized schematic of power, network, and science fiber routing into the enclosure and telescope is shown in Figure 6.

Also kept in the box will be the network fiber for remote control of all systems and computers as well as a connection for power. The Electrical/Network/Fiber box (ENF) will be buried in the ground and will be hard to keep watertight, so we need to keep exposed connections, junctions, and electrically powered items out of this box. Therefore, the box only contains items like the network fiber junction box (as under the table in the CHARA control room) that requires no power and can tolerate wet conditions. This box converts the large (6-12) fiber bundle cable to individual fibers. These individual fibers and the power patch line will be run from the box through the one or two embedded channels to the central pillar. From there, the power and fibers will be connected via locking connector to a junction box attached to the trailer.

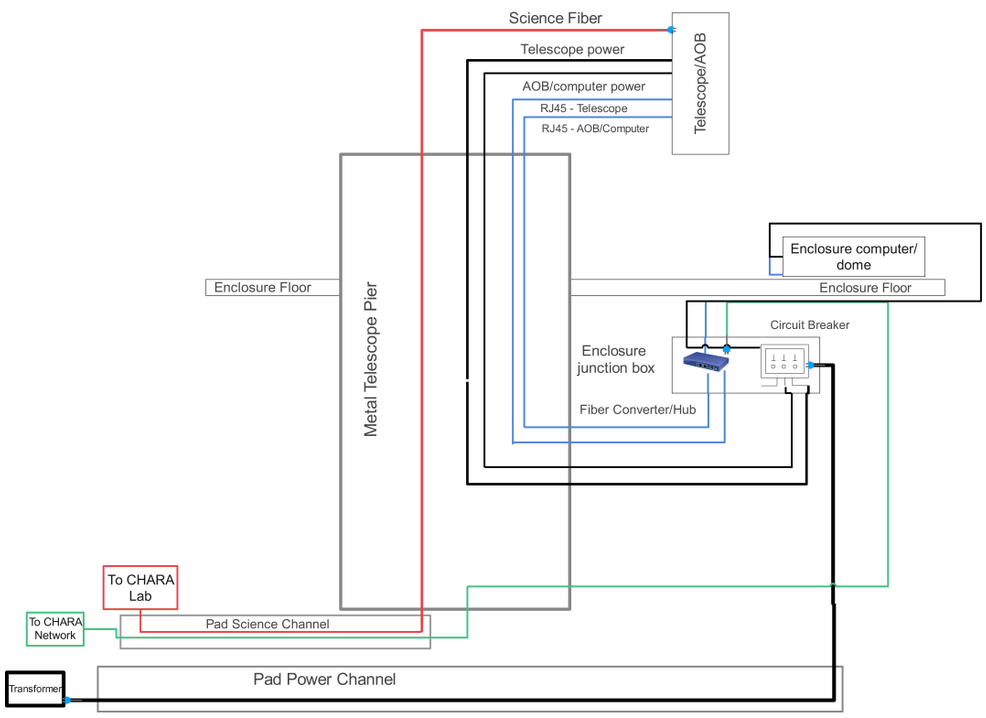

FIGURE 6. Diagram of network and science fibers (green and red, respectively) and the power cable (black) routing into the telescope enclosure. Blue lines represent the network after being converted from fiber to RJ45. Routing for the science fiber will be directly up through the support pillar, while the power and network will connect to a junction box on the enclosure.

Inside this junction box will be a circuit breaker box to split the power into three segments (Telescope, AOB/Camera, and Enclosure). The fiber will connect to a media converter (RJ45) and to a router that will split into at least two cables (Telescope/AOB and Enclosure), From there, the enclosure power and network cables can be transferred inside the enclosure, and the three other cables (Telescope power, AOB/Camera Power, and Telescope/AOB network cables) can then be run into the central pier via access holes and up through the telescope cable wrap to their destinations.

In terms of power budgeting, all power draw will be contained within the enclosure and nothing powered would remain at the site when the enclosure is at another location except for a two receptacle power outlet (weatherproofed). All instruments, enclosure, telescope, and computers, run on 120V power. Table 2 lists the individual segments of the mobile

enclosure, the amps/watts with and without uninterrupted power sources required for each, and the overall total needed at each site.

Location	Amps	UPS (W)	Non-UPS (W)	Total (W)
Site	15	0	1800	1800
Trailer	16.7	6	2000	2006
Enclosure	59.3	846	6264	7110
Telescope	42.3	2005	4074	5079
Total	**133.3**	1857	14138	**15995**

TABLE 2. Power budget table for each segment and totals for each.

4.1. S3 - Electrical and Network Box

For S3, the power and network box should be easily accessible from S2 (the closest telescope). This is the easiest location for power and network access as it is within 10m of current Array buildings. We will probably need a separate transformer to power the mobile telescope. The ideal placement for the power and network box is the north west corner closest to the S2 bunker (see Figure 4 for ENF box and drainage (white) locations).

4.2. S4 - Electrical and Network Box

The best option for the placement of the S4 power and fiber cable box, is near the north-east side. While this is currently obstructed by rocks and dirt, it has many advantages over the west and south sides. Both south locations would require using extra science data fiber to pass the intended location and loop back. The west side would require additional support as it would be in the significant drop off down-slope. The east side also allows access to the currently buried power-lines in the pullbox to the east northeast of the intended location of the telescope pier. With the ENF box on the up-slope on the east side, drainage will be needed to ensure no standing water interferes with the cable inside (See Figure 5 for locations in white).

5. ROADWORK, APPROACH, AND INFRASTRUCTURE

There are several locations where roadwork will need to be done to smooth out the road grade and minimize any external stresses on the equipment. Both sites are well within the observatory's boundaries, so the sites should not need additional access control like fencing.

5.1. S3 - Roadwork, Approach, and Infrastructure

Due to the already improved area surrounding the site, minimal work on the existing roadwork is needed to achieve what we need for access to the site for the mobile telescope. No existing road needs to be removed or graded for site usage. The east side of the road (across the road from the S2 bunker) could be widened to allow for extra turning space as the S2 bunker impedes access in the other direction. Paving the area surrounding the reinforced pad was shown previously in Figure 4. The locations surrounding the road approach that may need modification are shown in Figure 7.

(a) Topographic map of S3

(b) S3 approach looking south-east.

FIGURE 7. Location of road approach for S3. Red locations will need modifications.

5.2. S4 - Roadwork, Approach, and Infrastructure

The junction between the road leading to the southern buildings on the observatory grounds and the Cooke dome is irregular and awkward even for small cars due to the change between nearly a negative ten degree grade for the road and the positive five degree grade driveway. At the northernmost point where the roads intersect, the junction is smooth and continuous. The southern end of the junction however is discontinuous and needs work. There are multiple options in how to accomplish this task and we invite suggestions from contractors about how to improve the driveway. The driveway approach that will need modification is shown in Figure 8.

(a) Topographic map of S4.

(b) S4 approach looking south.

FIGURE 8. Location of road approach for S4. The junction of the road and driveway will need work to enable a shallower grade.

6. TREE REMOVAL AND SKY COVERAGE

There are a number of trees near the two sites that may block parts of the sky from the view of the telescope. We considered the proximity of these trees in the site selection, and pier/pad locations were chosen to minimize tree obscuration of the sky. Nevertheless, there remain trees that need to be removed from both sites to maximize the accessibility of the sky.

6.1. S3 - Tree Removal and Sky Coverage

The short baselines involved between the S1-S2-S3 triangle are small, and thus the CHARA Array has sufficient delay line lengths to enable observations over the entire sky from this site. While much of the surrounding area had been cleared for the construction of the S1 and S2 telescopes, tree growth in the past 20 years has left little option but to remove some of the remaining nearby trees in the area. Directly west and east of the desired position (see Figures 9 and 10) are several clusters of large scrub oak trees that should be removed as they are close enough to the telescope at ground level as to obstruct much of the eastern and western sky.

(a) Tree Removal facing west for S3

(b) Tree Removal facing east for S3

FIGURE 9. Trees near S3 that need removal marked with red dots.

FIGURE 10. Aerial image of S3 site. Areas of needed tree removal are circled in red.

6.2. S4 - Tree Removal and Sky Coverage

Site S4 has a number of trees that are close to the pier/pad location. The closest trees that will need removal are marked in Figures 11 and 12. There are several older and larger trees situated to the east of the Monastery road that may block parts of the eastern sky. However, because of the very long baselines associated with the use of the S4 site, the available delay line lengths will limit most observations to objects above 55 degrees in elevation in the east. Consequently, the more distant trees will probably not affect operations from this site.

(a) Tree Removal image for S4 facing NE

(b) Tree Removal image for S4 facing West

FIGURE 11. Trees near S4 that need removal marked with red dots.

FIGURE 12. Aerial image of S4 site. Areas of needed tree removal are circled in red.

7. PEDESTRIAN ACCESS TO THE COOKE DOME

The placement of the telescope enclosure in the middle of a driveway leading to the existing Cooke telescope dome could possibly hamper access to the dome when the CMAP enclosure is on-site. It will be possible to move the mobile telescope to other locations at times when vehicle access to the Cooke Dome is needed. When the CMAP telescope is placed on site S4, we will need to create pedestrian access to the Cooke Dome. A possible option is to craft a walkway around the mobile telescope pad in such a way as to allow access to the

Cooke dome. The walkway would also provide access points on the side and back doors of the mobile telescope enclosure. The location, orientation, and size of this will depend on many issues that are currently unknown, such as what grading we do to the hill, how many trees are removed, relocation of currently installed utilities, etc. Once these details have been finalized, further action on the options for the pathway can be determined.

8. DISCUSSION OF TIMELINES

With so many parts of the project requiring attention at different times, there is a need to make a timeline for pad building and to set deadlines on when we will need the individual sites completed. Our first goal is to complete site preparation for S3 as soon as possible in order to place the telescope there upon delivery in Q3 or Q4 of 2023. The S4 site can be started after the first location is complete as there will be commissioning time for the fiber transport and telescope while stationed at S3 that will require time and effort. At this stage:

- The Planewave 1m telescope is expected to arrive Fall 2023.
- The Ash Dome is ordered and expected to arrive in Spring 2023.
- We have the base trailer for the preliminary design we have shown here and are in the process of structural and vibration analysis.
- Modifications to the trailer, including the addition of fail-safe redundant braking systems are underway.
- Design work remains to be done related to routing of fiber optics and electrical wiring.
- Fabrication of the enclosure should begin in Spring of 2023.
- **March 2023 - Accept bids and begin clearing, roadwork and construction of pad for S3**
- **During Spring/Summer of 2023 the sites will be prepared and concrete pads poured.**
- **May 2023 - Roadwork for S4, completion of S3 pad, begin pad construction for S4**
- **July 2023 - Completion of S4 pad**