CHARA TECHNICAL REPORT

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# Telescope Structural Analysis

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## 1. TELESCOPE STRUCTURAL OVERVIEW

The telescope comprises four main frame and truss structures. The lowest frame (FRAME 1) is a support cell which holds the primary mirror. This primary mirror cell carries the weight of the primary mirror with a set of six cross-beam structural members. FRAME 2, located approximately in the middle of the telescope structure, has a spider structure with four arms to hold the tertiary mirror. FRAME 3 is located below the top frame (FRAME 4) by approximately 3 inches. The top frame hold a secondary support assembly which includes the secondary mirror, the spider structure, and the mechanism assembly for the secondary corrections (tip, tilt, and focus). A finite-element model of the telescope structure was established using the I-DEAS program. The model comprises mostly beam and mass elements. Mass elements were used to represent weights of the primary, secondary, the tertiary mirrors, as well as the mechanism of the secondary mirror assembly. The model is shown in Figure 1.

## 2. STATIC ANALYSIS OF THE TELESCOPE

Several design iterations were performed in an effort to minimize distortions of the telescope structure. An optimum location for the center of gravity of the structure was determined, based mainly on balancing the weights of the top and bottom ends. A total of 440 lbs counterweight on FRAME 3 was calculated for the structural balance. Additional finetuning was applied according to the results of the structural displacements.

Selfweight-induced structural deformations were evaluated for two extreme gravity orientations: (1) ZENITH — the mirror points at zenith and the gravity vector acts along the optical axis, and (2) HORIZON — the mirror points at the horizon and the gravity vector acts normal to the optical axis. The deformed shapes of the telescope at ZENITH and HORIZON are plotted in Figures 2 and 3, respectively. Telescope errors for both gravity orientations are listed in Table 1 below.

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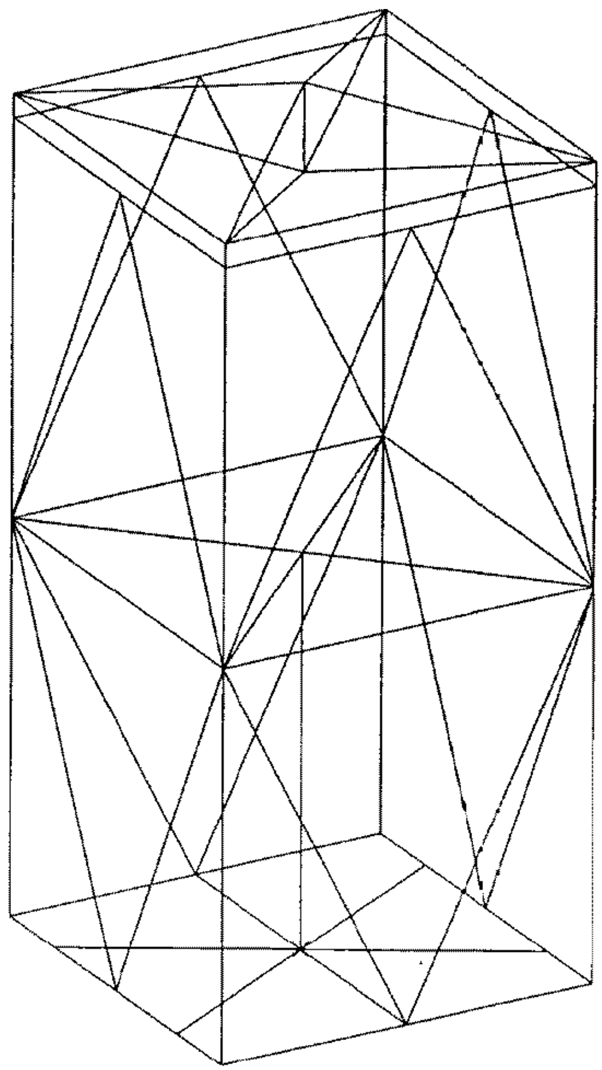


**FIGURE 1.** FE model of a CHARA telescope.

**TABLE 1.** Telescope errors for different gravity orientations.

| Orientation | Despace (microns) | Decenter (microns) | Tilt (arcsec) |
|---|---|---|---|
| Zenith pointing | 12 | 2 | 5 |
| Horizon pointing | 1 | 13 | 1 |

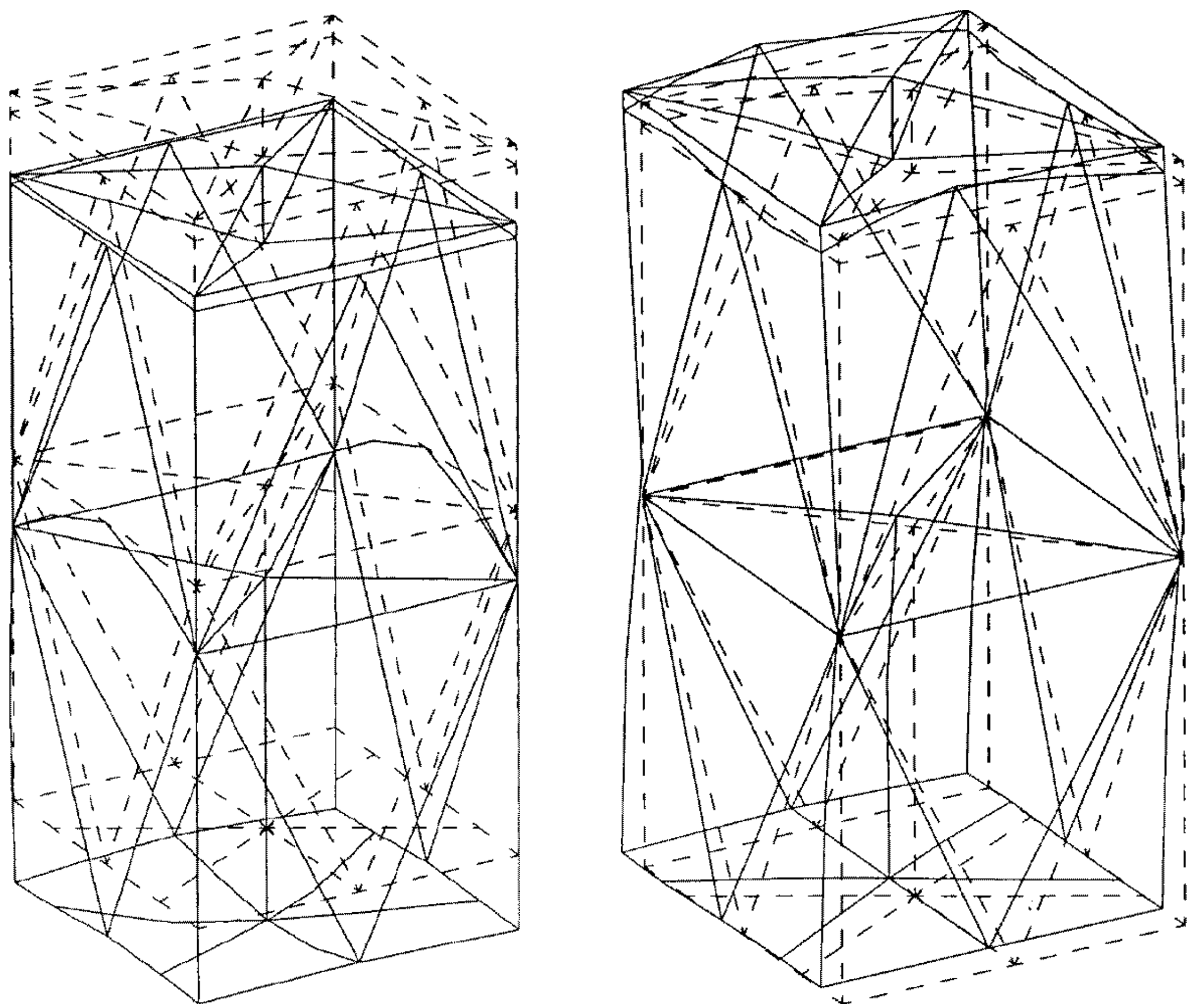


**FIGURE 2.** (left) Deformed shape (ZENITH).

**FIGURE 3.** (right) Deformed shape (HORIZON).

## 3. NATURAL FREQUENCY ANALYSIS OF THE TELESCOPE

A complete frequency analysis was performed with the telescope model of a fixed boundary condition at the ground. For this analysis the base (yoke) structure was included in the finite element model and the entire telescope model is shown in Figure 4. The first three natural modes were calculated and are summarized in Table 2. Mode shapes of the first three frequencies are plotted as show in Figures 5, 6, and 7.

**TABLE 2.** Mode shapes of the first three natural frequencies.

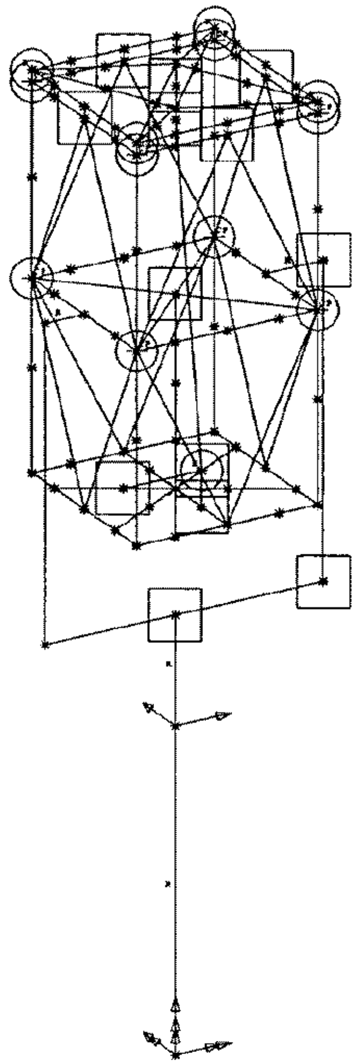
| Mode | Frequency (Hz) | Shape |
|---|---|---|
| 1 | 12 | rotation about X |
| 2 | 19 | translation in X and rotation about Y |
| 3 | 24 | translation in Y and rotation about X |

## 4. WIND LOADING ANALYSIS

The effect of wind loading on the telescope structure was considered. The wind loading was applied along the optical axis to the telescope in HORIZON, since the lowest natural mode (first mode) appeared to be sensitive to image motion. For a first order analysis, a steady state with an average wind velocity of 10 m/s was applied. Wind pressure loading was avaluated from the steady state wind velocity and was applied to the finite element model. As a conservative analysis, the loading were located to FRAME 4 and the secondary assembly. The model with the wind loadings are shown in Figure 8. Deformed shape of the telescope structure is plotted in Figure 9. A decenter of 5 microns and a despace of 1 micron were evaluated with a dynamic magnification factor of 1.5.

## 5. SUMMARY

From the static analysis of the telescope due to the gravity orientations, it was found that the telescope met the error budget requirements. Maximum decenter error of 13 microns (HORIZON) was well under the specification of 40 microns. Relative tilt of 5 arcsec between the primary and secondary mirrors was found with a marginal factor of two (10 arcsec in specification). The first natural frequency (rocking mode) of the telescope system was found at 12 Hz, which is relatively higher than a generic common telescope system response of 5 to 7 Hz. The steady state wind analysis shows a good indication of the telescope performance. Decenter of 5 microns is well under the error budget. This result was obtained with highly conservative assumptions. For a random wind environment, a dynamic response analysis can be performed. However, a highly sophisticated random spectrum analysis may not be necessary for a telesacope system with a high frequency like this telescope system.



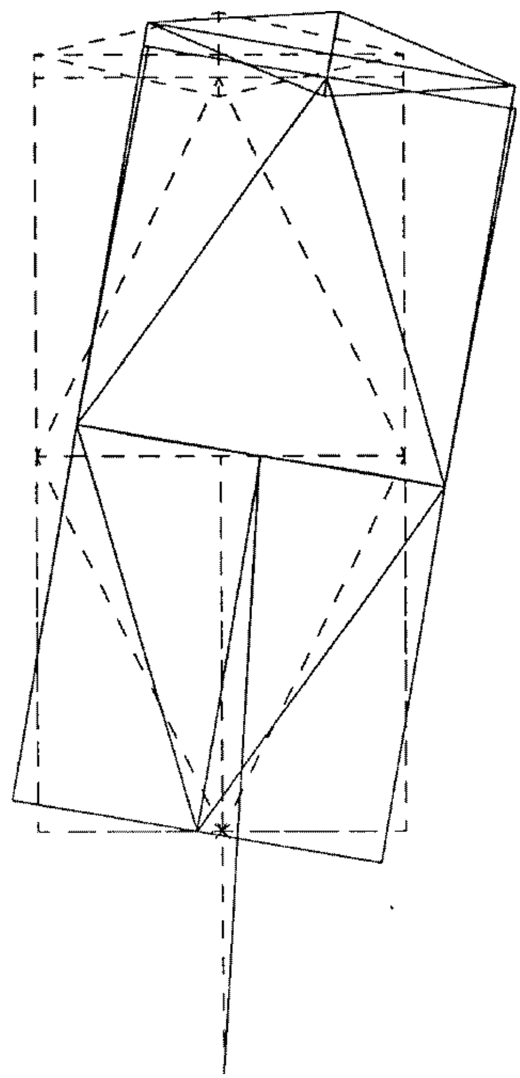
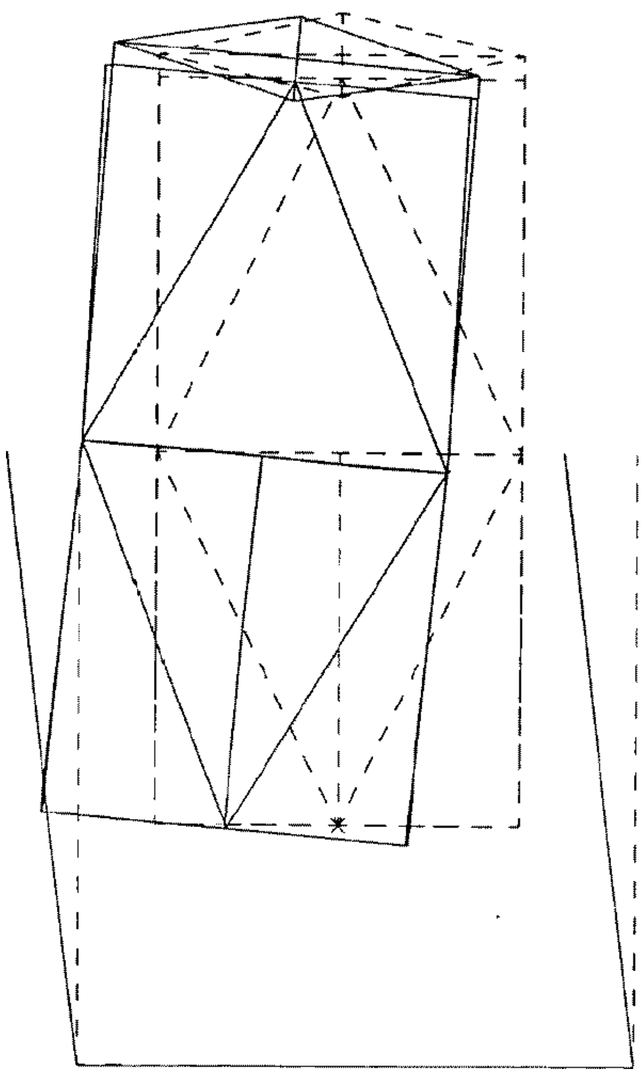


**FIGURE 4.** (left) Telescope model with a yoke.

**FIGURE 5.** (right) First mode at 12 Hz.



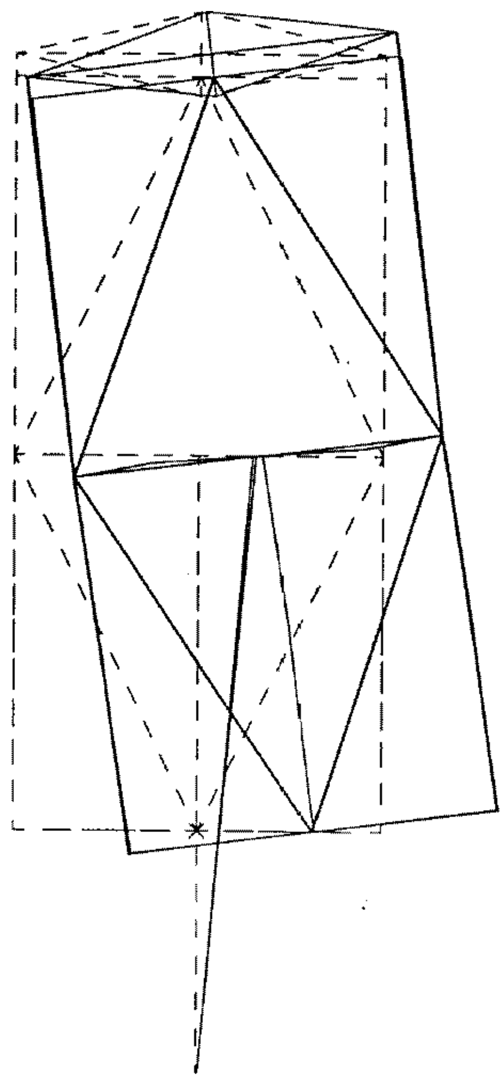


**FIGURE 6.** (left) Second mode at 19 Hz.

**FIGURE 7.** (right) Third mode at 24 Hz.

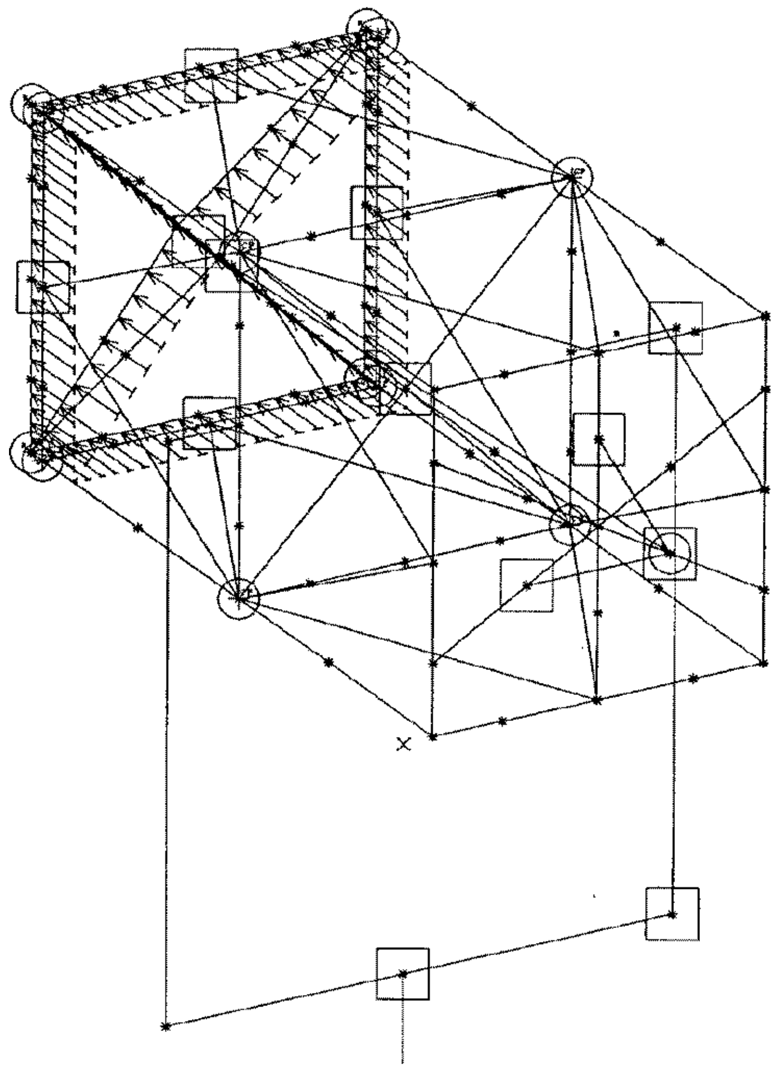


**FIGURE 8.** Horizon pointing with wind loading.

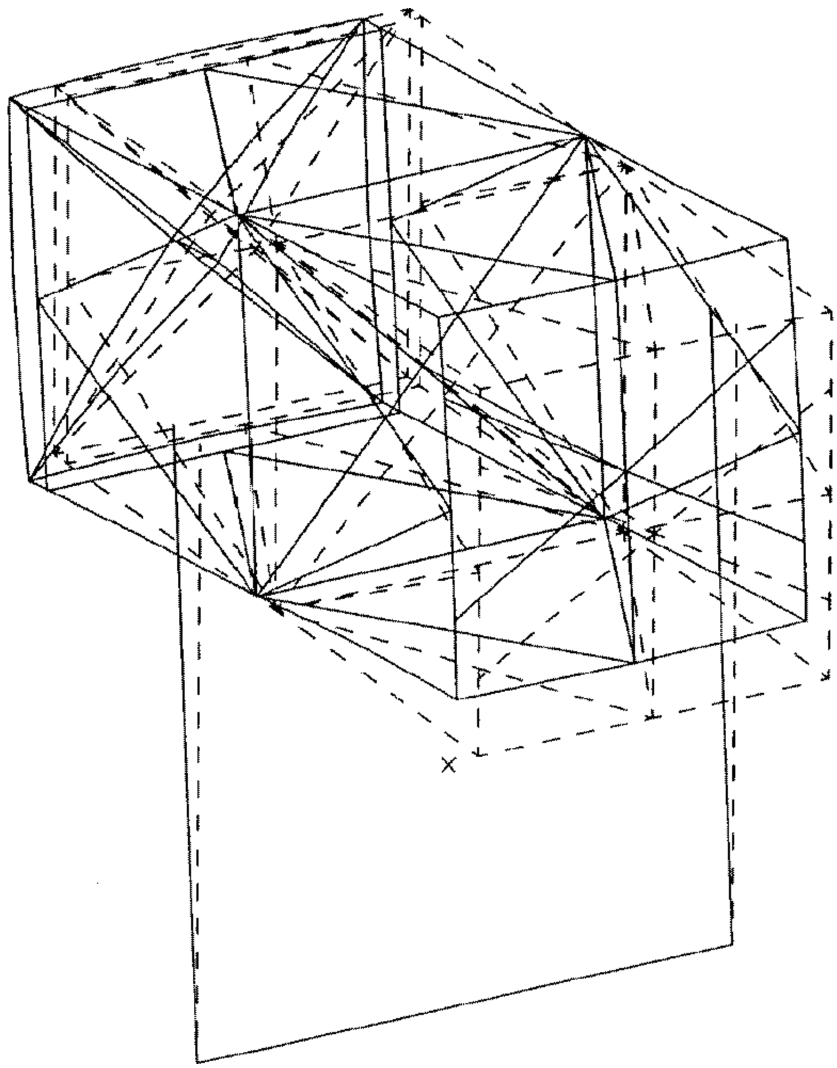


**FIGURE 9.** Deformed shape due to steady state wind.