CELT Report No. 17
Design Team Quarterly Report No. 3
June 2001

Contents

1. Introduction

The University of California and the California Institute of Technology (partners in the W. M. Keck Observatory) are collaborating to build a 30-meter telescope (CELT), designed to be fully steerable and operate on the ground. With its Ritchey-Chretien optical design it will have a large, 20-arcminute, field of view; and with planned adaptive optics, it will produce diffraction-limited images for wavelengths as short as one micron.

A year-long Conceptual Design Phase is described in CELT Report No. 9 "CELT Conceptual Design Plan", Jerry Nelson, Terry Mast, Gary Chanan, Richard Dekany (July 2000). The first two quarters were reported in CELT Reports 12 and 14. Report #12 which describes many details of the Tasks. **For efficiency we have not repeated them here; we describe here only those specific tasks where there has been significant progress in the third quarter.** Table 1 lists some aspects of the full CELT Observatory Project and organizes the thirty conceptual design phase tasks by aspect.

Table 1. Tasks in context of full CELT program

Observatory Requirements	**Task [1]**
Telescope Design	
Error Budgets	**Task [2]**
External Design Driver: Wind	**Task [3]**
Optical Design	**Task [4]**
Primary Mirror	**Tasks[5 -17]**
Auxiliary Optics	**Tasks[18-19]**
Telescope Structure	**Tasks[20-21]**
Adaptive Optics	
Modes of operation	**Task [22]**
Error budgets	**Task** [23]
Alternative Design Concepts	**Tasks[24]**
Conceptual Design Review	**Task [25]**
Preliminary Design Plan	**Task [26]**
CELT Working Groups	**Task [27]**
Conceptual Design Phase Management	**Task [28]**
CELT Website Management	**Task [29]**
Contingency Management	**Task [30]**

Table 2 gives the titles of the 30 conceptual design-phase tasks and serves as a table of contents.

Table 2. Task List

2. Summary

Significant progress has been made on a number of key design issues during this quarter. However, the rate of progress overall is less than expected.

We have hired consultants to work with us on the telescope structure, telescope bearings, drives, and encoders. We have also hired consultants to create an initial design of one of the candidate actuator types.

A UCO/Lick engineer is designing a prototype stressing fixture.

A technical staff member of UCO/Lick is working on CELT sensor design issues and prototypes.

During this quarter significant progress was made on:

- error budgets
- segment displacement sensors
- segment support actuators
- segment fabrication stressing-fixture prototype

Details about these issues and others are given in Section 6.

At the end of this coming 4th quarter we would like to be in a position to write a substantial summary of the project as whole including the work completed during this design phase. This document is dubbed "the green book."

Given this goal and the slower progress than we had planned, we will implement the following changes.

1. Hold a weekly management meeting
2. Have more frequent interactions with consulting engineers. We have been meeting only once per week.
3. Hold one or more all day, face-to-face meetings on the structure, and include discussions about alternative design options for ELT structures.
4. After additional analysis of the expected errors of the point diffraction interferometry, we will hold a workshop of those interested in segment testing.
5. After testing a prototype stressing fixture, we will hold a workshop with candidate vendors to present our results and collect ideas about future segment fabrication programs.
6. Given the critical nature of wind issues, we will hold a workshop. Participants will include experts in wind modeling, structural dynamics modeling, and possibly soil mechanics.

3. Budget

Task	**Description**	Budget	Q1	Q2	Mar	Apr	May ***	Liens	Total	Balance
	ADMINISTRATION									
28	Project Management	20.0	12.8	8.9	6.0	1.5	0.6		29.8	
28	Travel	20.0	9.9	6.3	0.8	4.6	2.0		23.6	
	TOTAL ADMINISTRATION	**40.0**	**22.7**	**15.2**	**6.8**	**6.1**	**2.6**	**0.0**	**53.4**	**(13.4)**
	OBSERVATORY									
3	Wind influence on telescope	60.0		0.1					0.1	
27	Working Groups Support	50.0							0.0	
29	Website Management	10.0		0.3	0.6	0.2	0.2		1.3	
1	Observatory Requirements	10.0	7.1	0.1					7.2	
25	Conceptual Design Review	15.0		0.1					0.1	
	TOTAL OBSERVATORY	**145.0**	**7.1**	**0.6**	**0.6**	**0.2**	**0.2**	**0.0**	**8.7**	**136.3**
	OPTICS									
4	Optical Design	5.0							0.0	
5	Segmentation Geometry	5.0							0.0	
6	Segment Material	5.0							0.0	
7	Segment Fab vendor candidates	20.0						3.6	3.6	
9	Stress fixture design, fab & test	45.0		3.4	1.3	7.7	8.0		20.4	
11	Design segment passive support	55.0	15.7	16.8	22.5				55.0	
12	Combine Displace /TCWS readings	12.0							0.0	
13	Primary mirror control SFR	19.0							0.0	
14	Segment Displace Sensors	60.0		0.7	2.7	0.8	20.0		24.2	
15	TCSE hardware Design	7.0							0.0	
16	Segment Support actuators	45.0	8.1	6.1		15.3	3.0	15.5	48.0	
17	Camera design	14.0							0.0	
24	Conceptual AO sys optical designs	50.0							0.0	
	TOTAL OPTICS	**342.0**	**23.8**	**27.0**	**26.5**	**23.8**	**31.0**	**19.1**	**151.2**	**190.8**
	TELESCOPE									
20	Telescope Structure Design	65.0	35.0	10.0		4.0		16.0	65.0	
21	Prelim design bearings, drives	30.0						30.0	30.0	
	TOTAL TELESCOPE	**95.0**	**35.0**	**10.0**	**0.0**	**4.0**	**0.0**	**46.0**	**95.0**	**0.0**
30	**CONTINGENCY**	**128.0**								**128.0**
	TOTAL	**750.0**	**88.6**	**52.8**	**33.9**	**34.1**	**33.8**	**65.1**	**308.3**	**441.7**
	TOTAL PERCENTAGE	**100.0**	**11.8**	**7.0**	**4.5**	**4.5**	**4.5**	**8.7**	**41.1**	**58.9**

*** May is estimated only

5. Concerns

Although there has been important and significant progress, there are key issues that are unresolved and are required for many other parts of the study. Their timely resolution is critical.

The effects of the wind are not yet adequately understood,, and the plan for completing this task is vague. The effect of wind **may** be a critical driver for the telescope, but this must be made quantitative. Hence completion of the telescope structural design is seriously hindered by the poor progress on understanding wind.

It **may** be that the most acceptable telescope structures (acceptable due to wind) produce significant blockage of the primary. The likely scientific impact of this blockage needs to be carefully assessed. If it is viewed as a serious problem, and if none of the current telescope structure designs are acceptable, then more radical departures in design may be necessary. This could drive the entire design study.

Plausible costs for edge sensors, actuators, and segment fabrication are needed before we can reasonably optimize the segment size and the primary mirror focal length. We will also need the segment alignment error budget and secure knowledge about the mirror cell gravity deformations. Concerted effort needs to be applied here so we can freeze the optical design sooner, rather than later.

Adaptive optics requires technologies not yet available and building designs around non-existent technology is risky. An adaptive secondary mirror may be extremely challenging, so its value must be carefully understood. If needed, it will influence the telescope structure design. Further, the optical design for MCAO may drive the telescope optical design. The auxiliary requirements of MCAO (number, launch locations, and power of lasers) may have a strong influence on the observatory design, and the requirements are unknown.

Many tasks are either not started or barely begun, and our ability to complete the conceptual design study in 12 months is assured. The fact that many tasks are strongly inter-related and that some key ones are barely begun is a contributing factor. The current commitment of key personnel to other activities is the primary cause of these delays.

6. Task Descriptions

For each task for which substantial progress was made this quarter we briefly repeat from CELT Report No. 9 "California Extremely Large Telescope (CELT) Conceptual Design Plan", the description of the task. Then for each task we describe the progress made this quarter and the plans for the future.

Task [2] Error budgets

Description

Error budgets for image quality will be completed. These are being constructed for both observing modes; AO-on (in terms of rms wavefront error) and AO-off (in terms of 80% enclosed energy diameters).

Objectives

Construct global telescope error budgets and detailed error budgets for the segmented primary mirror. Also construct error budgets for image motion.

Inputs

Complete Task 4

Initial work on Tasks 5 and 10

Initial values of telescope optical design. Baseline design for primary mirror active control.

Site environmental properties

Impact on Other Tasks

All other tasks will interact strongly with the error budgets. Candidate designs will define the budgeting and the budgeted errors will drive the designs.

Progress this Quarter

Draft error budgets for AO-on and AO-off modes have been written and supporting calculations are being completed. The error budgets include both a global telescope budget and a detailed budget for the primary mirror. There are about 70 supporting calculations that need to be completed.

A number of these rely on the efficacy of a warping harness to improve the segment figure. The final figure of each Keck segment is achieved with a set of springs that slightly deforms the surface to remove low order segment aberrations that are measured in the telescope. We completed a draft of Technical Note No. 6 on the efficacy of a Keck-style warping harness design for CELT. This design is based on the segment axial support of Steve Gunnels and applies a moment at each of the 15 flexures (the Keck warping harness uses 30 moments). Using finite element analysis Steve calculated the surface deformation caused by the three fundamental pivots. Using symmetry we then extended these to surface deformations for each of the 15 moments. We then fit each pure low-order Zernike to a combination of these moment-surfaces and calculated the rms residual surface. The ratio of the residual rms to input Zernike rms is a measure of the efficacy for removing that Zernike. Compared to the Keck warping harness, this design is **ineffective** for removing low order Zernikes. We assume this is a result of the fewer moments (15/30) and their geometry. We may be able to design warping harness springs that are independent of the axial support system to increase the efficacy. In the meantime, we have assumed a warping harness cannot be used in our assumptions for an error budget.

Supporting calculations that need to be completed include: segment fabrication errors, deformations of the segment surface induced by a temperature change with spatial variations in the thermal expansion coefficient, spatial variations in the temperature gradients in the segment, residuals from AO DM adjustment to remove segment Zernike aberrations, fabrication and assembly errors in the segment support, and others. Progress this quarter was not as rapid as planned on the completion of these supporting calculations. As a result, the draft error budgets are not yet fully related to fabrication, assembly, and alignment tolerances. As such they must be considered to be temporary goals.

Plan for Future

Progress this quarter has not matched expectations. Given the central role of the error budgets in demonstrating feasibility, they will be given high priority in the fourth quarter.

.

Task [9] Stressing fixture design, prototype and test

Description

We will design, build, and test a full-scale prototype stressing fixture. We will apply it to an aluminum segment, and measure the response, repeatability, and temperature and vibration sensitivities. If discussions with vendors show that this demonstration will have no significant impact on the cost estimates, then we can postpone the prototype and test phases.

Objectives

All candidate vendors have no experience with Stressed Mirror Polishing in a planetary polishing facility. Thus, this is likely to be a high cost-risk process for both CELT and the vendors. A detailed demonstration of the process will allow the vendors to make a credible estimate of the fabrication costs. Experience suggests that without such a demonstration all vendors will be required to provide very high cost estimates.

Impact on Other Tasks

The design (and perhaps the fabrications and tests) on Task 8 Establish the segment fabrication cost

Status

Some initial concepts for stressing fixture design are given in CELT Report No. 1 " Giant Optical Devices" and in CELT Report No. 5. "Primary Mirror Segment Fabrication for CELT"

Progress this Quarter

Jerry Cabak, an engineer at UCSC, has begun finite-element analyses required to design a prototype stressing fixture. The studies were made initially using an educational version of ANSYS, and Jerry has now acquired and configured a professional version that allows the required number of nodes to model the deformations at the nanometer level. Jerry has built several models and applied azimuthally-symmetric loads. Studies of a system with levers attached to edge of the blank (as was done for Keck segments) showed that 48 levers are sufficient to give a inter-lever scalloping of only 3 nm rms at the radius of the hexagon vertex (96 attachment points were used for Keck). He has now begun to model designs with the levers attached to the back of the blank. We believe this configuration will be more economical to use for CELT and will still provide the required deformations.

Plan for Future

Jerry Cabak is now modeling a quarter of a segment and will apply the loads required for stress mirror polishing the outermost CELT segment. Following these finite-element studies, we will proceed to a hardware design for the prototype stressing fixture.

We expect to complete CELT Report No. 11 describing the required loads and the predicted deformations (analytic and finite-element) in the fourth quarter.

Task [14] Segment Displacement Sensors (design, prototype, test)

Description

> This a potentially very expensive and complex item for CELT. About 6000 displacement sensors are required for segment stabilization. We will create an in-house design and also complete a thorough survey of commercially available devices. If no commercially suitable devices are available and affordable, we will prototype and test the in-house design.

Objectives

> Complete a thorough survey of commercially available devices
>
> Create an in-house design. If no commercially suitable devices are available and affordable, prototype and test the in-house design

Status

Initial Sensors design concepts are given in CELT Report No. 6 "Segmented Mirror Control System Hardware for CELT", Terry S. Mast and Jerry E. Nelson (Proceedings of the SPIE, 4003, 2000). We have made measurements at Keck to understand discrepancies in the Keck sensor noise and we have begun a program of prototyping CELT sensors

Progress this Quarter

Keck Sensor Noise

Kirk Gilmore and Gary Chanan went to Keck and made a variety of measurements to help understand the long-known discrepancy between the laboratory-measured noise in Keck sensors (~ 1 nm) and the telescope-measured noise (~ 6 nm).

On March 29 and 30, Kirk Gilmore and Gary Chanan made sensor noise measurements at Keck 2, using the Fast Data Capture mode of the Active Control System. Supplementary FDC analysis code written by Edwin Sirko provided on-line access to power spectra of individual sensors for the first time.

Two significant effects were observed:

1. Of the 18 outermost sensors, the 6 that are located at the middle of the telescope edges are typically the least noisy, often by as much as a factor of two in power. This may suggest some sort of node in a mechanical vibration.

2. One sensor was removed from the ACS and replaced with a stand-alone unit that could be controlled by a micrometer, but was otherwise mechanically and electrically identical to the active sensors. This sensor was manually tuned with the micrometer until its residual was small, so that it was participating in the active control system. When this

sensor was rested on foam padding on the floor of the mirror cell, its noise contribution virtually disappeared.

Both of these results suggest a mechanical origin for sensor noise-manifested either as rigid body motion of the segments or as distortion of the segments (or some combination of the two), but there are problems with either interpretation:

1. The sensor noise can be separated into physical (rigid body) motion and unphysical motion. Above 10 Hz - which is where most of the power is - there is little difference between the physical and unphysical noise spectra. If the effect were rigid body motion, there should be little or no unphysical noise; it should all be physical.

2. Johannsen and Chanan in their memo of 6 June 2000 showed good agreement between optical (AO) and electro-mechanical (ACS) measurements in a static test, but no correlation whatsoever in a dynamic test. This suggests a non-rigid-body source for the sensor noise; otherwise it should have manifested itself optically.

3. The resonant frequencies for non-rigid-body motion of the segments are too high to account for the power seen in the sensor noise spectra.

NASA will be making accelerometer tests at Keck, and these are likely to help in our understanding of some of the inconsistencies. All of the hardware is in place, i.e., pucks on the segments, all of the cables are run. Software is being developed by JPL, and one estimate gives at least two months before the tests will be made.

CELT Sensor Development

This quarter we acquired a Keck sensor test facility from Bob Minor and Dick Jared at LBNL. They are eager to assist in the CELT sensor development, and Bob has some funding to do so. Kirk Gilmore is beginning to test and make some modifications of the test system electronics so the output can be used.

He has a working sensor test stand, preamp card and dummy sensor. He can vary the trim capacitor value by the adjustment on the front panel of the dummy sensor box and see a change in voltage at the input to the A/D converter on the preamp card. Sampling at a fixed 100Hz frequency, he can see all the clocking signals on the preamp card. The achievable peak-to-peak offset is ~20 mv in this configuration.

In the coming weeks we will test 1) a "dummy sensor" consisting of variable capacitors, 2) a "copper plate sensor" consisting of an initial CELT design made using etched printed circuit boards, and 3) an initial prototype CELT sensor using coated Zerodur blocks. These initial capacitor layouts have been designed to match the Keck electronics.

Plan for Future

Future prototypes will be modified to be 1) optimized for CELT, 2) provide a measurement of the gap, and 3) provide capacitive coupling across the gap.

Task [15] Design Telescope-Control Wavefront Sensor (TCWS) hardware

Description

It will be highly desirable for CELT to have a Gemini- or VLT-style Telescope-Control Wavefront Sensor (TCWS) for monitoring the lowest ten to thirty spatial frequency modes of the primary mirror. The baseline assumption is that the TCWS will be a Shack-Hartmann-type camera in which the primary mirror is re-imaged onto a lenslet array, producing an array of stellar sub-images (containing wavefront gradient information) on a CCD. The current task will determine the conceptual design parameters of the TCWS.

Progress this Quarter

Gary Chanan submitted the following report.

We have assumed that CELT will require a telescope control wavefront sensor to control the lowest spatial frequency degrees of freedom of the primary mirror (although with the most recently proposed sensor geometry, this may not be strictly necessary). We have further generally assumed that this sensor would be of the Shack-Hartmann variety. The purpose of this note is to outline some of the issues that would be involved if we instead used a curvature sensor for low spatial frequency wavefront control.

In curvature sensing with a segmented mirror telescope, as opposed to a monolithic primary, there are two obvious regimes to consider. The first is the unresolved case in which there are several segments per resolution element in the out-of-focus image. The second is the resolved case in which there are several resolution elements per segment. [The resolution element is probably the seeing disk, but could in principle be a pixel of an AO-corrected image.]

I claim that the unresolved case is highly impractical for a highly segmented telescope like CELT. First, consider curvature sensing on a monolithic mirror. In the difference image (the difference between an inside-of-focus and appropriately rotated outside-of-focus image), one can show that intensity of the difference image (expressed as a fraction of the one-sided out-of-focus intensity I_0) is proportional to the Laplacian of the wavefront phase. In addition, the difference image will have an extra strip around the circumference whose width is proportional to the normal derivative of the wavefront phase, and whose intensity is +/- I_0. [It is important to note that the two constants of proportionality in the above relations are identical.] We can estimate the Laplacian of the phase as z_{rms}/R^2 and the normal derivative as $z_{rms}R$, where z_{rms} is the rms wavefront phase, and R is the radius of the mirror, which we take to be circular. Multiplying these two estimates by the area and circumference of the mirror respectively, we find that there are roughly twice as many "rms photons" around the boundary of the difference image as there are in the interior. Thus the boundary signal effectively swamps the Laplacian at the boundary, but this is usually not a problem, since the boundary represents a small fraction of the total area of the image.

However, when we move to a highly segmented telescope, the boundary area is greatly expanded and the scheme falls apart. The Laplacian associated with a global aberration can still be estimated as z_{rms}/R^2, but now the rms number of photons in the segment interior is proportional to $(a/R)^2$ z_{rms}, where a is the hexagon side length. If the segments have random tilt errors corresponding to a phase error of e_{rms} at the segment edge, then the rms number of photons near the boundary is just proportional to e_{rms}, with no a/R factors. The edge and boundary contributions are equal when:

$$e_{rms} = (a/R)^2 z_{rms}$$

Suppose we are interested in global aberrations with z_{rms} = 1 micron. Taking a = 0.5 meters and R = 15 meters, we find e_{rms} = 1 nm, corresponding to an rms tilt of 0.5 milli-arcseconds. Thus we would expect that in the unresolved case, segment edge effects, due for example to residual tilt errors, would virtually always swamp the global signal of interest everywhere, and thus curvature sensing is probably not workable in this regime.

We are thus left with the resolved case, in which there are many resolution elements per segment. Global aberrations of the primary are due purely to segment tip/tilt (and piston). In this regime there is no contribution to the Laplacian from the primary, although despace of the secondary does cause a constant offset in the difference image (because the Laplacian of focus is a constant). This does not mean that global aberrations are not detectable in this regime, but rather that they must be detected by the small slope discontinuities which they produce at the segment edges. This can actually be an advantage, since for example the small edge discontinuities associated with focus mode could be used to distinguish it from focus (secondary despace). The main disadvantage of the method is that one must go far enough out of focus to be well removed from the unresolved regime, and this means in turn that the reference stars must be very bright.

I have written a simple Monte Carlo simulation to show how this scheme would work for the 91 segment Hobby Eberly telescope, and it appears to give reasonable performance in distinguishing focus from focus mode, although the necessary star brightness is an issue. I believe the next step is to convince the people at HET to try out the algorithm on their telescope, as real experience should be more valuable than further simulations. There should be some interest in this at HET, since the telescope currently does not have an on-sky alignment system, and furthermore has a very tight tolerance on focus vs. focus mode. [Visual inspection of out-of-focus images suggests that this latter tolerance is not being met.] A figure of merit for the ease of implementation of this technique is r_0 divided by the number of segments across the telescope diameter. If we take r_0 to be 10 cm on Mount Fowlkes (the HET site) and 20 cm at the prospective CELT site, then this figure of merit is only 50% higher for HET than CELT. On the other hand, if we were to test at Keck, the figure of merit is a full five times higher, so a considerably larger extrapolation would be required.

Plan for Future

We plan to make a study of the VLT wavefront sensor and write a note describing the design issues and candidates designs for the TCWS.

Task [16] Segment support actuators (design, select, test)

Description

> The segment support actuators are potentially very expensive and complex. About 3300 segment actuators are required. We will make a thorough survey of the availability and cost of commercial actuators. We will design a lever-actuator system in order to expand the range of applicable commercial actuators. Every effort will be made to define the actuator requirements to minimize the costs: acquisition, fabrication, and maintenance. Robustness of candidate actuators will be tested, since the active control system has zero redundancy for actuator failure.

Status

Quarterly Report No. 1 described the actuator requirements and gave many details of the survey by Alan Schier. At the end of this quarter, Alan submitted a substantial and detailed final report summarizing his survey of many types of actuators and many vendors. After collecting the data and comparing a very large range of potential candidates, he identified six candidates that are likely to meet the CELT requirements and meet a cost goal of less than $2000.

Progress this Quarter

On March 8 we held an Actuator Workshop where Alan Schier and others presented the results of actuator studies and candidate designs. The participants agreed with Alan's study conclusion that the voice coil actuator holds the greatest promise for an actuator that will be meet both the lifetime and cost goals. They also recommended pursuing a backup candidate of the motor driven screw/ Hatheway motion reducer design.

We have signed a contract with Ken Lorell and Jean Aubrun to design and prototype a voice-coil actuator. They have presented four classes of voice coil design that differ in the method of off-loading the force on the voice coil. The major drivers in this selection and in the design are reliability and cost. We selected for further study the class that uses a counter weight to off load most of the force plus a small motor to fine tune the off-load force. Ken and Jean, in collaboration with an electrical and a mechanical engineer, are now developing a detailed design and cost estimate. They are also preparing to manufacture a prototype actuator for testing, with an emphasis on reliability testing. We are developing with them the requirements for a test facility and test program to be operated at UCSC to test their prototypes and other candidate actuators. We expect that the testing will help define modifications to the design that will need to be implemented and then further tested.

Plan for Future

The design report is expected in about six weeks and a prototype for testing at the end of the summer.

Task [20] Design the Telescope Structure

Description

We will produce a conceptual design of the telescope that satisfies the constraints of primary mirror and final f-ratio. The location of foci, size of science instruments, support of segments, handling of segments, support and handling of the secondary, rapid exchange of the secondary, cleaning of the mirrors, repair of key active components including replacement of actuators will also be considered in the design. Methods for periodically CO_2 cleaning the mirror will be described. A method for aligning the segments in all 6 degrees of freedom will be addressed.

Objectives

Produce a design that is compatible with all the physical and geometric constraints. The stiffness and natural frequencies will be determined, particularly the lowest modes that influence image location and quality. The possible effects of wind loads will be included in the design choices. The design will be compatible with plausible drive, bearing, and encoder systems. The support and exchange of secondary mirrors will be described.

Progress this Quarter

Design work on the telescope structure has been seriously impeded by the weak participation of Nelson. Medwadowski has been working on the structure. It has proven difficult to produce an upper structure with small blockage of the primary, high natural frequencies, and adequate margin against buckling.

Medwadowski found that the tensioned structures as designed have a problem in that the tensioning cables interest the converging light beam as it approaches the secondary. This makes the cable blockage much larger than just their blockage of the incoming beam. These cables are fundamental load carrying members, not anti-buckling members, so their cross sections can not be easily reduced. As a result of this, other structures are being explored.

We have opened up the design space to include tripod, tetrapod designs that penetrate the primary mirror. This will probably increase the blockage somewhat, and may cause the elimination of some segments under the legs. This design space has only barely been studied.

The mirror cell and elevation support structure now has a strawman design. It is not at all optimized. It has four elevation rockers in order to provide adequate support of the primary mirror. The primary mirror undergoes significant rigid body motions due to gravity (several centimeters), and the non rigid body motions may be several mm.

We expect to put significantly increased time into this activity during the summer.

Task [21] Generate strawman designs of the bearings, drives, encoders

Description

A conceptual design of the telescope elevation and azimuth bearings, the elevation and azimuth drives, and the elevation and azimuth encoders will be generated. Attention will be given to meeting the requirements, and providing a cost effective design. Design alternates will also be given, so options are understood.

Objectives

We will develop suitable designs for all 6 systems and describe their performance. The influence of wind will be given. Alternative designs will be sketched, to provide a start for a more detailed evaluation later in the project.

Inputs

The telescope structure will define the design requirements.

Progress this Quarter

A team at Vertex/RSI under the direction of Stan Hermann has begun work on the conceptual design of the telescope bearings, encoders, and drives. We have agreed with them on a set of detailed requirements and strawman values for the telescope masses and moments of inertia. Since the telescope structural design is incomplete, these masses and moments will change in the future. We have asked Vertex/RSI to not only create a strawman design, but also to indicate how it might change with changes in the masses and moments.

They have submitted a report on some of their initial work on the azimuth and elevation drives and bearings.

They are studying candidate drives systems:

- high-speed (> 1000 RPM) motor with gear box and final reduction
- low-speed (< 1 RPM) motors with final reduction
- on-axis motors

They are studying candidate bearing configurations

- roller (wheel / track)
- hydrostatic

They call out some problems with the Wheel / Track bearing configuration.

- track joints induce pointing errors that are difficult to correct because they are local (very high frequency)
- pointing errors caused by radial runout of the wheel and bearings are unrepeatable over the long term.
- running friction variations may objectionably degrade the pointing accuracy

Plan for the Future

We expect the contract to be completed by the end of the fourth quarter.