UNIVERSITY OF CALIFORNIA

LICK OBSERVATORY TECHNICAL REPORTS

NO. 42

TEN-METER TELESCOPE TECHNICAL DEMONSTRATION

PROGRESS REPORT EXCERPTS JULY 1981 TO JULY 1984

Jack Osborne

Santa Cruz, California

February 1985

Introduction: What follows is a chronology of excerpts from the published U.C Ten Meter Telescope Reports. The purpose is to point out the input from the Lick Observatory Shops in Santa Cruz. The fraction of the total cost is about 3%, while the fraction of the total weight of the Technical Demonstration hardware is nearly 75%.

Comments: The structure for holding the optical components was conceived by Jerry Nelson and the Science Office. The necessary space frame structures were designed as sets of nodes in space with element cross sections specified. From this set of X Y Z coordinates, real live steel frames were designed and fabricated.

TMT # 65
Dec 81

TEN-METER TELESCOPE (TMT) TECHNICAL DEMONSTRATION

Progress Report

July 1, 1981, to November 30, 1981

INTRODUCTION

This report is the first monthly progress report for the Ten-Meter Telescope (TMT) Technical Demonstration Project. This particular report will cover the period beginning July 1, 1981, to November 30, 1981. The subsequent reports will cover only the one-month period preceding the issuing of the current report. While the narrative will be current, the cost reports may lag because of the accounting reporting structure.

A reduced size Critical Path Diagram is included and is intended to serve only as a graphic indication of the project status. With this report we include a larger and more legible copy for reference.

The motivation for these reports is the need for communication within the Technical Demonstration Project group. They will also serve as reminders as to where the elements of the Project stand relative to each other, where they should be and the need to stay coordinated. The budget reports are important for obvious reasons. These reports will not be polished documents, so please look at the contents and excuse the form.

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Summary

The Technical Demonstration started off July 1, 1981, with funding carried over from the previous study funding. While we movedahead on some critical requisitions, we were uncertain as to the level of staffing until August 10 when we were informed that the T.D. had been funded for the minimum demonstration plus contingency. The contingency is to be controlled by the EMC which has now allocated $60K for an Environmental Impact Study and $25K for some A&E preliminary work.

The Project Science Office has acquired the services of Mr.Budianski which fact should speed up the necessary analysis and decisions preceding the engineering designs.

Prolonged discussions of almost 3 months preceded the signing of the contract by Schott for the glass blank. The contract with Tinsley Laboratory is in the final negotiation stage with an estimated time table of 12 weeks for tooling plus 22 weeks for the grinding, polishing, cutting to a hex and hole-boring. It should be noted that the 22 weeks is an optimistic estimate. In anticipation of the contract signing, the test tower has been designed in consultation with Tinsley. The mirror is on the critical path.

The mirror support system has suffered a setback in that further analysis has shown that the 18-point support system will introduce unacceptable deflections. A 36-point system is now being analyzed post haste as the whiffle tree design is now held up pending the study. This is becoming critical in that it impacts on the actuator mounting design and mirror grinding.

The precision sub-cell for mounting the mirror and the active systems to the basic cell is being studied. The decision will bear directly on the cell design and the mirror support components such as the radial support post and the actuator and its mounting.

The UCSC-Lick engineering has been given a tentative go-ahead on a yoke design to be presented for discussion.

The search for qualified fabricators for the actuator roller screw has been troublesome and a source of delay. An interim solution now in progress is fabrication by Lawrence Livermore National Laboratory in order to proceed with the Technical Demonstration. However, there is still need to develop a commercial supplier for TMT so negotiations are still going on with SKF, France.

The Reduction-in-Force now taking place at LBL will impact on the Active System Group led by G. Gabor. The penalty in schedule has not yet been fully assessed, but the guess is from 1-1/2 to 3 months, depending on the transition.

Yoke Fabrication

Yoke fabrication at UCSC/LO has progressed to approximately 2/3 of the finished height inside the shop. The balance of the work will be completed outside. Presently the work is being held up pending determination of the best way to increase the natural frequency of the structure. Meanwhile, fabrication of the pivot point components is proceeding. The bearings are on hand.

Whiffle Tree and Radial Support Post

The 36 point support system has been finalized. Fabrication of the redesigned whiffle trees for the Tinsley Laboratory grinding is now better than 40% done. The final design of the point between the tripod and the actuator is almost complete. The target date for delivery to Tinsley Lab is March 15.

Material for the radial support post diaphragms is now at LBL for fabrication by the EDM process. These diaphragms will be subject to flexural testing at the Space Science Laboratory as soon as the pieces are delivered.

Bldg. 60 Preparations

The fabrication of the air circulation system has been completed. Installation will start next week. During that period, the heat pump for the control room will be placed so that the electricians can wire up both systems.

The DC power supply for the crane will be delivered at the end of February. After that installation, the Bevatron riggers will do the reaving and load testing.

Whiffle Tree and Radial Support Post

The 36 point support system for the mirror grinding effort is expected to be available for installation at Tinsley approximately April 1. The design is complete except for the solid support back-ups for the 36 contact points. The hydraulic actuator components for the system are in house. Fabrication is approximately 60% complete - one week of machining effort was lost due to machine shop personnel illness.

The radial support post diaphragms have been fabricated and a 0.020 inch thick diaphragm has been installed in the fatigue tester with a setting which produces a stress level of approximately 170% of operational values. After 50,000 cycles no degredation is evident. However, the test has been interrupted in order to modify the fatigue tester wobble motion drive are to reduce an undesired vibration problem resulting in dynamic overstressing of the diaphragm.

Structure

The yoke fabrication resumed February 17 with the work moved to the outside of the shop. The 3.4 hertz frequency was determined to be sufficient for this demonstration.

The bearing housings and axles are finished. The elevation ring weldment has been completed, annealed and sand-blasted. The final machining for the axle attachment will be done in early March.

The drive worm has been attached to the shaft. The drive worm and motor will be attached to them when the center section is installed to the yoke structure in March.

Summary

The generated glass blank is now in the annealing oven at Schott in Duryea, Pennsylvania. Meanwhile the design and fabrication of tooling is proceeding at Tinsley Laboratory in Berkeley for the grinding. Tinsley Laboratory is readying an area by moving in and installing the grinder for the job.

A symmetrical layout for the 36 point support has been selected. Engineering layout and analysis will proceed hand-in-hand to determine the final layout which will be used for the Technical Demonstration as well as the TMT. A schematic layout is included in this report.

Fabrication of mechanical parts for the actuator has been started in the shops at LBL and UCSC/LO. Delivery of the integral screws from France has been delayed to April 19 from March 5.

Fabrication of the first mirror mountable sensor has started. After some investigations and trials by industrial vendors, we will do the plating of the sensors at LBL.

Glue joint tests for sensor mounting have been successfully concluded.

The whiffle tree components for the grinding has completed the machining phase and are ready for the welding phase.

The yoke structure is completd and has been checked for natural frequency and mechanical fit and clearance with elevation ring. The structure is now ready for shipping to LBL.

The elevation ring drive system is in the final phase of fabrication and assembly. The system will be installed on the yoke structure and checked out before the structure leaves UCSC/LO.

Segment Support and Passive Control

After exploring a number of possible designs we have selected a symmetric whiffletree pattern for the support of the hexagonal mirror (shown in the attached Figure). The exact position of the 36 support points for the whiffletree will be determined in the next 2 weeks using a finite element analysis program that includes the effects of the central hole in the mirror, the weight of the displacement sensors, and the curvature of the mirror. In addition the structural design of the subcell and cell combination using SAP4 will begin in the next week or two.

Yoke

Modifications of the partially completed yoke were made on the basis of SAP4 analysis in order to increase the TD structural resonance frequency to 3.7 Hz. These were completed at the Lick shops, and the elevation box was built and installed on the yoke. The yoke will be shipped to LBL by the end of the month.

Science Office Reports Issued

A Computer Program for the Determination of Zernike Coefficients by Analytic Integration. (TMT Technical Note # 32)

Deflections of a Hexagonal Mirror Segment due to Error in Position of the Radial Support Post. (TMT Technical Note # 33)

An Atlas of Zernike Functions (TMT Technical Note #34)

Whiffle Tree and Radial Support Post

Machining of all whiffle tree components is complete. Welding and assembly is scheduled to be completed by April 1, at which time the assembled whiffle tree, solid support back-ups and hydraulic actuator components will be delivered to Tinsley.

The radial support post diaphragm (.020 thick version) continues to be tested in the fatigue tester. To date, approximately 1 1/2 million stress cycles have been generated and no sign of diaphragm degradation is evident.

Support Structures

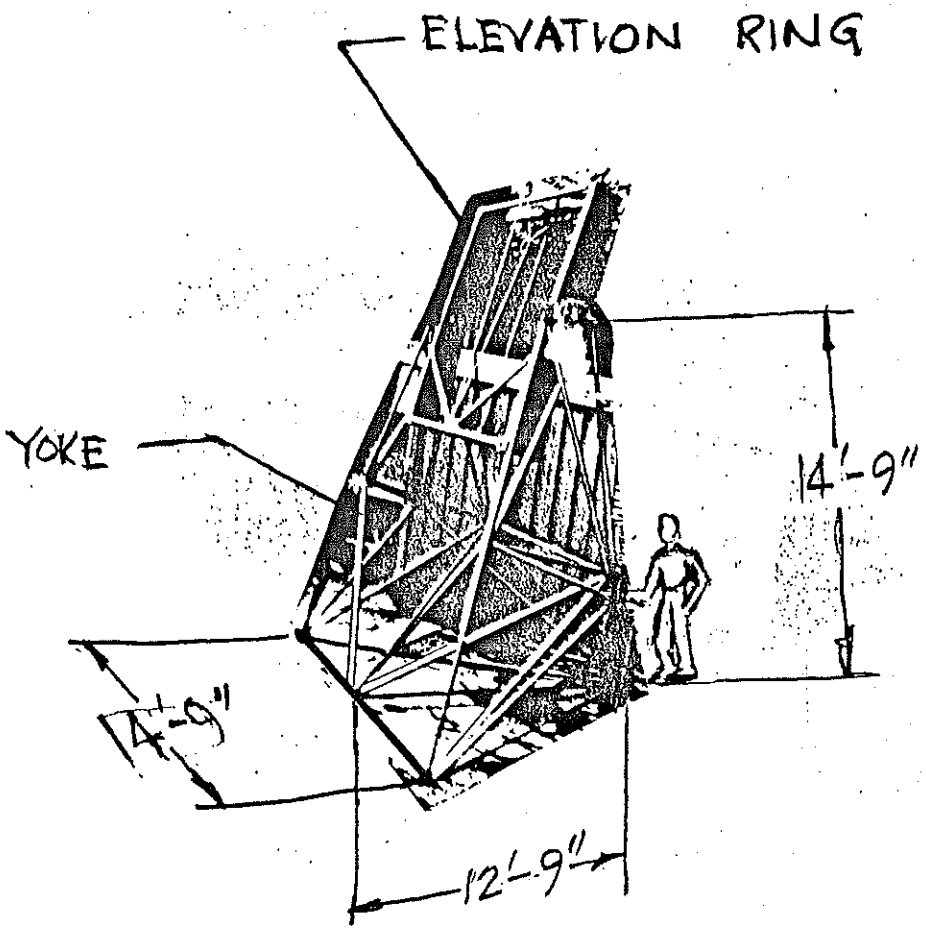
The yoke structure is now complete and the Elevation Ring has been installed in the yoke for a trial fit. The Elevation Ring has been rotated, and there is no interference with the yoke structure.

The worm drive housing is now 50% complete. The limit switches are wired but not installed. Final assembly of the drive to the yoke will be finished March 30 after which date the yoke will be ready for shipment to LBL. Shipping arrangements are in progress.

Site/Installation

The air circulation system has been completed. Air flow measurements have confirmed that the total air flow is 10,000 cfm.

The bulk of the power supply and controller for the building crane has been delivered. The bridge platform will need to be extended in order to accommodate these components. Expected completion date is May 1.



YOKE & ELEVATION RING ASSEMBLY

81

TMT # 81
Apr 82

Summary

The primary mirror blank has been delivered to Tinsley Laboratory for the final grinding, etc. The annealing was accomplished without any significant change in dimensions.

A separate tilt sensor system has been found to be unnecessary. Instead, the displacement sensors will be called to provide the necessary input for tilt control. This will place an extra load on the present displacement sensors and control systems, but the total hardware requirements will be reduced.

The integral roller screws fabricated in France are now in hand and the quality is excellent. The testing should begin the first part of May.

The problems associated with coating the glass sensors have been overcome, and the LBL shop has produced excellent reproducible coatings with superior adhesion.

The whiffle tree and jacking systems are being installed at Tinsley Laboratory preparatory to the grinding of the mirror.

Fatigue testing of the radial support post diaphragm has now passed the 4.5×10^6 cycles without any problem.

The yoke structure has been shipped from UCSC/LO and is now installed at LBL.

Passive Support Structure

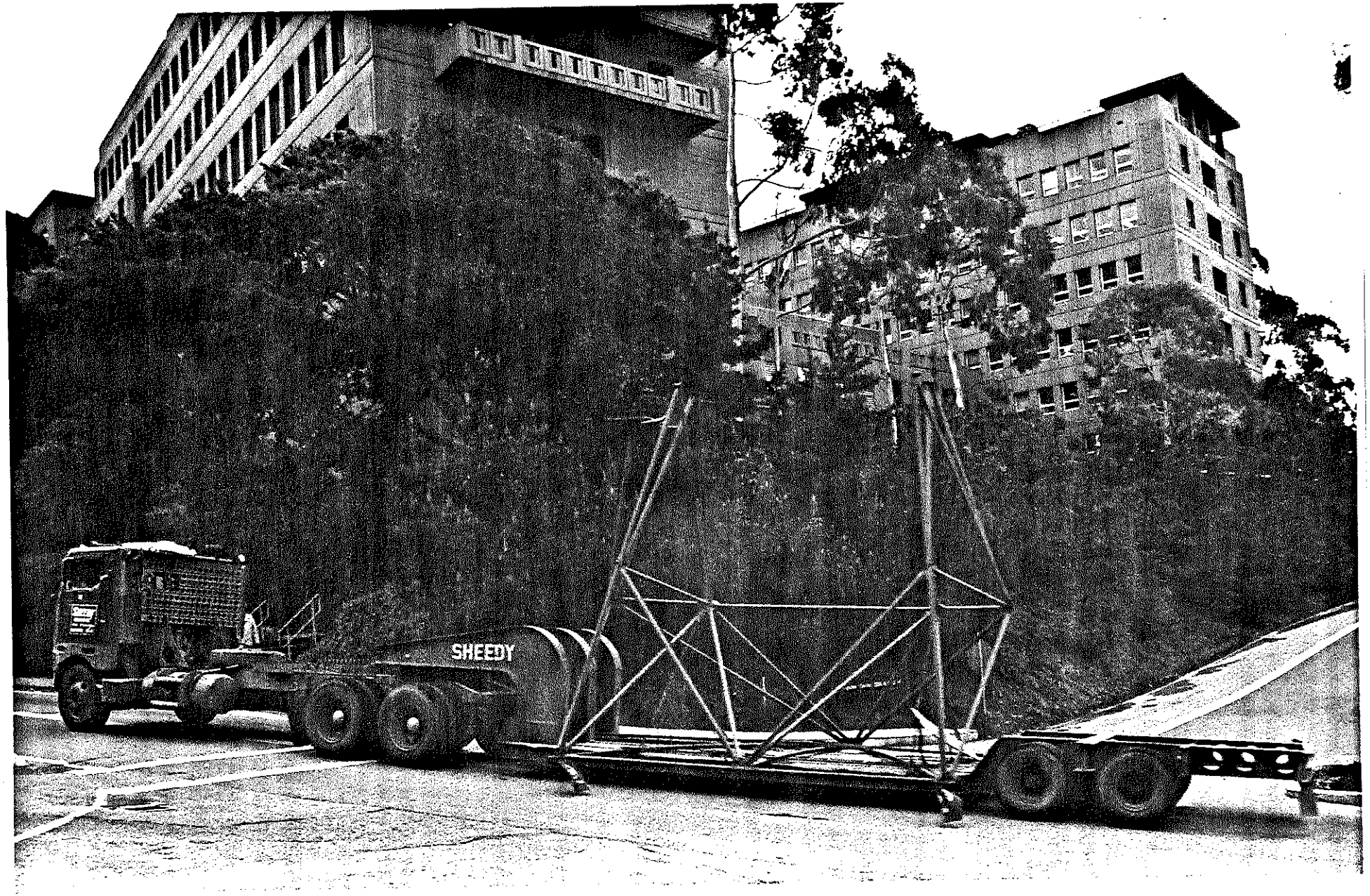
The yoke structure was shipped April 5, 1982 from the UCSC Lick shop to LBL (see photo). The yoke is now installed in Building 60 and a working platform is now in the design process at LBL.

The elevation box drive system fabrication is now finished including the limit switch brackets. The telescope tube, sub-cell, cell and the various miscellaneous support structure engineering design is waiting on the completion of the analysis from the Project Science office.

Site and Installation

The sheet metal ducting for the heat pump is now in fabrication and installation should begin the week of May 10.

The yoke has been installed with the vibration isolators and earthquake motion limiters



YOKE STRUCTURE ARRIVING AT LBL

TMT #83
May 82

Summary

Tinsley Laboratory has ground and polished the back of the 1.9m mirror. Meanwhile, the support system is checked out to support the mirror for the grinding of the front.

Analysis of the rest of the support system is continuing. However, the month of June will be slow because of other previous commitments.

The testing of the KPNO sphere is in progress with Nelson and Mast being drawn in for close consultation. This is a further dilution of the Science Office effort for the Technical Demonstration.

The fabrication of the actuator mechanical hardware is being completed. The first integral roller screw has been assembled into the existing actuator hardware and the initial testing has been very satisfying.

As a work-around the delayed mirror support system, a test structure is being designed in order to enable the testing of the dynamics of the whiffle tree with actuator and sensor.

Testing of the diaphragm for the radial support post is continuing. It seems that the testing apparatus is the subject of the test rather than the disk.

ACTIVE CONTROL SYSTEM PROGRESS REPORT FOR MAY 1982

Illness has continued to plague the group. A quarter of the work group was out sick during the month.

A new digital technician will join the group the second week of June. His help should speed the actuator servo loop development.

A temporary drafting person is also being hired to reduce the backlog of mechanical and electronic drawings need completion.

Control Computer and Data Highway

The hardware and software of the fast sampling system for studying the actuator dynamics is complete and in use. The measuring system is intended to mature via software and hardware modifications as the development of the actuator servo loop progresses. Measurements of the dynamic behavior of the integral roller screw are now in progress.

The emulator software for the actuator microprocessors has not been delivered yet. The development of the servo loop software cannot begin until the emulator is installed on the PDP 11/23. The present delivery date is the first week of June.

Actuator Electronics and Hardware

The fabrication of the actuator mechanical hardware will be completed during the first week of June. The machining has proceeded very smoothly and in general below cost estimates.

The actuator drive electronics mechanical package is complete. The

TMT #84
June 82

Progress Report
June 1982

Science Office

Much of the Science Office staff was on vacation or involved with the NNTT workshop at Flagstaff this month. This limited substantially the amount of progress.

KPNO Mirror Fabrication

After insulating the test tower, KPNO made another series of interferometric optical tests of the mirror. These results showed a much improved reproducibility of the measurements made during the night but showed about a 4 sigma variation from night to night. Measurements made with temperature sensors on the folding flat and tower suggested that changes in the flat temperature and associated gradients were causing the flat to warp. A second series of modifications were then made to the tower. A steel support band which contacted the flat via a mercury ring (on one side only) was removed; a second box was placed around the first box insulating the flat (the measured diurnal variations had been 1.5 - 2 ^{o}C); and a fan was added to circulate air around the top and bottom of the flat. A second series of test were started during the final week of the month.

The datalink between KPNO and LBL was completed and tested. However, no data has been analysed at LBL due to lack of manpower.

Optics

Tinsley is using the polishing table to work on another project. In the meantime they are building the support for the flat and the radial support for the sphere. Hopefully these will be completed by the end of the month. The whiffletree support system was assembled and aligned and is now waiting for installation on the table. A first draft of the description of the procedure and equipment to be used to test the mirror during the polishing is now complete. Fabrication of the equipment (particularly that for measuring the radius of curvature) is beginning.

Segment Support

Recognition of additional forces from the whiffletree acting on the mirror blank has caused some concern. Determining the magnitude of the effect of these forces has posed some calculational difficulties, and has impeded work on the support of the hexagonal mirror segment.

Technical Demonstration Structure

The computer design of the mirror cell was completed and Jack Osborne is making detailed designs of the nodes. Fabrication of the cell should begin next month.

mirror cavity is being conducted to determine the stress level at the Invar/Epoxy/Glass interface for thermally induced stresses. A graph was presented at the June 29 TMT meeting showing stress values as a function of epoxy bond line thickness and epoxy moduli. This information will aid in establishing bonding details.

Structures

Engineering design work has started on the cell and sub-cell. The cell will be engineered and fabricated at UCSC/LO and the precision sub-cell will be engineered and fabricated at LBL. A coordinated plan of execution has been agreed on to insure that the parts will assemble properly at installation.

The platform fabrication is nearing completion in the shop. Installation is expected in July.

TMT #86
July 82

PREFACE

In the beginning, the progress report was intended to be an internal document for the TD project. With this in mind we have not made much effort to go beyond the bare reporting of highlights. However, the distribution has now expanded to over 40 and includes people not closely coupled to the effort. For that reason we feel that these reports would be more informative if they were to be less terse. From here on, we will endeavor to publish with that in mind.

For the more inquisitive, the project principals meet at LBL Building 50, Room 154, every Tuesday at 10:00 AM to discuss progress, problems, solutions, ideas, etc.

Summary

Summer vacation season is with us and its effect will be felt stronger this coming month. In an R&D project like the TD, a constant effort level is not possible unless absences or diversions of any kind are declared illegal.

The optical system now owns the critical path. The Project Science Office will work closely with Tinsley Laboratory to shorten the schedule.

The flat has been mounted in its support but the optical testing is still to be done. Tinsley has not yet begun work on the front surface. Lost schedule time to date is 10 weeks.

The active control system has graciously given up its tenancy of the critical path to the optical system. The testing of the actuator and the sensors is continuing with very encouraging results.

The whiffle tree design is being completed now that the finished analysis has given the final attachment points for the mirror supports.

A revised and improved scheme for the radial support post will allow the post to be screwed into place instead of being bonded directly to the back of the mirror.

The cell design is being completed and fabrication has begun at the Lick shops.

The Nasmyth platform in Building 60 and the installation have started.

The CPM diagram has been updated. The revised version is included in this report.

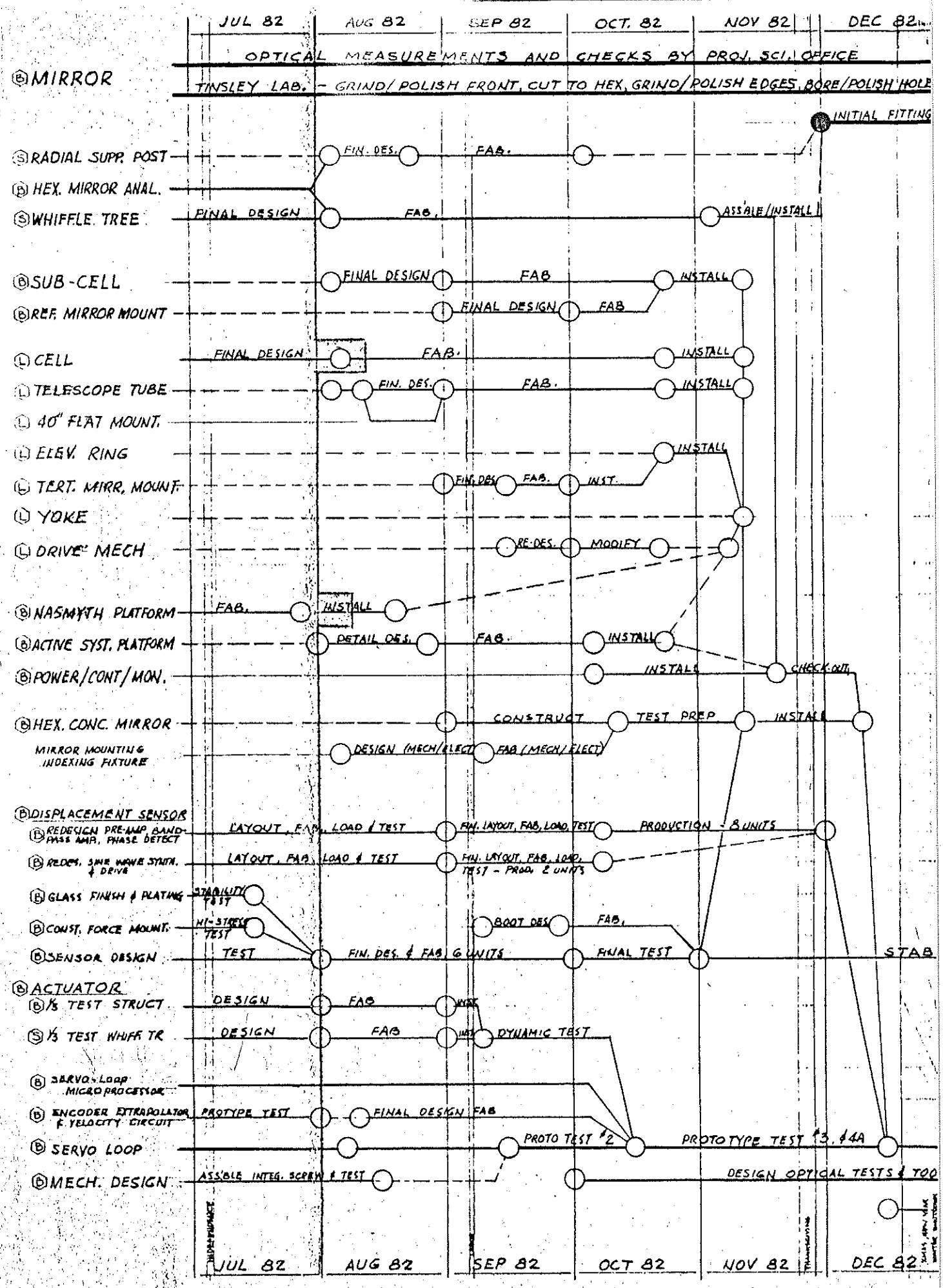
STRUCTURE

Lick engineering and shop are moving ahead on the cell. The design of the nodal point connections have been completed. The steel balls for the nodes are being machined by an outside shop. The pipe members have all been cut to length and the welding assembly of the cell is waiting on delivery of the balls.

The Nasmyth platform steel framing fabrication has been completed and the erection and installation have started. Detail design of the Active System Platform has started. This platform will house the electronics originally planned to be placed within the mirror cell.

The 1/3 test structure plan had been dropped once but has been revived because of the delay in the cell fabrication. This structure with one whiffle tree assembly will be located in Building 29A where the group under G. Gabor will carry out Tests #3 and 4A.

#86


JUL 82
AUG 82
SEP 82
OCT. 82
NOV 82
DEC 82
OPTICAL MEASUREMENTS AND CHECKS BY PROJ. SCI. OFFICE
MIRROR
TINSLEY LAB. - GRIND/POLISH FRONT, CUT TO HEX, GRIND/POLISH EDGES, BORE/POLISH HOLE
INITIAL FITTING
RADIAL SUPP. POST
FIN. DES.
FAB.
HEX. MIRROR ANAL.
WHIFFLE TREE
FINAL DESIGN
FAB.
ASS'BLE/INSTALL
SUB-CELL
FINAL DESIGN
FAB
INSTALL
REF. MIRROR MOUNT
FINAL DESIGN
FAB
CELL
FINAL DESIGN
FAB.
INSTALL
TELESCOPE TUBE
FIN. DES.
FAB.
INSTALL
40" FLAT MOUNT
ELEV. RING
INSTALL
TERT. MIRR. MOUNT
FIN. DES.
FAB.
INST.
YOKE
DRIVE MECH
RE-DES.
MODIFY
NASMYTH PLATFORM
FAB.
INSTALL
ACTIVE SYST. PLATFORM
DETAIL DES.
FAB.
INSTALL
POWER/CONT/MON.
INSTALL
CHECK-OUT
HEX. CONC. MIRROR
CONSTRUCT
TEST PREP
INSTALL
MIRROR MOUNTING INDEXING FIXTURE
DESIGN (MECH/ELECT)
FAB (MECH/ELECT)
DISPLACEMENT SENSOR
REDESIGN PRE-AMP, BAND-PASS AMP, PHASE DETECT
LAYOUT, FAB, LOAD & TEST
FIN. LAYOUT, FAB, LOAD, TEST
PRODUCTION - 8 UNITS
REDES. SINE WAVE SYNTH. & DRIVE
LAYOUT, FAB, LOAD & TEST
FIN. LAYOUT, FAB, LOAD, TEST - PROD. 2 UNITS
GLASS FINISH & PLATING
STABILITY TEST
CONST. FORCE MOUNT
HI-STRESS TEST
BOOT DES
FAB.
SENSOR DESIGN
TEST
FIN. DES. & FAB 6 UNITS
FINAL TEST
STAB
ACTUATOR
1/3 TEST STRUCT
DESIGN
FAB
1/3 TEST WHIFF TR
DESIGN
FAB
DYNAMIC TEST
SERVO-LOOP MICRO PROCESSOR
ENCODER EXTRAPOLATOR & VELOCITY CIRCUIT
PROTYPE TEST
FINAL DESIGN FAB
SERVO LOOP
PROTO TEST #2
PROTOTYPE TEST #3, #4A
MECH. DESIGN
ASS'BLE INTEG. SCREW & TEST
DESIGN OPTICAL TESTS & TOO
JUL 82
AUG 82
SEP 82
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NOV 82
DEC 82

TMT #88
Aug 82

STRUCTURES

The fabrication of the cell at the Lick Shops has been held up by the late delivery of the nodal point balls from a sub-contractor. J. Osborne will investigate.

The design of the sub-cell by J. Bercovitz is proceeding and is expected to be completed by mid-September. The start of the design was delayed by the lack of manpower and the priority needs for the 1/3 sector test structures.

The 1/3 test structure designed by J. Bercovitz is now in the shops as are the whiffle tree components for the test.

The Active System Controls Platform Design drawings will be issued to the shops next week. The start of the design work was delayed one week by the unavailability of manpower.

Analysis and design of the tube have fallen behind. Part of the delay has been due to a two-day power outage at the Grizzly Peak Substation which shut down the computers. The analysis and design will be further delayed for another week while the Project Science Office focus their efforts on the test equipment for measuring the sphere. The work on the tube is expected to resume around Labor Delay.

SITE/INSTALLATION

No activities to report.

TMT #92
Sep 82

TD TELESCOPE STRUCTURE

Miror Cell: The Lick shops received the 20 machined steel balls for the cell nodes. Necessary machining for welding the structural pipes to the balls was done and the cell structure was welded together.

Precision Subcell: Components for the subcell are being fabricated at LBL.

Telescope Tube: Fabrication at Lick awaits the completion of the design.

One-third Test Structure: The test structure is complete and installed in Bldg. 29 where the tests will begin soon.

TMT #94
Oct 82

Summary

The equipment for testing and checking the work at Tinsley has presented a host of problems which are now largely resolved. The optics is estimated to be 1-1/2 to 2 months behind schedule.

The sensor plating problem has been determined to be in the discharge cleaning. The setup has been re-configured and the results are now within specifications.

Initial trial of the damping material on the test whiffletree reduced the first mode frequency from 54 hertz to 50 with a Q of 50.

The mirror cell has been completed at Lick and is now in storage along with the elevation ring and drive mechanism pending the design and fabrication of the balance of the telescope structure.

Fabrication of the sub-cell has been suspended for a redesign to allow for better access.

The locating fixture for the attachment pads on the mirror back is now finished.

because the inner cages on four of the balls were touching their outer cages because of the misalignment of the mirror. Damping material was applied to the upper and lower surfaces of the three main whiffletree beams before the error was discovered. With the eighth-inch layer the frequency dropped to 50 hertz with a Q of 50. Measurements are continuing. These measurements are not the final ones. The test whiffletree, although very close to the TD whiffletree, has teflon bushings in place of flexpivots in the outer universal joints. The damping property of these joints is unknown at this time.

Passive Mirror Support System

Fabrication of the final whiffletree assembly is on hold awaiting results of dynamic testing now underway on the one-third whiffletree/concrete mass dummy test setup.

The locating fixture for glueing the Invar contact points to the back of the mirror has been completed and is ready for use.

Final design of the radial support post hardware which mounts inside the back of the mirror is underway. Assuming that dimensions and tolerances for the hole in back of the mirror will be settled with Tinsley by November 1, the radial support post hardware is scheduled for completion by December 1.

TD Telescope Structure

Mirror Cell: The fabrication has been completed and the cell has been painted. This is now in storage at the Lick Shops until Budiansky can be freed enough from the work at Tinsley to provide more input for the engineering design.

Sub-Cell: Fabrication work at LBL has been suspended temporarily as the result of a design review. The problem centers on the overall size of the nodal points and access to the back of the mirror and the various support and control elements. The redesign layout will be completed by the end of October and fabrication is projected for completion by the end of November.

Site

Active Systems Platform: Fabrication and painting have been completed. Installation will be started the first week of November. With the completion of the platform, the 4"-diameter metal conduit can be installed to carry cables between the control house and the mirror.

TMT # 95
Nov 82

Mirror Support

Problems were also discovered with the support of the spherical mirror on the polshing table. The lift and set procedure utilizing the lazy susan on the polishing table was found to progressively shift the mirror more and more off center. The was due to the transverse mobility of the mirror on the rolling balls of the whiffletree. A temporary method of lifting and setting the mirror was established using dial gauges and the vertical braces to keep the mirror centered. A more permanent solution will be installed next week by modifying the whiffletree so that the balls cannot roll. Thermal expansion of the whiffletree members will then be accommodated by a slight shearing of the rubber stoppers.

A number of mirror support problems remain to be solved both for the TD and for the TMT. In preparation for this effort some modifications to the finite element analysis programs are in progress.

For the TD hexagonal mirror support (and the TMT) the balls will be replaced by a flex-rod. Thus there will be no moving parts in the whiffletree. Using a prototype flex-rod assembly we have measured the lateral forces it places on the mirror, and analysis shows the effects to be adequately small.

TD Structure

Again no work was done this month on the TD structure design due to the higher priority of the work at Tinsley.

Design Report

Again no work was done this month on the design report due to the higher priority of the work at Tinsley.

KPNO Stressed Mirror Polishing

Mast and Nelson went to KPNO and examined their progress on the off-axis mirror. KPNO has just completed a series of modifications to the test tower and the mirror support They have instrumented the test environment with many temperature sensors and completed their insulation program. They have modified their whiffletree giving much the same effect as the modification we are now making to ours, i.e. they have eliminated the rolling action of the balls. They will now repeat the same series of tests: repeatability, mirror support, and test optics, to see the effect of these modifications. They will then proceed to stressing the mirror to test the performance of the stressing jig.

The special equipment for measuring the radius of curvature in the test procedure has been further modified and improved to speed up the test procedure. Among these changes is a hand paddle to ease the alignment of the flat.The most recent test cycle took 30 minutes.

The radius of curvature of the mirror has been measured twice, and the results are in excellent agreement with each other. We obtained

k = 10002.398mm
k = 10002.380mm

All known systematic errors except that due to the curvature of the flat have been included. We are pleased with the high level of reproducability of these tests.

The third cycle of grinding and polishing should be finished before the end of January.

TD STRUCTURE

While analyzing the telescope tube structure, Michael Budiansky found a low-frequency (about 1Hz) resonance due to flexibility of the elevation box. Consultation, discussion, and more computer work brought about a solution which will be implemented by Jack Osborne. Tube structure analysis continues.

TMT DESIGN REPORT

As in the past few months, no work was done on the design report because of the higher priority Tinsley work.

MEETINGS AND CONFERENCES

Jerry Nelson spoke on the University of California Ten Meter Telescope Project at the 11th Texas Symposium on Relativistic Astrophysics held in Austin on the 13-17 of December.

Terry Mast and Jerry Nelson attended the S.P.I.E. conference on Deployable Optical Systems held in Los Angeles on the 18-19 of January.

Michael Budiansky, Terry Mast, Jerry Nelson, and Barbara Schaefer attended the Santa Cruz hosted TMT Instrumentation Conference on the 24-25 of January.

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Mirror Polishing Support

After the second grind/polish cycle we found that the polishing ring caused substantial astigmatism in the sphere. The polishing ring is a cork-lined steel band which provides the coupling between the glass and four vertical braces attached to the polishing table. It provides transverse and azimuthal constraints on the blank. Since the amount of distortion was substantial (0.32 microns rms, primarily astigmatism) we decided to remove the polishing ring. It has been replaced with four thin aluminum blocks bonded to the edge of the blank with RTV. Radial forces and torques from the polishing tool are now transferred to the table through these blocks and the vertical braces.

After the third grind/polish cycle there was still substantial astigmatism in the mirror. We believe this was due to the asymmetry in the coupling used between the aluminum blocks and the four braces. (Two braces were used to take torques in one azimuthal direction and the two remaining in the other direction.) We modified the coupling so all four braces resist torques in each direction. In addition, in the past the grinding and polishing were done primarily with the mirror and tool rotating in one direction. On the fourth grind/polish cycle we are spending half the time in each direction to further symmetrize the process.

Grind/Polish/Test Cycles

The third grind/polish was carried out in January. The major objectives were to improve slightly on the radius of curvature and to evaluate the effects of removing the polishing ring.

After the second grind/polish the radius of curvature was k=10002.39mm.

After the third grind/polish the radius of curvature was k=9999.20mm ± 20 microns.

Thus the radius was substantially improved by this cycle. The optician believes that the radius is close enough to 10m that further grinding to adjust it would be unnecessary. Unfortunately a substantial amount of astigmatism remained and the best way to remove it is through grinding.

Tests made with the 48-inch spherometer used to measure the radius during the grinding showed its reading to be very unstable and quite sensitive to temperature. Additional insulation was added to it and the stability of the measurements improved substantially.

A fourth grind/polish cycle has begun and will be completed by 24 February 1983. Testing in the final week of February and first week of March will measure the radius of curvature and the surface. These will tell us the effects of the symmetrization of the grinding and polishing and the improvements in the spherometer. Improvements in the test environment and tests of those changes will also be made. Without the improvement in the test environment and consequent reduction of the testing errors we cannot be certain that additional mechanical difficulties are absent.

TD STRUCTURE

By the end of February the design of the telescope will be completed. The final phase of the construction can then begin at Lick.

Structures

No metal has been cut yet for the revision of the elevation box. The first analysis has been completed but the engineering design needs to be reviewed and approved before fabrication can start.

The subcell has been completed, machined and painted. Installation of actuators is taking place.

Site

Extended occupancy of the LBL test site Bldg 60 was investigated and there appear to be no conflicts until possibly late CY 1985 at the earliest. Another project, the Infrared Spatial Interferometer (C. H. Townes), has asked to share the building for staging in CY 1984. This seems to be compatible as the T.D. will be conducting life tests and anticipated TMT developments.

TMT #100
Mar 83

TD Structure

The conceptual design of the telescope tube and the elevation box have been released for construction at Lick Observatory. Fabrication is expected to be finished by June. The design of the fixture for handling the hexagonal segment was also sent to Lick. We expect the cell and subcell to be available in early May for the initial assembly and testing of the control system with a concrete dummy mirror.

The one major design project remianing is the support system for the reference mirror and the design is expected to be completed by early April.

SCIENCE OFFICE REPORTS ISSUED

THE UC TMT. (TMT Report No.97)

Dimensional Parameters of the TD Telescope Tube. (TMT Technical Note No. 59)

Tests of a Position Actuator for the Ten Meter Telescope Segments. (TMT Technical Note No. 62 and Lick Observatory Technical Report No. 29)

Fortran Subroutines for Geometric Manipulations in 3 dimensions (TMT Technical Note No. 63)

On 21 March a new updated version of the index of Reports and Notes was issued.

Structures

A handling fixture for the hexagonal segment has been designed and fabricated at USC/LO. It will be tested with the concrete mirror. Dimensional clearance allowance for this fixture is a prerequisite for the redesign of the elevation box for additional rigidity.

A brief explanation of the sequence and priorities is in order here. To do a proper job of fabrication and installation of the lower tube, the cell, precision sub-cell, and the revised elevation ring should be temporarily assembled at USC/LO for fitting the lower tube members. When that is accomplished, then the cell, sub-cell and stands will be shipped to LBL. At LBL, the concrete mirror will have the mounting pads installed. Then sensors, whiffletrees, actuators, sub-cell, cell and concrete hex mirror will come together for its initial testing as a full system on the floor, not in the yoke.

Meanwhile, design and fabrication of the upper tube will proceed at USC/LO. When that is completed in June, it will be shipped to LBL. The full installation on the yoke will take place and the dynamic testing of the system will continue in the yoke. The system should be debugged with the concrete mirror before the glass mirror arrives from Tinsley. The object is to spare the precious glass mirror the hazards that may develop from the first testing of a new system.

At the conclusion of the testing with the concrete mirror, the hardware needs to be removed and installed on the glass mirror at Tinsley. After satisfactory testing, the glass mirror will then be shipped to LBL for the final installation and testing.

A whiffletree using flex rods was assembled and measured for counter balance weight requirements. The weights are being fabricated now.

During the assembly of the whiffletrees it was discovered that the flex rod material was different from the prototype material. An annealed rod evidently was used which yielded during torsional motion of the rod. Replacements made of music wire are being made.

Telescope Structure

Elevation box modifications are in progress and should be done by April 29.

Reference cell in progress and should be done by April 29.

Handling fixture tests and modifications in progress and should be done by early May. Concrete mirror arrived from LBL on April 20.

Lower tube parts ready for fitting and welding and should be done by May 6, if the elevation box is finished in time.

Precision sub-cell arrived at UCSC on April 20 and was fitted to the mirror cell. Initial fitting looks very good. No shimming will be required.

Preliminary design has begun on the reference mirror air bag support. The bag material arrived and some of it will be sent to LBL for analysis. Air pressure regulators have been ordered.

Engineering the details of the upper tube has been started.

Very preliminary thinking has started on the 3rd mirror support.

Passive Mirror Support System

Final whiffletree machining is complete and the hardware has been delivered to LBL.

An additional set of support contact pads for use with the full-size concrete mass dummy has also been machined.

The Technical Demonstration schedule calls for completion of the polishing by 1 July. We now feel optimistic that the azimuthally symmetric terms can be adjusted in time to meet the schedule. The error budget allows an rms surface error of 40nm. During the "polishing out" cycles when no effort has been made to control in detail the aberrations the rms surface error has fluctuated from 100 to 250 nm. If the non-axisymmetric terms remain low, the final surface should meet the goal.

TD Structure

The conceptual design of the axial support for the reference mirror support was completed. The finite element analysis of the design is described in TMT Technical Note #70. The hardware design and construction will take place at Lick. Work continues on the finite-element analysis of the radial support of the hexagonal segment. The programs are being improved to attack this problem and the general parameters and space of solutions are being studied. As mentioned previously, the radial support post and flex disc do not provide an adequate radial support for the segment. Solutions involving some coupling of the whiffletree with the radial support are being studied as they will require minimum modifications of hardware.

SCIENCE OFFICE REPORTS ISSUED

Evaluation of a Recent KPNO Polish of Sphere (TMT Technical Note No. 68)

Finite Element Analysis of Axial Support for Reference Mirror (TMT Technical Note No. 70)

Stress Mirror Polishing at KPNO

We are pleased that Joe Magner, the TMT Optics Manager, is now spending half his time in Tucson assisting with the Stressed Mirror Polishing project. Last month KPNO polished a high quality sphere onto their mirror with the stressing jig attached but basically not warping the mirror. This optical system (sphere plus flat) images 80% of the light from a point sources into 0.3 arcseconds. The radius was not controlled. Subsequently, very local warping effects where the bending levers attach to the mirror were found, and the attachment mechanisms are now being modified and retested.

Hartmann testing using a CCD camera is still in development, but the agreement between interferometric results and Hartmann results is improving. Evidently the major difference is astigmatic, presumably due to an alignment problem.

Current plans may include another polishing run to check the modifications of the stressing lever attachments. This will be followed by the first good test of the stressing jig; warping the sphere to a sphere with a different radius. June may see the start of the actual off-axis parabola grinding.

Telescope Structure

Elevation box modifications completed (box was 1600 lbs; now is 2700 lbs).

Flanges mounted to the elevation box for the upper tube.

Reference mirror sub-cell finished and stress-relieved.

Lower tube built.

Concrete mirror: edges coated with epoxy and sanded smooth. Tested in handling fixture with new rubber epoxy and safety clips installed.

Shipped mirror cell, precision sub-cell, reference mirror sub-cell, three cell stands, concrete mirror and handling fixture assembly, to LBL Building 60 via Lick truck.

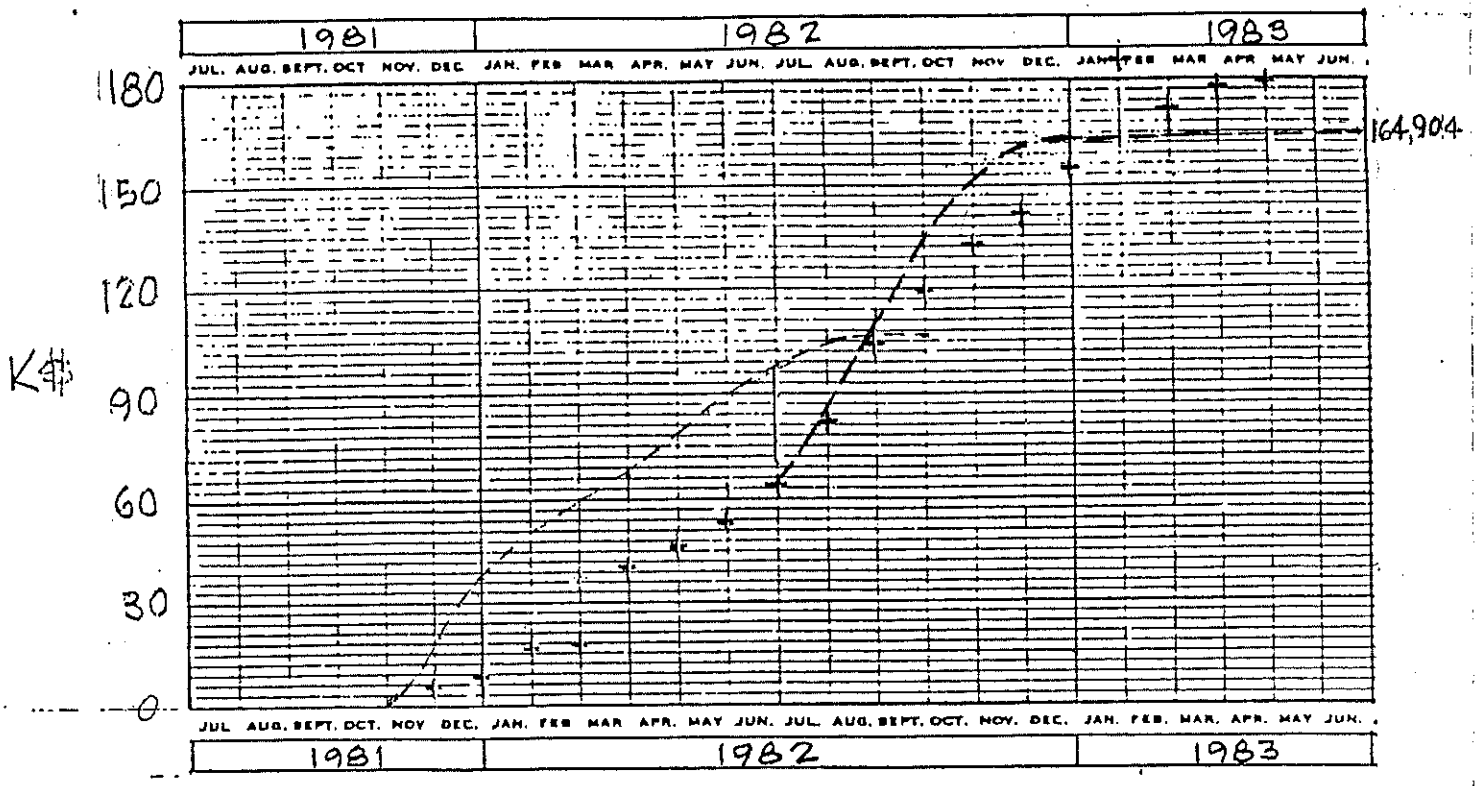
MANAGEMENT AND ADMINISTRATION

The cost curves for the Radial Support Post and Whiffletree System as well as the Structures are well above the plan curves and explanations are in order.

The Radial Support Post and Whiffletree System was the task originally given the Space Science Laboratory. Not fully appreciated at the beginning was the amount of development necessary as well as all the fixturing required for the application. In addition, there were other problems better handled by SSL because of their association with the Whiffletrees and/or the Radial Support Post. So the cost figures being presented are not the cost of producing the components alone, but also represent the cost of development, re-design, fixturing, field work, etc.

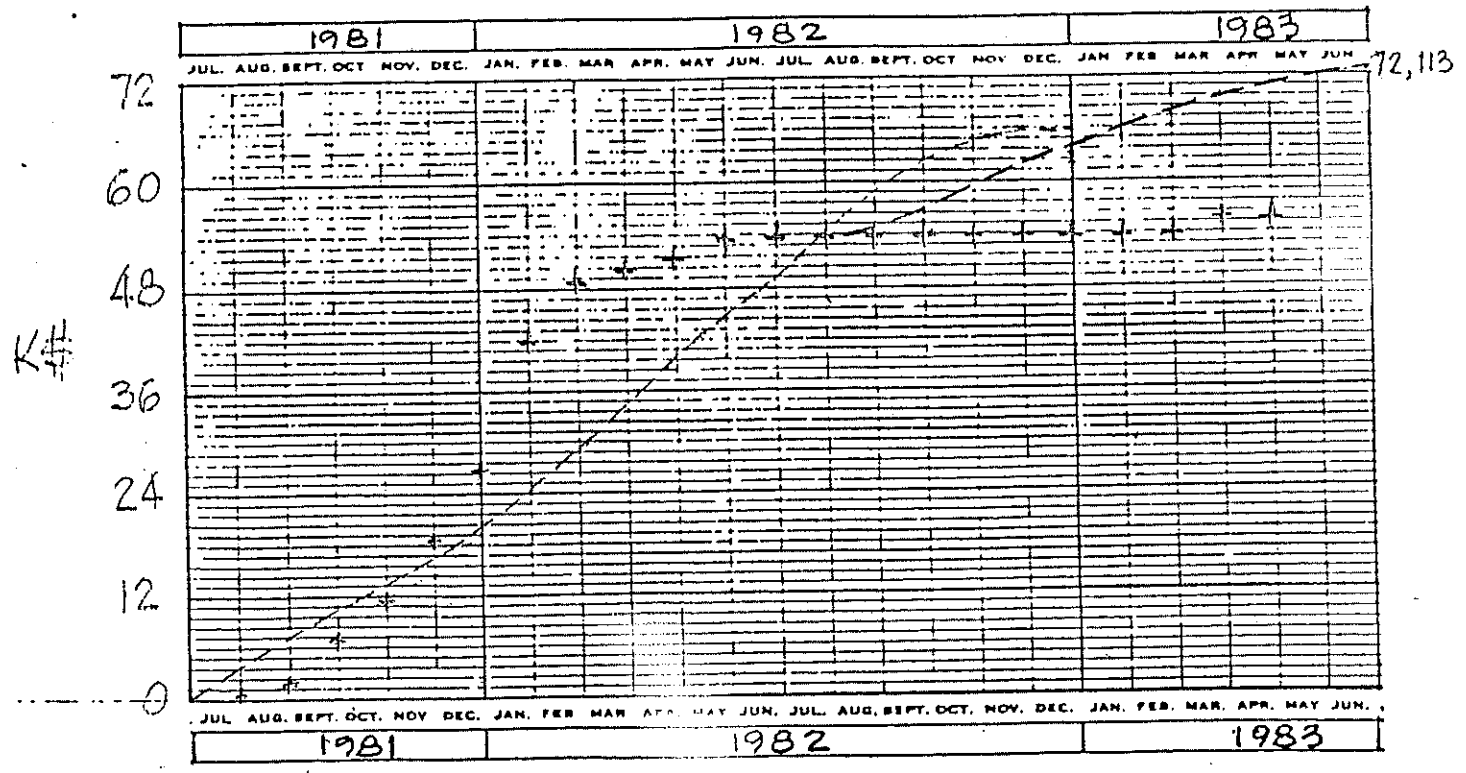
The cost figures for Structures now include the cost of the 1/3 test fixture, an additional platform in Bldg 60 for the active system, redesign and re-work of the elevation box and development of the handling fixture for the hexagonal mirror.

Since the completion date for the Technical Demonstration is now Dec. 31, 1983, we will have new curves in July for the beginning of the new fiscal year.



STRUCTURES

INCLUDES YOKE, ELEVATION RING, CELL/SUB-CELL, TELESCOPE TUBE, DRIVE MECHANISM, PLATFORMS



TEST SITE / INSTALLATION

INCLUDES BLDG. 60 PREPARATIONS AND PASSIVE SUPPORT

105

TMT #105
June 83

1 X10^{-6}

Summary

The milestone for mirror polishing has been met. The radius of curvature is 10,000.012 mm and the surface rms deviation is 44 nm.

Testing continues on the single sensor control loop as well as the actuators and local servo loop.

The sensor mounting development is progressing satisfactorily with a minor 100-200 nm settling drift problem to be resolved.

Trial assembly of the concrete mirror/whiffle/tree/actuator/cell has been made. Problems have surfaced and are being dealt with.

The upper tube has been completed as is the modifications to the elevation box. The upper and lower tubes and the elevation box will be shipped from UCSC/LO to LBL July 15.

#105

PROGRESS REPORT
JUNE 1983

Telescope Structure

1. The upper tube was built, sand-blasted and painted. Final weight of the assembly is 1500 lbs. Six connecting bars were added to the assembly so that it may be removed from the telescope as a single unit. Nine holes remain to be located for the #2 mirror mounts. The upper tube will be shipped to LBL on July 14 or 15.

2. The reference mirror sub-cell was returned to UCSC for modifications. This was completed and a 3-point support plate was designed and built which can be positioned on the reference cell to accommodate lateral positioning of the reference mirror. This assembly and the sub-cell were shipped to LBL June 28.

3. A set of balance weights for the bottom of the primary mirror cell was completed.

4. Nothing was done to the elevation box during June. It will receive tapped holes for the #3 mirror mount before shipping to LBL on July 14 or 15.

NO

5. The lower tube will also be shipped to LBL in July. The lower tube was finished in May.

TMT #106
July 83

Telescope Structure

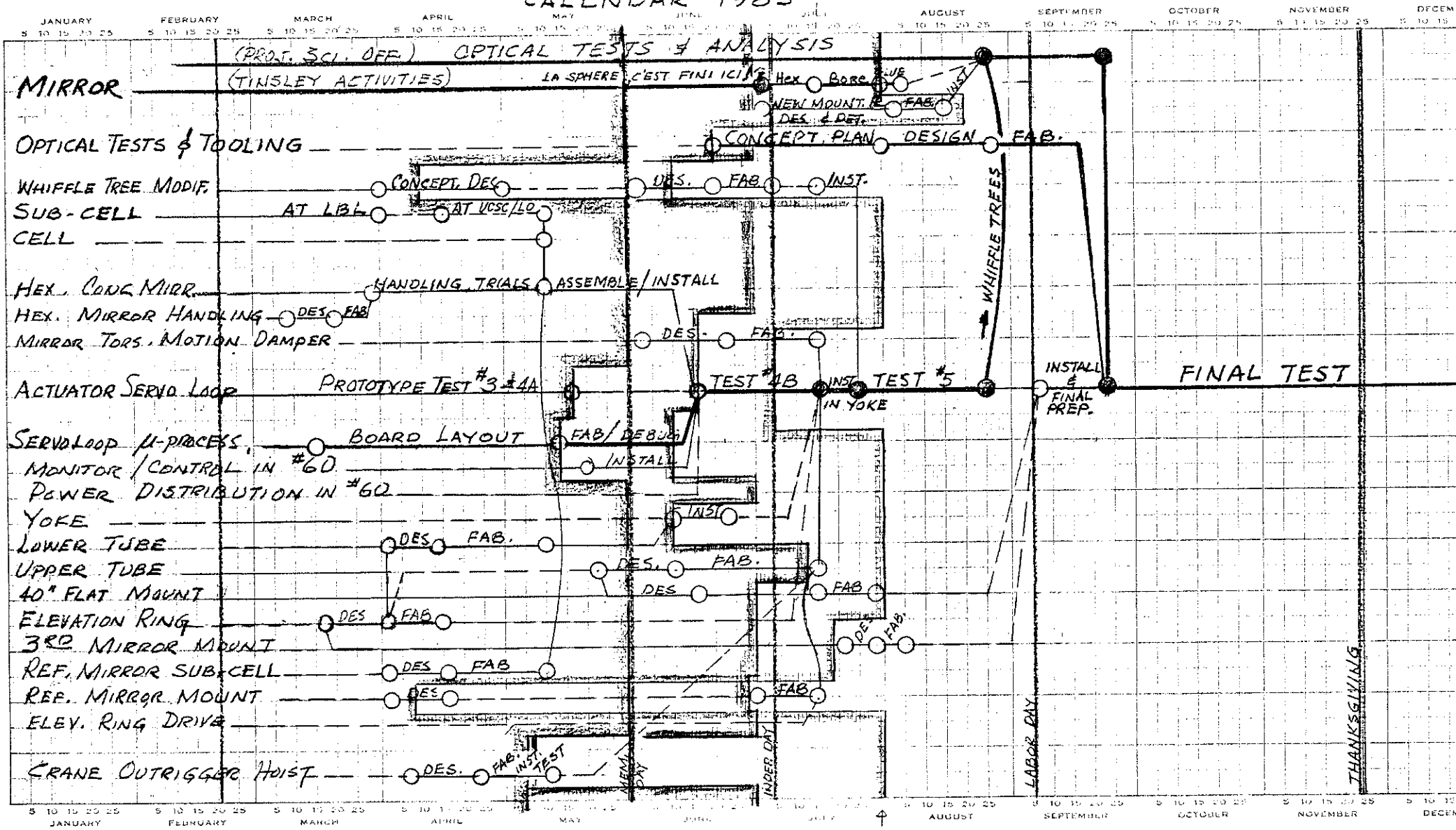
Shipped the following items to LBL in July: 1) elevation box complete with axles, bearings and bearing housings, and the drive gear; 2) upper tube assembly and lower tube assembly; 3) counter-weighting components.

Completed building the secondary mirror mounting hardware.

TMT TECHNICAL DEMONSTRATION

3/30/83

CALENDAR 1983



#10

TMT #110
Aug / Sep 83

PROGRESS REPORT AUGUST 1983
STRUCTURES, ET AL
Jack Osborne

1. Osborne and Lewis from Lick spent 2 days at Bldg 60 going through the telescope assembly scenario. Gabor made a video tape record of the critical procedures. The elevation box was assembled to insure the bearings and drive still functioned properly. The lower tube was then assembled below the elevation box. The box was lifted from the yoke and the mirror cell fitted to the lower tube. This entire assembly was replaced back into the yoke with the large hook. The small hoist was then used to lift the upper tube assembly onto the elevation box. Provisions were devised for moving the tube into horizontal alignment and the concrete mirror was fitted to the upper tube with the attachment hardware. The mirror was then removed.

2. A procedures notebook was put together and sent to LBL for permanent storage in Bldg 60.

3. The final pieces for attaching the glass secondary mirror to the tube were finished.

4. A box full of miscellaneous hardware was sent to Joe Magner for the operation in Tuscon.

5. Additional lead counterweights were constructed for balancing the tube.

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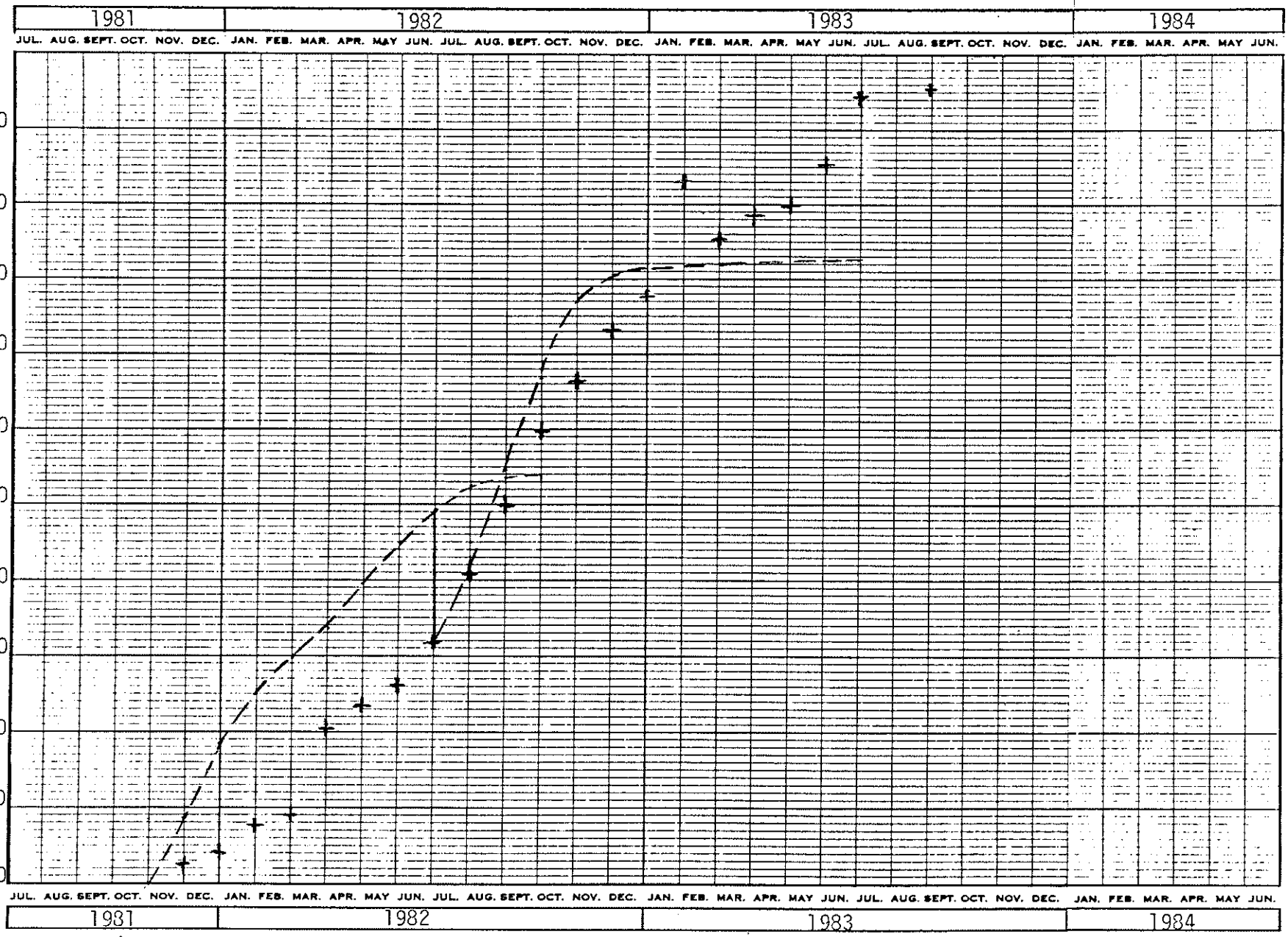


STRUCTURES

INCLUDES YOKE, ELEVATION BOX, CELL & SUB CELL, UPPER & LOWER TUBES, DRIVE MECHANISM, PLATFORMS, 1/3 TEST STRUCTURES, ETC.

TMT #112
Oct 83

OCTOBER SUMMARY

Problems persist with the passive axial support (whiffletrees). New fixtures were designed to make an accurate assembly of the whiffletrees. The whiffletrees were re-assembled with these fixtures and reinstalled. The 36 pads on the mirror back were also more accurately positioned. Optical testing showed the whiffletrees were still inducing more than 100 nm of astigmatism.

The software for the global control of the TD actuators and sensors was coded in fast assembly language, is operational, and should allow a 100 Hz sampling rate. Using simulated sensor readings this global loop is being used now to test the three actuators.

The architectural firm MBT Associates in San Francisco was selected for the next phase of architectural and engineering design of the building and dome. Pending approval by the EMC they will probably begin work about 1 December.

TMT # 116
Nov 83

NOVEMBER SUMMARY

Another round of work directed towards improving the axial passive support system (whiffletrees) occurred. Reconstruction of the flexrods in the whiffletrees produced a substantial reduction in the astigmatism induced in the mirror by the whiffletrees. About 50 nm of astigmatism remains. This level is now low enough and stable enough to allow us to continue with testing and cutting. Further testing and improvement of the whiffletrees will be postponed until after the cutting of the circular mirror into a hexagon.

The final series of tests to measure the mirror surface prior to cutting were performed and a preliminiary analysis of the data shows the results to be consistent and of sufficient accuracy to proceed with the cutting. Preparation of the back of the mirror and tests with the cutting equipment are in progress and the cutting will take place next month.

A great milestone was successfully achieved in the stressed mirror polishing demonstration at KPNO. The first grind (and shine) of the mirror with stressing forces and couples applied was completed. After release of the stresses the mirror was tested and was found to be only one wave from the desired off-axis section of a paraboloid! This was within 1% of the desired surface and was better than expected given the uncertainties known to exist in the first step of the iterative procedure. KPNO will now proceed with further iterations to achieve the final desired surface. This first step alone demonstrates that the method is very useful for quickly and economically achieving an aspheric surface to to the one wave level of accuracy. Even if other techniques (computer controlled polishing or hand polishing) were required to achieve the final surface, KPNO has demonstrated on the full scale that the method can successfully be used in the fabrication of the TMT segments.

TMT #117
Dec 83

DECEMBER SUMMARY

The major achievement of the month was cutting the circular mirror at Tinsley into a hexagon. Improper support of the initial edge piece removed caused serious fracturing in the edge piece and a small fracture left in the segment. Improved methods to monitor the support and adjust the support of the glass during cutting lead to a succesful completion of the cutting. Tests will be made in January to determine the extent of warping of the figure caused by the cutting.

The electronics hardware for the active control system was moved to Bldg 60. Initial dynamic tests moving the concrete segment with the actuators were successful. The installation of the sensors and tests of the entire control loop await the installation of the reference mirror.

Testing and improvements have reliably reduced the thermal coefficient of the electronics box for the sensors to 0.1nm / ^{o}C. Tests of the thermal sensivity of the sensors presently give an anamolously high value of 2-4 nm / ^{o}C and the test fixture itself is possibly the source of the problem. The plates making up the sensors have up to now been simply held together by the spring loaded mounts. The plates are now being glued together and this is expected to reduce an oberved sensitivity to the direction of gravity.

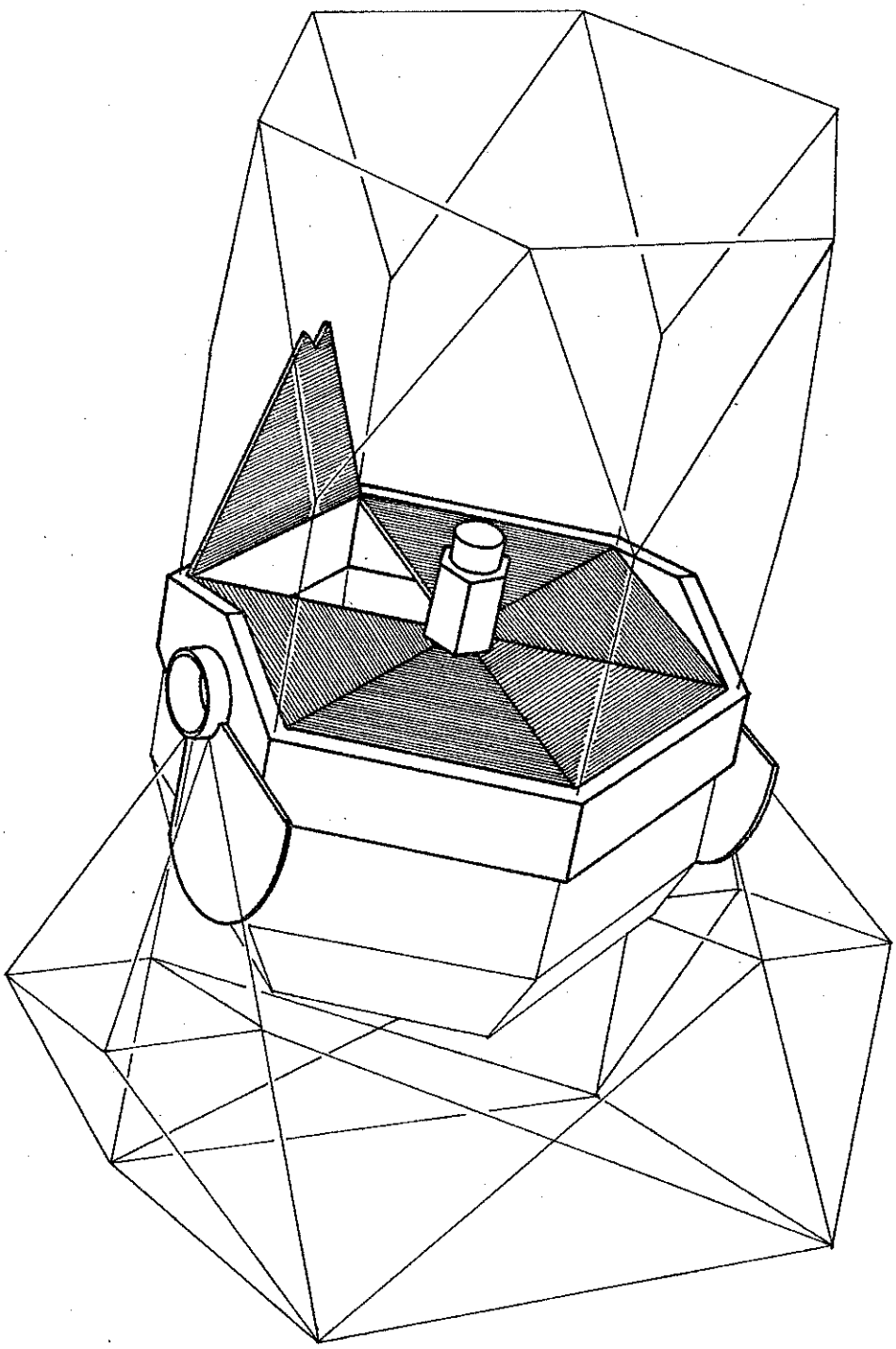


FIGURE 12 - PRIMARY MIRROR COVERS
(ONE COVER SHOWN OPEN)

TMT #118
Jan 84

118

JANUARY SUMMARY

The major work this month was the testing and data analysis of the hexagonal mirror. The mirror warped in the cutting process. The major warping occurred in the focus term with a significant, but smaller amount of warping in the non-axisymmetric terms.

Work has begun on a redesign of the whiffletrees. This was thought necessary when the deflections in the circular mirror due to the whiffletrees was found to be 26nm rms.

The reference mirror cell has been to Lick for modifications and is now back at LBL, ready for use in zenith tests with the concrete mirror.

#118

SCIENCE OFFICE PROGRESS REPORT
JANUARY 1984

Technical Demonstration Optics

During the first part of January the hexagon was tested. There was a large uncertainty in the radius of curvature measurement. Most of the uncertainty was later shown to be an error in testing, but about a 0.5mm warping from cutting remained. This is equivalent to a C_{20} focus coefficient equal to 1.027um. The nonaxisymmetric terms changed by about 100nm rms between the precut and postcut surface. While the focus change is about 5 times greater than the other errors, the nonaxisymmetric warping is still too large to be acceptable. The goal is to have rms surface errors less than or equal to 40nm. We are now considering the alternatives for correcting the warping.

The mirror and whiffletrees were removed from the polishing table and preparations for boring the hole in the back of the mirror were begun. It was discovered that most of the pieces for the the boring equipment were made incorrectly. A delay of about one week resulted. At the end of the month it was expected that we would be setting up to bore a test hole soon.

Passive Support

Final data analysis of the tests of the circular mirror showed that the whiffletrees add 26nm rms deflection to the surface of the circular mirror. Because of the large deflection introduced by the whiffletrees it was decided that a redesign of the whiffletree was needed. Jack Frank and Larry Brown of LBL will work with Bob Weitzmann on the redesign of the present whiffletree system (phase I). They are presently reviewing a modified ball mount replacement for the flex rod mount. This new design is expected to overcome some of the problems found during testing of the flex rod design. The new design is scheduled to be fabricated, installed, and tested by 1 July 1984.

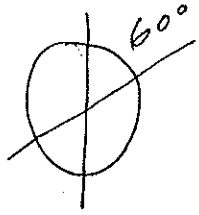
Conceptual designs are being considered for a "Whiffletree Phase II Prototype." This prototype is for the follow-on improvements after the TD goals are accomplished.

The reference mirror cell was returned to Lick for modification because neither the glass or concrete reference mirror fit into the cell. The reference mirror cell was then returned to LBL and fits the concrete mirror so the zenith tests are able to begin.

The final dimensions of the reference mirror were incorporated into the finite-element model of the reference mirror. We then re-optimized the support configuration, and began a complete sensitivity analysis to determine the tolerances for the support hardware.

Tests have been made of the gluing configuration for the radial support post ring. Using RTV 700 and a 20 mil gap, a linear response was seen up to 6000lbs. The spring constant is $k = 4.0 \times 10^5$ lbs/in. A 40 mil gap was also tested. Under the segment weight we expect a radial displacement of about 0.005 inch for a 40 mil glue line.

#118



KPNO

During January the aspherized mirror was tested for variations of figure with time. Tests were performed over two one-week periods with the mirror stressed and unstressed. The variation in figure was traced to two causes. One was interference between support hardware and the stress jig frame which was corrected. The second cause was a variation in load applied to the mirror by the stress jig due to tilting the mirror to aid in testing. This variation occurs when a zero and sixty degree orientation test is performed to subtract out the effects due to a test flat used as a fold mirror. The mirror must be tilted back and realigned in the sixty degree orientation to test it. With these problems solved a second iteration of polishing on the mirror is planned.

Documentation

Documentation of TMT drawings has been proceeding. More than 300 drawings and sketches from diverse sources (including SSL, UCSC, LBL Mechanical Dept.) have been placed in a centralized file in the Building 90 Vault, given drawing titles, and category codes. This will facilitate future printing of special drawing lists. This work is continuing. (100 from Lick)

PERT charts have been prepared and are being continuously updated as work progresses. To date it has been impossible to get a totally correct chart, but we feel that we are getting closer and the charts may be useful in the near future.

#118

TMT TD PROGRESS REPORT FOR JANUARY 1984
J. Osborne

3rd MIRROR CELL:

Parts are 90% on hand.
Fabrication of cell and mount is 50% complete.

REFERENCE MIRROR CELL:

Modifications completed so that everything assembles with no interference.

CONCRETE MIRROR:
7 invar pads glued onto mirror.
Axial support installed (compression only).
Radial support is "workable" although temporary.

GLASS MIRROR:
Invar pads awaiting design of tensioning technique so that axial support can take compression AND tension.
Radial support brackets (4) awaiting final determination of c.g. of mirror, sensor bodies, and sensor paddles assembly.
Axial force supporters have been conceived. Bellows were ordered and are on hand. Final design of force supporters is in progress and is about 10% done.

see disc w2 "TMT Jan 84"

TMT PROJECT

CUMULATIVE COSTS FOR (74) TECHNICAL DEMONSTRATION
(73) SCIENCE OFFICE

7/1/81 THROUGH 1/31/84

	LBL	SSL	UCB	UCSC/LO	TOTAL COSTS ALL SITES	LIENS ALL SITES	TOTAL COMMITTED ALL SITES
(74) Technical Demonstration							
Administration & Management	$ 175,277	$ 0	$ 0	$ 2,611	$ 177,888	$ 0	$ 177,888
Optics	$ 21,850	$ 0	$ 0	$ 215,966	$ 237,816	$ 5,149	$ 242,965
Active System	$ 976,843	$ 5,142	$ 0	$ 104,697	$1,086,682	$ 3,968	$1,090,650
Whiffletree/Rad. Support	$ 80,074	$213,238	$ 3,392	$ 1,721	$ 298,425	$ 0	$ 298,425
Support Structure	$ 131,445	$ 0	$ 0	$ 83,486	$ 214,931	$ 3,825	$ 218,756
Site Installation	$ 75,526	$ 0	$ 0	$ 0	$ 75,526	$ 0	$ 75,526
T. D. TOTALS	$1,461,015	$218,380	$ 3,392	$ 408,481	$2,091,268	$ 12,942	$2,104,210
(73) Science Office	$ 95,756	$259,574	$122,322	$ 81,896	$ 559,548	$ 65	$ 559,613
TOTALS FOR SCIENCE OFFICE AND TECHNICAL DEMONSTRATION	$1,556,771	$477,954	$125,714	$ 490,377	$2,650,816	$ 13,007	$2,663,823

39%

#118

TMT #119
Feb 84

SCIENCE OFFICE PROGRESS REPORT
FEBRUARY 1984

Technical Demonstration Optics

A test boring was successfully made in one of the "ears" removed in the cutting of (smaller diameter the hexagon. The hexagonal mirror was mounted on the mandrel and the radial support hole was bored. Etching procedures were established, the test hole was etched, and then the mirror hole was etched.

Passive Support

Detailed design of the revised ballmount (sphere-pin) for the whiffletree has been completed and a prototype is being fabricated at the SSL machine shop. This change required that a new set of Y's for the whiffletree be designed and machined to provide the proper mounting interface for the new ball mounts. John Carrieri of LBL is preparing assembly drawings to reflect all changes in the revised whiffletree.

A separate effort is underway to explore means to apply forces and/or moments to the back of the mirror to compensate for the warping which resulted when the mirror was cut into its final, hexagonal shape.

The dimensions of the reference mirror, as cut, were obtained. This allowed final determination of the positions and tolerances of the reference mirror support points, and these were transmitted to the Lick shops.

Radial Support

The threaded Invar Liner has been machined and glued into the radial support hole in back of the mirror. The glue joint was subjected to axial load tests by suspending the mirror from the threaded Invar liner. The mirror load was maintained for approximately 14 hours during which time a permanent set of approximately 8 mils was observed. Under full mirror load the elastic shear displacement is approximately 80 mils. Based on the 40 mil glue gap used, this corresponds to approximately 200% strain for the RTV 700 glue whose strain limit is 400% as given by the manufacturer. In its normal mode of use, the bulk modulus of the glue should provide the stiffness, and allow only a few mils of in-plane deflection under the full weight of the mirror.

KPNO

During February the radius testing apparatus was set-up and the radius of the mirror measured. It was about 7mm long. This is equivalent to about 3.5 waves of surface sag and thus can be polished out. The radius was tested over a one week period twice a day to determine any variations in measurement due to thermal changes in the test tower. A sub diameter polishing tool was also prepared for the expected radius shortening exercise.

Documentation

The OPTICS schedule PERT chart is being continuously updated and is now fairly accurately showing work progress. Work is continuing on the SYSTEMS Schedule PERT chart.

Reports Issued

Finding the Conic of Revolution That Best Fits a Given Mirror Surface (TMT Tech Note No. 7 revised - originally published October 1979).

#119

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TMT TD PROGRESS REPORT FOR FEBRUARY 1984
J. Osborne

3rd MIRROR CELL:

Parts were finished in February and sere sent out for blackening. A trial fit is planned for early March.

REFERENCE MIRROR CELL:

Design of the mirror support system was submitted for design review. A spherometer was built for glueing on the 2 radial support pads. A fixture was built for glueing on the 6 force actuator pads. The final determination of the c.g. of the mirror and paddle assembly was done and the radial support is being finalized. It is very crowded where the radial support and axial support come together.

see discw2, tmt feb 84

TMT #120
Mar 83

120

SCIENCE OFFICE PROGRESS REPORT
MARCH 1984

Technical Demonstration Optics

At the end of February the radial support ring was bonded into the central hole. During March the optical fabrication of the mirror segment was brought to completion. Testing of the surface showed the boring, etching, and gluing induced a small amount of focus change and astigmatism. The edge of the hexagon was then etched and testing showed the surface was not changed by this. An annular region about 10 cm wide at about half the radius was etched on the back and this also had no effect on the surface. The results of all of the recent optical testing will be described in detail in TMT Technical Note No. 92 to be completed next month.

To understand the effects of surface stresses induced by grinding and polishing we have begun a series of tests on a 9.5-inch diameter flat. This flat was originally made by Tinsley using a blank of VO2, the Chinese ceramic-glass. Substantial changes in the focus term in the front surface were seen as the back of mirror was ground through a series of grits, and polished out. The back will be etched next month. We expect the series of tests will give us the quantitative information needed to establish the correct procedure for finishing the TMT segment backs, and also partially explain the warping from cutting.

Passive Support

After finding that the mirror warped substantially upon cutting into a hexagon, we have begun to study several different methods to deal with this. One method uses a passive set of hardware to permanently apply forces and/or moments to the mirror. This hardware would remain on the mirror in the telescope and maintain the surface in an "unwarped" configuration.

One realization of this method would use springs and a base plate to apply forces at the whiffletree support pads. The set of forces required to unwarp the mirror have been calculated and are in the range of 5kg. As a test of our FEAP calculations we applied a representative sample of 11 weights of about 3kg to the mirror and testing the surface. We predicted surface deflections of 406 nm rms. The difference between the measured and predicted surface was 35 nm, consistent with the measuring noise. This success suggests that if a simple spring device that is stable with time and temperature can be built, then such a fixture could be used to take out the warping due to cutting.

An alternative method of applying forces at the whiffletree pads is to apply moments at the whiffletree flex pivots. To test this method we constructed very simple leaf springs and used them to apply moments about the secondary flex pivots of the whiffletrees. Initial tests showed that although the measured change in focus agreed with the predicted change, the change in astigmatism was not as expected. Further hardware changes and testing are in progress.

The reference mirror support pads were fabricated and bonded to the mirror at Santa Cruz. The reference mirror was delivered to LBL and is ready for installation in the telescope.

KNPO

KPNO polished the 2m mirror in order to change the radius. They have successfully matched the radius to the length of their Invar chain. They plan to restress the mirror soon and make the second iteration of stressed mirror polishing.

#120

TNT TD PROGRESS REPORT FOR MARCH 1984
J. Osborne

3rd MIRROR CELL:

The cell parts were finished in February and the third mirror was fitted to the supports at UCSC. The cell support structure was then taken to LBL and attached to the center section of the test structure. Everything went as planned.

REFERENCE MIRROR CELL:

The preliminary design for the support system for the glass reference mirror was deemed suitable and the design moved right along. Parts for the support pads were finished and the reference mirror was picked up, brought to UCSC, and the pads (16) glued on. While the mirror was at UCSC, a lifting fixture was built which will clear all the pads and also clear the hexagonal mirror and reference mirror cell.

The pieces for the bellows support system are being fabricated and should be done by April 23 for installation in the reference mirror cell.

PARKING BARS:

A rigid support was designed and built so that the tube can be held in the horizon-looking position. This hardware is adjustable. A similar support was fashioned for holding the tube vertically. Lick technicians made the necessary mountings on the main mirror cell and fit the support attachment mechanisms onto the yoke and tube.

LIFTING RING:

Fred Hendy designed the apparatus for lifting the tube from the center section with the number 2 mirror in place. The parts will be sent to LBL in mid April and holes drilled for attachment.

TMT # 121
Apr 84

APRIL SUMMARY

TD The optics testing at Tinsley was completed and the segment and reference mirror were delivered to LBL. The segment and the reference mirror were installed in the telescope and the sensors were installed on the mirrors. Preliminary control system testing was begun. A variety of mechanical difficulties were uncovered and are being fixed. Noise from the environment appears to add objectionable oscillations to the segment, thus limiting the control system tests. Further work on this is underway.

TMT Work with the architects on the building and dome is proceeding and we are now down to two possible configurations of the system. The final concept selection will be made in early May.

The University has offically received a gift of about $36 Million from the Hoffman Foundation and the telescope and the observatory will be named the Maximillian E. and Marion O. Hoffman Observatory.

TMT #126
May 84

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TMT TD PROGRESS REPORT FOR MAY 1984
Jack Osborne

REFERENCE MIRROR SUPPORT:

Testing the hermeticity of the bellows system was completed in May (less than 3 x 10-8 std cc/sec with helium) and installed in the reference mirror cell with the glass mirror in place.

A modified support was built to replace the left side support to accommodate the 1/8" height misalignment.

TMT:

I have proof read the 5th draft of the report on bearings and drives for the TMT and will have the copy back to David Nelson in mid June.

see disc W2 "tmt may 84"

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83	"	May 82
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92	TMT Progress Report	Sep 82
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95	"	Nov 82
96	"	Dec 82 to Jan 83
99	"	Feb 83
100	"	Mar 83
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104	"	May 83
105	"	Jun 83
106	"	Jul 83
110	"	Aug/Sep 83
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116	"	Nov 83
117	"	Dec 83
118	"	Jan 84
119	"	Feb 84
120	"	Mar 84
121	"	Apr 84
126	"	May 84