MULTIPLE MIRROR TELESCOPE OBSERVATORY

Smithsonian Astrophysical Observatory *and* Steward Observatory, University of Arizona

MMTO Technical Memorandum 84-4

From: Clinton Janes

Subject: MMT TCS EVALUATION, Dec 10 - 13, 1983

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I. Summary.

The purpose of the Telescope Coalignment System evaluation was to measure the limits of operation of the computerized control of the telescope secondaries:

A. The accuracy of the "auto-stacking" of the 6 images.

B. The accuracy of the track using look-up coefficients to move the telescope "open loop."

C. The accuracy of the "closed loop" operation where-in the individual image positions are measured and corrections are made accordingly to the secondary mirror positions.

D. Define operational limitations of "auto-stacking" and "auto-tracking".

II. The test setup.

The test setup used the acquisition TV in the top box and the SAO CCD.

A. In the typical MMT instrument setup, the image at the focal plane is reflected by a mirror located below the top box in the observer's instrument. This reflected image passes through a collimating lens and a focusing lens before reaching the acquisition TV. Either an I-CCD or an I-vidicon may be used as the acquisition TV. For this experiment the I-vidicon was used because the I-CCD shutter was nonfunctional at the time. Two different focusing lens may be used, the American Optical and the Canon. The AO lens has a resolution of roughly 6 pixels per arc-second; the Canon has a resolution of roughly 2 pixels per arc-second. The video from the acquisition TV is digitized by the TCS computer system for measurement of star position.

A prism assembly mounted on a rotating wheel may be inserted in the optical path to the acquisition TV where there is an image of the 6 pupils. The TV will then display the individual images from the 6 telescopes. The wheel may be rotated synchronously with the derotater so that the prism assembly stays constant with respect to the pupil images.

B. The SAO CCD has a reflecting surface at the telescope focal plane. The silvering has been removed from a large aperture at the center of the mirror to permit a small amount of reflection (4% from each surface), and to allow the remaining light to pass on through to the CCD. The CCD signal is recorded by the instrument computer using SAO software. The data may be displayed after measurement on a monitor, but no real time video is available. No reduction software is available on-site so that measurements for this report were made by taking a cross-section of the image intensity as recorded by the CCD and measuring the distance between the estimated FWHM points in pixels. The image resolution of the SAO CCD is given as .321 arc seconds per pixel.

The SAO CCD saturates at intensities greater than magnitude

9, so that tests were made on objects of this brightness or fainter.

The CCD was focused to the focal plane by placing a slot of known width on the focal plane mirror and optimizing the width of the light received through the slot. The acquisition TV was focused to the focal plane by placing a piece of newsprint on the focal plane mirror and moving the focusing lens (the AO or Canon) until the print appeared as sharp as possible on the acquistion TV.

III. Measurements.

The following measurements were made for the test.

a. FWHM of individual images and stacked images using the AO lens and the I-vidicon.

b. Same as a, but with the Canon lens.

c. FWHM of stacked images after 5, 10, 15, and 20 minute intervals while auto-guiding using the AO lens and the I-vidicon. This test was done with the prism wheel and without.

d. Same as c. but with the Canon lens. Measurements were not made on limiting parameters because of difficulties with the above measurements.

IV. Description of tests.

A. Dec 10. Shutter failed on the I-CCD acquisition TV; the I-vidicon was installed instead. Problems with the SAO CCD operation were traced to a bad cable which was repaired. Problems with operation of the software were later traced to lack of familiarity with the documented procedures.

Performed sky light level tests and seeing tests with and without the light baffle. Schild's data showed less scattered light at the zenith with the chamber opening pointing north than with the chamber pointed east, south, or west with the baffle in place. Angel performed similar tests with "fiber blue", but the data is not yet available.

The weather was clear and the seeing 1 arc-second or better.

The last part of the evening was scheduled for use by R. Angel.

B. Dec 11.

A problem with the SAO CCD was traced to the filter wheel out of place and partially blocking the light path. With the Canon lens and I-vidicon, used the SAO CCD to measure the single image FWHM to be 1.3 arc seconds, but the stacked image after auto-stacking to be 1.9 arc seconds. Made measurements on different areas of mirror (but only on the partially reflecting surface) , different stars, different size centroiding boxes on the Grinnell, but obtained the same result. The images appeared elongated on the SAO CCD. Switched to AO lens and received the same result. With the higher resolution, double intensity peaks were visible in the elongated image both at the SAO CCD and the acquisition TV. Made several measurements with the same result as the Canon lens: 1.3 arc second FWHM on individual images and 2 arc seconds for stacked images. The failure to point stack correctly with the FWHM of the stacked image equal to the FWHM of the individual images was almost certainly due to the inability to centroid on the two images reflected by both sides of the reflecting glass and by the consideration that the image from the second surface was out-of-focus by an amount proportional to the thickness of the glass.

Insertedthe rotating prism assembly and attempted auto-guide. The images fell apart quickly. By "nodding" the telescope secondaries individually, determined that the individual telescope images were properly divided into the 6 images shown on the acquisition TV. But at the completion of the test, components of a single telescope image could be observed in more than one TV image, thus indicating that the prism assembly was not rotating at the correct speed. Adjusted the level of the "position angle" signal input to the rotating prism assembly drive while rotating the top box between positions of -136 degrees and +132 degrees until no shared components were seen on stars on either extreme of the top box position. With this adjustment, attempted auto guide again with these results as measured at the SAO CCD:

Elapsed time	FWHM of stacked image
2 min	1.6 arc seconds
10	1.8 arc seconds
12	2.4 arc seconds
20	1.8 arc seconds

This data seems to indicate that the stack held together as good as it was initially formed, keeping in mind that auto-stacking was compromised, presumably by the double reflection problem. The weather was windy and cloudy; the star intensity was seen more than once to fall below the threshold set in software for performing the centroiding calculation. Constant adjustments were required to the acquisition TV intensity control as clouds passed overhead. Changes in I-Vidicon intensity are known to change FWHM measurements. In addition, no corrections are applied to a secondary if that image intensity falls below the threshold. As soon as the star image is again brighter than the threshold, the secondary position is corrected. One or both of these reasons may account for the large FWHM measurement seen at 12 minutes.

The test was repeated, but the operator attempted to focus the secondaries while auto-tracking, which disabled the computer control.

The test was again repeated, but the images fell quickly apart. It was apparent that the prism wheel was not rotating correctly. Unfortunately, the signal input to the prism wheel drive was adjusted before it became apparent that the prism wheel movement had failed altogether. Perfunctory examination failed to show the cause though work the next day seemed to show that the failure was a result of a loose "G" connector on the the top box.

Incidental to tests with the prism assembly, measured the noise on the I-vidicon. The symptom is a single noisy horizontal line that slowly rolls through the video. The cause is a 300 kHz burst that lasts about 30 ns and occurs at the rate of 180 Hz (line synchronous). This noise is readily visible on all the ground lines and goes away when the building drives are turned off. The noise is visible at the I-vidicon output at the top box. Simple isolation techniques had no effect. The result of the noise is to enter error into the centroiding calculation, though error could not be directly attributed to this effect during this test because of all the other problems.

C. Dec 12.

Wind from the northwest increased to speeds of 50 mph early in the evening and caused the telescope to be closed for 6 hours. Reopened at 3 am when winds subsided to 40-45 mph. The rotating prism assembly was repaired during the day, but was unable to synchronize before being closed for wind.

Performed a test without the prism wheel in which the images were point stacked and then spread out using the "+spread try" command to simulate the pattern used for autoguiding. The prism wheel was not inserted for this test. Instead, the spread images were used for autoguiding on the acquisition TV and recorded on the SAO CCD for a 20 minute interval. In retrospect, we should have measured the FWHM of the stacked image before doing the +spread try at the beginning of the test and measured again at the end of the test by doing a -spread try. As it is, we must wait for the results of data reduction at Cambridge. The relative position of the images both on the SAO CCD and on the acquisition TV, very subjectively, seemed to remain the same, though the array of 6 images rotated on the SAO CCD, presumably because of the rotation of the top box and the absence of the prism assembly. Seeing was 4 arc-seconds when we closed for wind.

The position angle signal and the top box positions were measured with respect to telescope azimuth to insure both were linear.

At the request of the observer, changed to the Canon lens in order to obtain a larger field more likely to contain a guide star. Reopened after being closed for 6 hours. Was able to adjust the prism wheel drive so that no shared components were found when moving between two stars. Tried autoguiding twice with prism wheel. Both times the stack fell apart after 20 min with the images tending to fall apart along the axis defined by the double images. Made sure that no shared components existed before and after each test by nodding each image and visually checking for motion in more than one pupil, as explained earlier. Also noted that the hexagon-shaped array of 6 images formed by the prism assembly on the acquisition TV distorted from generally circular to oblong during these tests.

Repeated the tests without the prism wheel, but this time reformed the stack at the end of the test with the -spread try. Found that the stack fell apart in the same manner as in the tests with the prism wheel inserted. The stack as shown by the acquisition TV looked the same as when the test started, perhaps because of the limited resolution of the Canon lens.

Recorded stacked image operating open loop. The FWHM of the stacked image increased from 1.5 arc seconds to 2.5 arc seconds in 5 minutes as measured on the SAO CCD. Separate images were clearly visible after 10 minutes and the images continued to diverge during the remaining 10 minutes of the test. The stack appeared unchanged from its original configuration on the acquisition TV display. The open loop coefficients used were those calculated manually in Sep 83, and used successfully before and after this test.

D. Dec 13. Closed for wind.

V. Discussion of results.

The inability to centroid correctly on the double image from the two reflecting surfaces plus the use of the low resolution Canon lens were two major obstacles that were not surmounted in this test. The error corrections to the telescope secondaries are 3 times as coarse using the Canon lens. The new top box scheduled for use by late next summer will permit off-axis guiding which hopefully will eliminate the need for the larger field provided by the Canon lens.

The images on the acquisition TV video always stayed in their centroiding boxes indicating that the software worked correctly.

Tests before and after this one show an autostacking accuracy using the AO lens equal to the width of an individual image, and open-loop tracking for up to 20 minutes with no measurable deterioration of the stacked image which seems to indicate the problem was with the setup rather than with the TCS software.

The new top box also includes a computer-controlled prism assembly rotation using a stepping motor, so that the problems with the prism wheel synchronization can also be anticipated to go away.

VI. Conclusions.

The guiding system appears to be sound though the test was inconclusive; it didn't show TCS works and it didn't show TCS doesn't work.

Point stacking and auto-guiding require a single reflection from a quality flat mirror to work correctly. Attempting either with the SAO CCD instrument until the double reflection problem is solved would be unproductive.

The prism wheel drive must be made to drive reliably in synchronization with the derotater before auto-stacking can be called operational. Some sort of readout from the wheel might be helpful. The new top box will relieve this problem. Careful measurement of the prism wheel movement with a protractor may be required in the interim.

Testing of the autostacking and autoguiding should be done with the AO lens only. Since a guide star is unlikely to be found in the AO lens 90 arc-second field, at least for most observations, the autoguiding is unlikely to be usefull until the new top box is installed. Then the AO lens used with offset guiding should provide an operational autoguide capability.

The noise must be removed from the I-vidicon and/or the I-CCD made fully operational (connect shutter and synchronize CCD with Grinnell) before the auto-stacking is considered operational. This work will also help speed up the corrections to 10 Hz, which is currently not possible. (Nothing was done during this test to support this conclusion, but earlier tests show the need.)

Further testing of the auto-stacking shouldbe done with a separate camera looking at the focal plane to record the image as seen by the instrument. An engineering mirror with a dichroic and camera mount is said to be available. Results of this test were inconclusive, but show the need for recording what happens to the image at the focal plane separately from the acquisition TV to insure proper stacking and tracking actually takes place.

The auto-stacking should be checked in its various modes of operation before being released as operational: +ESG, +MMT, +CCD, etc. (This was not part of this test and is mentioned here incidentally.)

Provisions must be made to provide automatic gain control of the acquisition TV, possibly from the TCS computer, and automatically vary the threshold of the centroiding algorithm, or auto-stacking must be advertised as not usefull when any clouds present. Now the operator must continuously vary the TV intensity control and type in different thresholds if the star intensity varies.

Need to provide a status bit from the secondary control paddle to advise the TCS computer when computer control of the secondaries is NOT selected; an error message will be printed if auto-tracking is selected. Otherwise, the operator will be tempted to focus during auto-guiding and disable the operation.

More reliable telescope-computer interconnections are needed.

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