Lick Automated Planet Finder

2.4m Telescope

Site Acceptance Test

ATP-13438-1

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DOCUMENT CONTROL

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1	12/4/2009	Initial Release	DSS	AL	DSS

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2.4 Meter Alt-Azimuth Telescope

Site Acceptance Test

1 INTRODUCTION

This document describes the test procedures and equipment used to perform the Site Acceptance Test (SAT) of the 2.4 m Telescope in accordance with the contract, the technical specifications, attachments and annexes between the University of California Observatory/Lick (UCO/Lick) and EOS Technologies Inc. (EOST).

1.1 SCOPE

This document outlines the test methods to be used to test the listed contract requirements or specifications. Where appropriate, high level tests of pointing and tracking are performed on-sky to validate the full system functionality. It should be noted that no test will be performed unless prior agreement is reached by the parties and the tests are entered into this document.

1.2 CONFIGURATION

This document has been configured as ATP-13438-1 and is a designated controlled document under the EOST Quality System.

1.3 REFERENCES

The following source documents may be used as reference materials for this document:

- Contract Agreement Number CTR-4875-1

1.4 DEFINITIONS AND ACRONYMS

- COTS – Commercial off the Shelf
- CTR – Contract document
- EOST – EOS Technologies, Inc.
- FAT – Factory Acceptance Test
- RMS – Root Mean Square
- SAT – Site Acceptance Test
- TCC – Telescope Control Computer
- UCO – University of California Observatory

1.5 DELIVERABLE ITEM

The 2.4 Meter Alt-Azimuth Telescope acceptance test documentation is deliverable as per Appendix B of the Contract.

1.6 RECORDS TO BE KEPT

All inspection and test results are to be recorded in this document and stored with the 2.4 Meter Alt-Azimuth Telescope documentation. Refer to Quality Procedure QIPT-T2973-3 Document and Data Control.

1.7 LIFETIME DISCUSSION

The telescope has been designed using components that will last indefinitely under the calculated loads assuming routine maintenance has been performed. No Lifetime or destructive Test to Failure testing is required or planned. The design life of the telescope is 20 years, meaning that all components and designs are based on established technologies and products.

1.8 TEST EQUIPMENT AND CALIBRATION

EOST maintains all inspection measuring and test equipment calibration according to the current revision of Quality Procedure QIPT-T2920. This procedure complies with the ISO-9001-2000 standard. Documentation and compliance reports are available upon request.

2 TESTS

The following sections describe items to be tested by EOST in order to verify telescope system function against the contract statement of work.

Where required, test procedures are described. These test procedures are provided to the customer in this document. Each test will be witnessed by the customer at their discretion. Each test will be signed by both EOST and the customer and a pass or fail status will be assigned. Tests that fail will be assessed and the reason for failure will be corrected, if applicable, and the test repeated. If it is found that the test procedure is not valid, it will be revised. The revised test procedure will be agreed upon with the customer prior to re-testing.

2.1 AZIMUTH AND ELEVATION AXES RANGE OF MOTION

2.1.1 Test Objective and Scope

The objective of this test is to verify that the motion range of azimuth rotation is -110° to +310° from True North (as limited by the enclosure wrap) and that the range of elevation motion is 0 ° to 90 ° from zenith.

2.1.2 Reference Documents

- 2.4 Meter Alt-Azimuth Telescope Contract Number CTR-4875-1

2.1.3 Safety Requirements

- Remain a safe distance from the telescope as it rotates.

2.1.4 Test Equipment

- No special equipment is required.

2.1.5 Test Procedure

1. Using the Telescope application, home the telescope axes.
2. Command an azimuth angle of – 110º.
3. Record the reported position and verify compliance.
4. Command an azimuth angle of + 310º.
5. Record the reported position and verify compliance.
6. Move the telescope to its zenith position (90º).
7. Record the reported position and verify compliance.
8. Move the telescope to its horizon position (0º).
9. Record the reported position and verify compliance.
10. Command the telescope to hold position (closed loop).
11. Manually trigger each Elevation and Azimuth inner limit and failsafe limit to verify functionality.
12. Review the results and assign pass/fail status.

2.1.6 Test Results

Item #	Description	Reference	Requirement	Test Results	Pass/ Fail
1	Azimuth Rotation	Appx. B §3.8	420º total range of motion (-110º to +310º limited by enclosure AZ wrap)		
2	Elevation Rotation	Appx. C §2	0 º to 90 º from zenith, both directions (0 º to 90º hard limits installed to protect enclosure)		

	Name	**Signature**
Test Conducted By:		
Test Accepted By:		
	Test Date	

2.2 SLEW RATES AND ACCELERATIONS

2.2.1 Test Objective and Scope

The objective of this test is to verify that the slew rates and accelerations of the telescope system meet the stated requirements.

2.2.2 Reference Documents

- 2.4 Meter Alt-Azimuth Telescope Contract Number CTR-4875-1

2.2.3 Safety Requirements

- Remain a safe distance from the telescope as it rotates.

2.2.4 Test Equipment

- Stopwatch

2.2.5 Test Procedure

1. Using the Telescope application, home the telescope axes.
2. Command the telescope to perform an azimuth slew of 16˚ from its current position.
3. Using the stopwatch, measure the time to complete the slew.
4. Command the telescope to perform an azimuth slew of 56˚ from its current position.
5. Using the stopwatch, measure the time to complete the slew.
6. Command the telescope to perform an azimuth slew of 196˚ from its current position.
7. Using the stopwatch, measure the time to complete the slew.
8. Command the telescope to perform an elevation slew of 4˚ from its current position.
9. Using the stopwatch, measure the time to complete the slew.
10. Command the telescope to perform an elevation slew of 24˚ from its current position.
11. Using the stopwatch, measure the time to complete the slew.
12. Command the telescope to perform an elevation slew of 84˚ from its current position.
13. Using the stopwatch, measure the time to complete the slew.
14. Verify that all measured times are within ±1 second of the calculated ideal times and determine pass/fail status.

15. Command the Tertiary rotator to move to the Left Nasmyth Port.
16. Command the Tertiary rotator to move to the Right Nasmyth Port.
17. Measure and record the time required to complete the move.
18. Command the Tertiary rotator to move to the Left Nasmyth Port.
19. Measure and record the time required to complete the move.

Axis	**Distance (degrees)**	**Minimum Acceleration (deg/s^2)**	**Minimum Slew Rate (deg/s)**	**Calculated Time (s)**	***Measured Time (s)***
Azimuth	16	1	4	8	
Azimuth	56	1	4	18	
Azimuth	196	1	4	53	
Elevation	4	1	2	4	
Elevation	24	1	2	14	
Elevation	*84*	*1*	*2*	*44*	

2.2.6 Test Results

Item #	Description	Reference	Contract Requirement	Test Results	Pass/ Fail
1	Slew Rates	Appx. C §2	> 4 º/s (azimuth) > 2 º/s (elevation)		
2	Slew Accelerations	Appx. C §2	>1 $º/s^2$ (azimuth) >1 $º/s^2$ (elevation)		
3	Tertiary Rotator	Appx. C §7.4	Rotates the tertiary mirror about the primary optical axis to direct the telescope beam to one of two Nasmyth Ports. Time to beam switch is < 1 min, remotely actuated		

	Name	Signature
Test Conducted By:		
Test Accepted By:		
	Test Date	

2.3 POINTING ACCURACY

2.3.1 Test Objective and Scope

The objective of this test is to verify that the pointing accuracy of the telescope system is better than 3 arcsec Root Mean Square (RMS) over the specified elevation range.

2.3.2 Reference Documents

- 2.4 Meter Alt-Azimuth Telescope Contract Number CTR-4875-1

2.3.3 Safety Requirements

Remain a safe distance from the telescope as it rotates.

2.3.4 Test Equipment

- StarCal software
- Camera at non-drive side Nasmyth port

2.3.5 Test Procedure

1. Set a camera at the non-drive side Nasmyth port.
2. View the currently installed mount model and record the post-fit RMS pointing error.
3. Using Starcal, start a new set of observations and record the positions of ~100 stars distributed throughout the sky.
4. Using these observations, compute the pre-fit RMS error and verify that it is less than 3 arcseconds.
5. Review the results and assign pass/fail status.

2.3.6 Test Results

Item #	Description	Reference	Contract Requirement	Test Results	Pass/ Fail
1	Pointing Accuracy	Appx. C §2.1	Better than 3 arcsec RMS to 70 º zenith angle after mount modeling correction		

	Name	Signature
Test Conducted By:		
Test Accepted By:		
	Test Date	

2.4 TRACKING ACCURACY

2.4.1 Test Objective and Scope

The objective of this test is to verify the tracking smoothness over 10 minute and 60 minute periods, neglecting seeing effects.

2.4.2 Reference Documents

- 2.4 Meter Alt-Azimuth Telescope Contract Number CTR-4875-1

2.4.3 Safety Requirements

Remain a safe distance from the telescope as it rotates.

2.4.4 Test Equipment

- Camera at the non-drive side Nasmyth port
- Centroid tracking and logging software and computer
- Microsoft Excel software

2.4.5 Test Procedure

1. Start up the telescope control system and start the telescope server on the TCC.
2. Acquire and track a suitable star that will pass near 85 degrees elevation.
3. Start the centroiding software.
4. Center the star image on the video monitor and optimize focus if necessary.
5. Measure and set the pixel scaling factor in the centroiding software by offsetting the telescope by a known amount.
6. Set the centroiding software up to collect 1 second exposures and average for 5 seconds to remove the effects of seeing.
7. Gather star centroiding data for the 10 and 60 minute periods.
8. Reduce centroiding data to obtain the RMS deviation and record the results.
9. Compare the measured results to the contract requirement and assign pass/fail status.
10. Repeat steps 2-9 for stars near 20, 45 and 70 degrees elevation.

2.4.6 Test Results

Item #	Description	Reference	Contract Requirement	Test Results	Pass/ Fail
1	Tracking Accuracy	Appx. B §3.10	0.5 arcsec RMS over 10 minutes		
2	Tracking Accuracy	Appx. B §3.10	2.5 arcsec RMS over 1 hour		

	Name	Signature
Test Conducted By:		
Test Accepted By:		
	Test Date	

2.5 WAVEFRONT QUALITY

2.5.1 Test Objective and Scope

The objective of this test is to verify that acceptable wavefront quality has been achieved after optical alignment.

2.5.2 Reference Documents

- 2.4 Meter Alt-Azimuth Telescope Contract Number CTR-4875-1

2.5.3 Safety Requirements

Remain a safe distance from the telescope as it rotates.

2.5.4 Test Equipment

- Shack-Hartmann Wavefront Sensor mounted at the non-drive side Nasmyth port
- PC with CCDSoft and ProSH software installed

2.5.5 Test Procedure

1. Set the Shack-Hartmann WFS onto the non-drive side Nasmyth port and secure.
2. Rotate reference LED into the optical path and power it on.
3. Mark the artificial star position on the video monitor.
4. Setup the CCDSoft and ProSH software to store data in a folder with the date and telescope name in its title. The ProSH software should also be configured to store a zernike data file to the same directory.
5. Using the CCDSoft software, take a reference image.
6. Load the reference image into the ProSH software.
7. Turn off and rotate reference LED out of the optical path.
8. Set the telescope system to image a suitably bright star near zenith and take ~50 images (depending on seeing conditions).
9. Copy the results of the exposures from the Zernike file into the Excel spreadsheet and analyze.
10. Repeat this procedure until an acceptable wavefront has been obtained for a star near zenith, a star near 60˚ and a star near 30˚.
11. Review the results and assign pass/fail status.

2.5.6 Test Results

Item #	Description	Reference	Contract Requirement	Test Results	Pass/ Fail
1	Wavefront Quality	Appx. C §4.2	~ 160 nm (80 % ee in 0.5 arcsec) Degrades at Kolmogorov power spectrum, $(\cos z)^{-3/5}$ Applies at 5 m/s wind and 1 deg C temperature gradient		

	Name	**Signature**
Test Conducted By:		
Test Accepted By:		
	Test Date	

2.6 SECONDARY ACTIVE TIP/TILT FOCUS SYSTEM

2.6.1 Test Objective and Scope

The objective of this test is to verify that the ranges of motion and slew rates of the secondary mirror mount satisfy the stated requirements.

2.6.2 Reference Documents

- 2.4 Meter Alt-Azimuth Telescope Contract Number CTR-4875-1

2.6.3 Safety Requirements

Observe general safety procedure when working on or near the telescope.

2.6.4 Test Equipment

- Stopwatch

2.6.5 Test Procedure

1. Command the secondary tip/tilt axis to move to its center of motion.
2. Command the tip/tilt stage to move to + 18 arcsec from the center of motion.
3. Record the reported position.
4. Command the tip/tilt stage to move to - 18 arcsec from the center of motion.
5. Record the reported position.
6. Using the stopwatch, measure and record the time required for the tip/tilt stage to move through 36 arcsec.
7. Command the secondary focus axis to move to its center of motion.
8. Command the focus axis to move to +8.5 mm from the center of motion.
9. Record the reported position.
10. Command the secondary focus axis to move to -8.5 mm from the center of motion.
11. Record the reported position.
12. Using the stopwatch, measure and record the time required for the focus stage to move through 17 mm.
13. Compare the results to the contract requirements and assign pass/fail status.

Axis	Commanded Position	Reported Position
Tip/Tilt	-18 arcsec	
Tip/Tilt	+18 arcsec	
Focus	-8.5 mm	
Focus	+8.5 mm	

Axis	Distance Moved	Maximum Velocity	Maximum Time (s)	*Measured Time (s)*
Tip/Tilt	36 arcsec	5 arcsec/s	7.2	
Focus	*17 mm*	*100 µm/s*	*170*	

2.6.6 Test Results

Item #	Description	Reference	Contract Requirement	Test Results	Pass/ Fail
1	Range (tip/tilt)	Appx. C §5.1	± 18 arcsec		
2	Slew Rate	Appx. C §5.1	> 5 arcsec/s		
3	Focus Range	Appx. C §5.2	± 10 mm travel of secondary mirror		
4	Focus Slew Rate	Appx. C §5.2	> 100 µm/s		

	Name	Signature
Test Conducted By:		
Test Accepted By:		
	Test Date	