
## Lick Automated Planet Finder

## 2.4 Meter Alt-Azimuth Telescope

# Maintenance and Installation Manual

# MM-12920-1



EOS Technologies, Inc. • 3160 East Transcon Way, Suite 180 • Tucson AZ 85706 • USA
Tel: +1 520 624 6399 • Fax: +1 520 624 1906 • Web: www.eostech.com

# DOCUMENT CONTROL



**Issue:** 1

| | | | |
|---|---|---|---|
| Prepared: | D. Shelby Stubbe | | Date: 11/30/2009 |
| Checked: | Andrew Carr | | Date: 11/30/2009 |
| Approved: | D. Shelby Stubbe | | Date: 11/30/2009 |
| Configured: | Rose Tharp | | Date: 11/30/2009 |

## Document Revisions

| Issue | Date | Description | Prep | Chk | Appr |
|---|---|---|---|---|---|
| 1 | 11/30/2009 | Initial Release | DSS | AC | DSS |

# TABLE OF CONTENTS

# LIST OF FIGURES



# LIST OF TABLES

# Lick Automated Planet Finder

# 2.4 m Alt-Azimuth Telescope

# Maintenance Manual

## CHAPTER 1 INTRODUCTION

### 1.1 INTRODUCTION

The 2.4 meter Alt-Azimuth telescope requires rountine, planned, and corrective maintenance to keep the telescope in good working condition. All maintenance personnel are required to adhere to safety precautions while performing maintenance procedures on the telescope. All personnel present at the observatory must be informed by maintenance personnel whenever any maintenance procedures are to be performed.

Carelessness may result in damage to the telescope system, or injury and/or death to the maintenance personnel.

The telescope system is comprised of modules that are large and heavy, and optical components and equipment that are delicate, expensive, and damage easily. The telescope can move at any time, therefore, all personnel in the observatory must be alert at all times.

*EOST and its related entities take no responsibility and shall not be liable for any injury, loss or damage (including death) which results from the operation, use or maintenance of the telescope and related systems, including the use of or reliance upon the contents of this manual. Such operation, use or maintenance of the telescope and related systems, including use of or reliance upon this manual is at the Customer's own risk.*

*Personnel operating, maintaining and performing work on or around the telescope and related systems should take all reasonable and necessary care for their safety, health and well-being and the directions, instructions and advice provided in this manual should not be followed as a substitute for observing safe work methods, or where injury, loss or damage may occur.*

### 1.2 SCOPE

This document describes the plan to maintain the 2.4 meter Alt-Azimuth Telescope. This plan outlines the philosophy used for designing maintainability into the telescope and identifies the major maintenance tasks required.

### 1.3 CONFIGURATION

This manual has been configured as MM-12920-1 and is a designated controlled document under the EOST Quality System.

## 1.4 REFERENCES

- Assembly Drawings
- Electrical Schematics
- Optical Alignment Procedure ASP-13964
- Primary Mirror Removal and Installation Procedure ASP-13952
- Software User Manual SUM-13948

## 1.5 DEFINITIONS AND ACRONYMS

- DC: Direct Current
- EOST: EOS Technologies, Inc.
- ESD: Electrostatic Discharge
- ESTOP: Emergency Stop button
- HV: High Voltage
- OEM: Original Equipment Manufacturer
- OSS: Optical Support Structure
- OTA: Optical Truss (Tube) Assembly

## 1.6 CONVENTIONS

The following conventions are used in this document to alert the reader:

**Notes**

**NOTE:** The note box contains helpful information about a topic being dicsussed.

**Caution**

**CAUTION: A yellow caution box alerts the reader to possible damage to equipment.**

**Warning**

**WARNING! A warning box contains information alerting the reader to situations or circumstances that may cause personal injury or death to individuals working in the observatory or around the telescope.**

## 1.7 SAFETY

Safety of maintenance personnel is extremely important when servicing the telescope. Safety equipment should be worn when appropriate. Avoid wearing loose clothing that may get caught

in moving parts of the telescope during maintenance. Eye glass straps are recommended for maintenance personnel wearing eyeglasses when working from heights and around optics.

**WARNING! All individuals present in the observatory during maintenance must be alerted that maintenance procedures are going to be in progress for the duration of the day.**

**Telescope and dome operation is very quiet, always observe all cautions and warnings to prevent damage to equipment or injury to individuals.**

### 1.7.1 DESIGNED FOR SAFETY

The telescope is designed for safety of personnel and equipment while satisfying performance requirements. Where the existence of a potential hazard can not be eliminated without substantial performance or maintenance impact, interlocks are employed to minimize the possibility of injury to individuals or damage to equipment. In locations where interlocks are impossible, or expected to be ineffective, warnings and procedures will be developed to minimize the risk of damage or injury.

### 1.7.2 PRECAUTIONS DURING MAINTENANCE

To avoid injury and or death to maintenance personnel and other individuals present in the observatory, follow the safety measures described below.

**WARNING! Alert all personnel at the site that the equipment is undergoing maintenance.**

**Wear safety equipment, such as a hard hat (except when working with optics), steel toed safety shoes and avoid wearing loose clothing items.**

**Disconnect power before attempting work or performing maintenance. “Lock out” and “Tag out” all power sources to prevent death or injury.**

**Turn off all power sources before connecting or disconnecting cables.**

**Do not attempt to service the system while it is in operational mode.**

**Install axis locks before attempting to perform maintenance.**

**Elevation axis locks are not to be used in an out-of-balance situation. A second safety device must be attached to ensure that the telescope does not move unexpectedly.**

To prevent damage to equipment during maintenance procedures, review the following caution statements.

**CAUTION:**

**Keep dirt and dust away from the optics by keeping covers closed whenever possible.**

**Wear a grounding wrist strap whenever performing electronics maintenance to reduce the risk of ESD damage.**

**Replace blown fuses only with identical fuses of the same current rating and type to avoid fire hazards and equipment damage.**

**The telescope system must be securely and adequately grounded whenever power is applied. During operation, grounding is accomplished through the connections to the building.**

**Protect cables from contact with sharp objects. Do not kink cables and never allow the cables to come in contact with oil, grease, hot surfaces or chemicals.**

**After maintenance or installation, carefully inspect the area to ensure that all tools, cleaning cloths, loose parts and so forth are not left on or near the telescope, dome or Telescope Control Cabinets.**

**Never touch any optical surface when working close to a mirror.**

**Clean optical surfaces using only approved procedures and materials.**

### 1.7.3 SAFETY FEATURES

The telescope incorporates the following safety features:

#### 1.7.3.1 Handles

Handles are provided for items that must be routinely moved manually. These are intended to minimize the risk of injury from improper lifting, or damage from dropping the item.

#### 1.7.3.2 Lifting Points

Identifiable lifting points are included in appropriate locations to reduce the risk of damage resulting from improper rigging.

#### 1.7.3.3 Axis Locks

Elevation axis locks are provided to lock the axis in position for alignment, maintenance or inspection.

#### 1.7.3.4 Self-Sealing Fittings

Self-sealing fittings are used for coolant lines to minimize spillage.

#### 1.7.3.5 Over-current Protection Devices

The telescope control system incorporates various over-current protection devices, including fuses and circuit breakers. In addition, the power supplies employed are self-protected against over-current.

#### 1.7.3.6 Connector Uniqueness and Pin Arrangement

Where reasonable, unique connectors are used to minimize the risk of incorrectly connecting the instrument. Within each connector, pins are arranged to reduce the risk of damage due to partial or an incorrect connection.

#### 1.7.3.7 Interface to Observatory Interlock System

The telescope is be interfaced to the observatory interlock system. Activating any Emergency Stop button in the enclosure disables power to the dome and telescope drives.

#### 1.7.3.8 Failsafe Design

Whenever possible, the telescope has been designed to fail in a safe manner when a fault occurs.

### 1.7.4 IDENTIFIED HAZARDS

The following hazards were identified during the conceptual design process:

#### 1.7.4.1 Weight and Impact

The telescope is a heavy piece of equipment that could cause serious injury or death, or be damaged if dropped or mishandled during maintenance or removal and installation of optics. If moved quickly during handling, it will develop substantial momentum and serious injury could result to a person or object between the telescope and an immovable object. Any collision with the building or other equipment could result in shocks that cause damage.

#### 1.7.4.2 Pinch Points

Pinch points may exist in several areas within the telescope and may be unavoidable due to constraints within the building. Crushing or shearing injuries may result if objects or body parts are placed in these areas.

#### 1.7.4.3 Cryogenic Gases

If cryogenic gases are supplied to instruments on the telescope, they may present a hazard. Since EOST is not providing any equipment or components that require cryogens, special precautions or markings are not provided. If features requiring cryogens are implemented later, EOST recommends a safety review to identify any necessary safety features that should be added.

#### 1.7.4.4 Electrical Shock

The main supply power presents a risk of electrical shock. This risk is minimized through isolation and procedures. In addition, several devices will require high voltage power supplies that may be hazardous. These will be shielded and separately enclosed where possible, with warning labels attached.

**WARNING!: Use extreme caution when working on or around telescope or dome electrical components.**

#### 1.7.4.5 Electrostatic Discharge

Static electricity may damage some sensitive electronic devices attached to the telescope. Photo detectors and CCDs are especially vulnerable. Adequate grounding is provided to protect against this hazard during operation. ESD safe repair procedures should be followed to minimize the risk of ESD damage during scheduled maintenance.

### 1.7.5 SAFETY PRECAUTIONS WHILE IN THE TELESCOPE ENCLOSURE

Follow all safety rules when in the enclosure and be alert. Keep a safe distance from the telescope or enclosure (dome) while they are in use, even if the telescope and dome appear stationary. If the system is in the middle of tracking, or is being controlled remotely, it can suddenly and unexpectedly move at any time. Casual visitors to the dome are strongly discouraged. Avoid wearing any loose fitting clothing items when working around the telescope enclosure.

#### 1.7.5.1 Emergency Stop Buttons

The telescope is outfitted with Emergency Stop buttons that should only be used for emergency purposes to stop telescope and or dome movement. Under non-emergency conditions, the telescope should only be stopped using software commands.

**CAUTION: Do not use the Emergency Stop button to turn off power while the telescope is moving, as damage to telescope or dome drive mechanisms may occur.**

The Emergency Stop button ensures the telescope and dome will not begin to move unexpectedly. This is particularly important because the telescope and dome can be operated remotely via an Internet connection.

**WARNING!: Whenever working on or near a moving part of the telescope and dome, ensure that a nearby Emergency Stop button is engaged. Always attach a sign to the button to warn other individuals on-site not to disengage the Emergency Stop button.**

**The Emergency Stop buttons do not normally prevent the operation of the shutter on the enclosure. Shutter buttons generally are setup to override the Emergency Stop buttons, allowing the shutter to be closed (or opened) in an emergency. Ask the appropriate observatory personnel about the operation of shutter mechanisms on the enclosure.**

**Generally, it is recommnded that shutters be controlled via software commands to avoid an override situation of the end-of-travel limit switches. The shutter can be damaged by being driven into an end-stop.**

#### 1.7.5.2 Determining Why an Emergency Stop Button is Engaged

If an Emergency Stop button is engaged, do not disengage it before determining the reason for the button being engaged. Someone may be working on the telescope and dome or may have discovered a problem and engaged the button to prevent damage to the system.

#### 1.7.5.3 Investigate Problems Before Continuing

If a problem has occurred (for example, if the telescope or dome stops tracking), determine the cause of the problem before attempting the operation again or rebooting the system.

**CAUTION: Damage to the telescope or dome may have occurred, or damage may be prevented by removing the cause of the problem.**

### 1.7.6 SAFETY INTERLOCKS

Limit Switches are controlled by Software and Hardware.

The limit switches, located on the Azimuth base and Elevation optical support structure (OSS) prevent the OSS from being driven beyond a specific point.

#### 1.7.6.1 Manual Reset

Whenever the emergency stop buttons are engaged, a manual reset is required. The manual reset is performed by manually disengaging each emergency stop button in the observatory.

### 1.7.7 ACCIDENTS OR INCIDENTS

Report all accidents or incidents as soon as possible when they occur to authorized engineering support personnel. This may prevent further damage or injury from occurring, and helps to

ensure it does not occur again. Advice can be provided on the possible consequences to system performance and suggested tests to conduct to determine if damage has occurred and whether the system is operational.

## 1.8 MODES OF OPERATION

The observatory has two basic modes of operation:

- Local
- Remote

Local and remote modes appear to users as essentially the same; the observatory is controlled in real-time via appropriate user interfaces. In local mode, the user is specifically using the on-site control computer whereas in remote mode, the user may be located anywhere on the network (for example, Local Area Network/Wide Area Network (LAN/WAN) or Internet).

The main distinction between these two modes of operation lies in the rights of access granted to particular types of users. For example, certain local users have the right to issue engineering-level commands to the system which are not available to remote users.

### 1.8.1 LOCAL (ON-SITE) MODE

In local (on-site) mode, the user is specifically using the on-site control computer and the observatory is controlled in real-time via appropriate (hardware and software) user interfaces.

### 1.8.2 REMOTE MODE

In remote mode, the user may be located anywhere on the 'network' (LAN/WAN or Internet) and the observatory is controlled in real-time via appropriate (software) user interfaces.

## 1.9 PRECAUTIONS BEFORE, DURING AND AFTER OPERATION

The telescope should only be operated by trained personnel, or under the guidance of trained personnel.

- Inspect the telescope daily to detect and correct any unsafe operating conditions.
- Periodically check all safety devices for proper operation. See Chapter 2 for more details.
- Avoid intentionally driving the telescope into a hard stop; use software commands to stop the telescope.
- Do not operate the telescope at speeds or accelerations in excess of those for which it is rated.
- Do not stop the telescope quicker than the rated stopping speed.
- Do not use the Emergency Stop buttons to stop the telescope during non-emergency situations; stop the telescope with software commands.
- Immediately report any problems to the observatory safety officer.

**CAUTION: If the power to the telescope or dome has been turned off, investigate the reason why before attempting to start the system up.**

**The system may have been turned off because a serious fault was observed, and turning it on again could damage system components.**

### 1.9.1 CHECKING THE OPERATIONAL STATUS OF THE SYSTEM

At the start of each session, if the observatory has a logbook or a notice board, check to determine whether the telescope and dome are operational, whether any new problems have surfaced or old ones have been solved, and to review the existing known problems.

## 1.10 GENERAL TELESCOPE SYSTEM INFORMATION

This section includes information on the system power requirements, motors, KVM switch, digital input/output subsystem, the encoder input/output subsystem, and the connection and termination of the emergency stop buttons to the drive motors and any other motors.

### 1.10.1 SYSTEM POWER REQUIREMENTS

The system power requirements are 120 VAC and 28 VAC RMS (2-phase).

A backup generator that works with the uninterrupted power supply (UPS) is being provided by the customer.

### 1.10.2 DC POWER SUPPLIES

The DC power supplies are:

24 Volt Power Supply

96 Volt Power Supply (two 48 VDC supplies in series)

### 1.10.3 MOTORS

The motors that operate the telescope system are direct drive DC brushed motors. DC right angle gear motors operate the mirror covers.

### 1.10.4 EMERGENCY STOP BUTTON CONNECTIONS

The Emergency Stop buttons (e-stop) are connected in series and terminate at the digital I/O box on the telescope control cabinet. Engaging an e-stop causes power to the drive motors and any other motors or moving parts to be shut off by disabling the power amplifiers. This is accomplished in hardware. Being connected in series enables the customer to install additional e-stops anywhere in the observatory.

If a cable became damaged, it would trigger the e-stop, shutting off power to all drive motors and any other motors and moving parts on the telescope.

## 1.11 MAINTENANCE CONCEPT

Maintenance of the telescope is divided into two regimes: preventive maintenance and corrective maintenance.

- *Preventive* maintenance tasks are those tasks to be performed regularly to ensure the continued operation of the telescope at the specified level of performance throughout its design lifetime. These tasks must be performed at the specified time, regardless of whether symptoms are exhibited by the telescope.

**CAUTION: Failure to perform preventive maintenance may result in premature failure of telescope components and/or the failure of the telescope to perform within specification.**

- *Corrective* maintenance tasks are required only to remedy a failure of a particular component or subassembly. Corrective maintenance involves replacing one or more field-replaceable units and, in some cases, realigning or recalibrating the telescope.

# CHAPTER 2 PREVENTIVE MAINTENANCE

## 2.1 PREVENTATIVE MAINTENANCE TASKS

The preventative maintenance tasks in this chapter are included in the recommended maintenance schedule shown in Table 1.

**Table 1 Telescope Preventative Maintenance Schedule**

| PROCEDURE | DURATION | FREQUENCY |
|---|---|---|
| General visual inspections:<br>Cable wear<br>Structural fasteners<br>Corrosion<br>Environment<br>(section 2.2) | 30-45 minutes<br><br><br>15 minutes | Daily / Weekly<br><br><br>Monthly |
| Telescope Control Cabinet:<br>Indicator Lamps<br>Cooling Fans<br>DC Power supply voltage check<br>(section 2.3) | <br>15 minutes<br>5 minutes<br>5 minutes | <br>Weekly<br>Monthly or more often as needed<br>Monthly |
| Emergency Stop Buttons<br>(section 2.4) | ~1 minute per button | Monthly |
| Cleaning the Encoder Tape:<br>Encoder Tape and Encoder Ring Cleaning<br>(section 2.5) | 30-45 minutes / axis | Normal conditions: bi-annually<br>Severe dust conditions: every 3 months |
| Lubricating the Azimuth and Elevation Drive Bearing<br>(section 2.8.3) | 30 minutes / axis | Yearly |
| Primary Mirror Covers Cleaning<br>section 4) | 15 -30 minutes | Monthly |
| Primary Mirror (M1) Cleaning<br>(section 2.8.3) | 30 minutes for $CO_2$ | Monthly or more often as needed. |
| Secondary Mirror (M2) Cleaning<br>(section 2.8.4) | 30 minutes for $CO_2$ | Monthly or more often as needed. |
| Tertiary Mirror (M3) Cleaning<br>(section 2.8.5) | 30 minutes for $CO_2$ | Monthly or more often as needed. |

> **NOTE:** Record all maintenance that has been performed in a log book and store it with the telescope in an obvious location for future use and reference.

## 2.2 GENERAL INSPECTION

Perform a general inspection of the telescope system by walking completely around the telescope and visually inspect the base, fork, and OTA. These preventative measures should and can easily be implemented as system checks prior to telescope operation. Note any discrepancies in the maintenance log book.

### 2.2.1 CABLE WEAR

1. On a daily/weekly basis, visually inspect the condition of the cables in the base, fork side, and at the secondary mirror assembly.
2. Note the conditions of all of these cables in the maintenance log.
3. If cable wear is present, thoroughly document the condition of the cable and take photographs of the wear.
4. Contact the maintenance personnel and provide the description and copies of the photographs of the cable wear.

### 2.2.2 STRUCTURAL FASTENING

Use tamper proof markers (where possible) to identify critical structural fasteners of the assembly, enabling service technicians to be able to clearly see fasteners which may become loose over time. Tamper proof markers are used for items such as the azimuth and elevation drives, elevation bearings, mirror cover assemblies, or even telescope hold down bolts.

### 2.2.3 CORROSION

Inspecting for corrosion helps to prevent fasteners and members from binding over time. Any early signs of corrosion can be corrected to prevent further degradation of hardware, cables, and maintain the telescope's appearance.

1. Perform a visual inspection of any accessible parts on the telescope to ensure that telescope parts and fasteners are free of corrosion.
2. Visually inspect the cables for corrosion at the terminating ends of the telescope and telescope control cabinet.
3. Record preventive maintenance completed in the log book.

### 2.2.4 ENVIRONMENT

Routine checks of the telescope's operational environment helps lead to low maintenance and lessens the likelyhood of severe damage to the telescope structure.

**CAUTION: During dome maintenance, the telescope can easily become a convenient work bench. Service personnel must ensure that any equipment placed on the telescope is removed prior to telescope operation, as damage to optics or the telescope structure could occur.**

## 2.3 TELESCOPE CONTROL CABINET

The telescope control cabinet houses the electronics for the telescope system.

### 2.3.1 INDICATOR LAMPS

1. On a weekly basis, verify that all indicator lamps on the front are operational.
2. Press the test button to illuminate all lamps.
3. Replace any burned out indicator lamps, as needed.

### 2.3.2 COOLING FANS

There are several different types of cooling fans located in the telescope control cabinet that require routine inspection and cleaning. Although a monthly inspection and cleaning of fans is recommended, environmental conditions may require more frequent cleaning of the fans and filter. See Table 2.

**Table 2 Inspection and Cleaning of Cooling Fans and Filters**

| Fan / Filter | Frequency |
|---|---|
| Drive amplifier fans | monthly |
| System fan | monthly |
| Inlet filter (bottom of cabinet) | bi-monthly |
| Computer fans | monthly |

1. Inspect and clean all drive amplifier fans every 30 days (monthly).
2. Open the front panel of the telescope control cabinet and examine the two (2) cooling fans for the two (2) drive amplifiers located in the encoder planers. These cooling fans exhaust heat from the inside of the encoder planar.
3. Inspect the two (2) fans in the Elevation and the Azimuth panel.
4. On the top of the telescope control cabinet, examine the system fan.
5. Test the system fan by applying heat from a heat gun to the thermostat, located inside of the telescope control cabinet, to trigger the fan to run when the predetermined temperature inside of the cabinet is reached.
6. If dust or dirt is present on the grill, vacuum with a soft brush attachment.

7. If the fan blades require cleaning, remove the hardware securing the fan grill and carefully clean the blades using a vacuum cleaner and soft brush attachment. Reinstall the fan grill and fasten the hardware.
8. Carefully remove and check the condition of the filter on the fan inlet located at the bottom of the telescope control cabinet bi-monthly.
9. If the filter is dirty and requires cleaning, take the filter outside and apply a mixture of dishwashing liquid and water in a squeeze bottle to the dirty side of the filter and let it sit with the dirty side face down for several minutes.
10. Using a garden hose, spray from the clean side of the filter to drive the dirt out of the filter and rinse off the dishwashing liquid.
11. Gently shake the filter to remove excess water after rinsing and allow the filter to completely air dry or blow dry using low pressure filtered (to eliminate oil from the line) compressed air.
12. Reinstall the dry filter into the bottom of the telescope control cabinet.
13. Record the maintenance completed in the log book.
14. For each computer, perform a visual inspection of the cooling fans monthly. With the computer running, perform an audio inspection by listening to the sound of the fan.
15. If the fan motor sounds as though it is nearing the end of its lifecycle, schedule corrective maintenance and replace the fan.
16. Record preventive maintenance completed in the log book.

### 2.3.3 VOLTAGE CHECK ON DC POWER SUPPLIES

There are 24 VDC and 56 VDC power supplies in the telescope control cabinet.

1. Turn on the 24 VDC power supply to confirm it is operational. Verify the indicator lamp illuminates.
2. Turn on the 56 VDC power supply to confirm it is operational. This is a dual 28 VDC supply. Verify the indicator lamp illuminates.
3. If the lamp for the power supply fails to illuminate, press the test button for the indicator lamps. If the lamp illuminates during the lamp test, but fails to illuminate when the 56 VDC power supply is turned on, the power supply is malfunctioning. Test the voltage at the amplifier using a digital volt meter, +HV, -HV and check for 56 VDC.
4. Record preventive maintenance completed in the log book.

## 2.4 TESTING EMERGENCY STOP BUTTONS

Test all emergency stop buttons located in the observatory monthly.

1. Verify that each Emergency stop button is operational. If an Emergency Stop button malfunctions, the telescope system shuts down.

**WARNING! If an Emergency Stop button fails the test, immediately tag the button with a warning message to alert others that the button has malfunctioned.**

**Schedule corrective maintenance to replace the Emergency Stop button.**

2. Record preventive maintenance completed in the log book.

## 2.5 ENCODER TAPE CLEANING

It is important to keep the encoder tape in the elevation and azimuth axes clean since dust, dirt, and moisture from the surrounding enclosure environment can settle on the telescope surfaces, including the encoder tape.

Of the two axes, due to the encoder tape being set on a horizontal plane during operation, the elevation axis is the most likely to require more frequent cleaning. Since the encoder tape on the azimuth axis is orientated vertically, it is less inclined to accrue contaminants on the surface.A maximum of four encoder assemblies can be used on the azimuth axis of this telescope.

### 2.5.1 REQUIRED TOOLS AND EQUIPMENT

- Acetone
- Optical wipes

### 2.5.2 TIME REQUIRED

- 30-45 minutes each axis, 2 persons required

### 2.5.3 FREQUENCY

- Six month intervals or 3 month intervals for extremely dusty conditions.

### 2.5.4 PROCEDURE

**CAUTION: The encoder tape is an extremely delicate optical surface the telescope uses to read the telescope's position to a fraction of an arc second.**

**The tape comes with an anti-corrosion layer on its surface (gold) to ensure that over the operating life of the tape, there is little degradation of the tape's optical surface.**

**Due to the frequency of maintenance, it is important to adhere to cleaning procedures during regular maintenance. Damage to the tape is cumulative.**

1. Turn OFF power to the telescope.
2. Orient the telescope so that the axis being cleaned is near the end of its travel limits.
3. Remove the access covers to the encoder tape. Do not remove the encoder assemblies.

4. Use one of the openings at an encoder location to access the encoder tape, and with clean fresh optical wipes dampened with acetone, gently place and hold the wipe against the surface of the tape as another technician, rotates the axis by hand at a slow speed, only cleaning approximately 100 mm of tape every 8-10 seconds.
5. After cleaning this area of the tape, either replace the wipe with a new clean wipe or fold the optical wipe being used to create another clean wiping area.
6. Repeat the wiping in the same direction until the telescope range of motion does not permit any further rotation.
7. Once completed, repeat in the reverse direction to ensure that the tape is completely cleaned of any residue from the first pass.
8. Reinstall the access covers.
9. Record preventive maintenance completed in the log book.

## 2.6 LUBRICATING THE AZIMUTH AND ELEVATION DRIVE BEARINGS

The drive system for the telescope consists of three roller type bearings which require lubrication over the life of the telescope.

### 2.6.1 PURPOSE

Replacement of the lubricant is required to maintain the protective lubrication film on the bearings. Any lubricant, including that used on the bearings, breaks down over time. Breakdown is accelerated by heat and load cycling, but occurs even during storage periods. Maintaining proper lubrication of the bearings ensures smooth operation.

### 2.6.2 REQUIRED TOOLS AND EQUIPMENT

- Clean, dry shop cloths
- Kluberplex BEM 34-132 grease (replace annually, or after any extended storage period)
- Grease gun

### 2.6.3 TIME REQUIRED

- 30 minutes (May require two persons for part of the procedure)

### 2.6.4 FREQUENCY

- Annually

### 2.6.5 PROCEDURE FOR AZIMUTH BEARING LUBRICATION

The azimuth axis of the telescope has one large bearing and the elevation axis has two smaller bearings (one on either side of the fork).

1. Load the Kluberplex BEM 34-132 grease into the grease gun.
2. Access the azimuth bearing through the base.

**NOTE:** Locating the grease fittings may require the assistance of maintenance personnel to rotate the fork (with the power to the systems switched OFF) until the grease fittings can be seen or felt by the service person.

3. Clean the grease fitting with a shop cloth to remove old grease.
4. Attach the end of the grease gun to the fitting and inject one pump of grease into the bearing cage.

   Since it is difficult to visually determine the amount of grease to apply, the recommendation is three (3) pumps from the grease gun lever per fitting per bearing.
5. Turn the telescope through approximately 90° and back.
6. Repeat steps 3-5 for each fitting.
7. Record preventive maintenance completed in the log book.

### 2.6.6 PROCEDURE FOR ELEVATION BEARING LUBRICATION

There are two elevation bearings, one on each side of the fork. There are four grease fittings in each bearing spaced 90° apart.

1. Load the Kluberplex BEM 34-132 grease into the grease gun.
2. Access the elevation bearings from either side of the fork.

**NOTE:** Locating the grease fittings may require the assistance of maintenance personnel to rotate the center section (with the power to the systems switched OFF) until the grease fittings can be seen or felt by the service person.

3. Locate and clean the four opposing grease fittings on the bearing with a shop cloth to remove old grease.
4. Attach the end of the grease gun to the fitting and inject one pump of grease into the bearing cage.

   Since it is difficult to visually determine the amount of grease to apply, the recommendation is one to three (1-3) pumps from the grease gun lever per fitting per bearing.
5. Turn the fork 90° from horizon to zenith and back.
6. Repeat steps 3-5 for each bearing four times to ensure the bearing is properly lubricated.
7. Record preventive maintenance completed in the log book.

## 2.7 CLEANING THE PRIMARY MIRROR (M1) COVERS

### 2.7.1 PURPOSE

Dust collects on the primary mirror covers and could eventually migrate onto the primary mirror surface. The frequency of removing dust that has settled on the primary mirror covers varies depending on dust conditions. Some environments contain more dust than others.

### 2.7.2 RECOMMENDED FREQUENCY

Vacuuming of the primary mirror covers should be performed monthly or more often as needed.

### 2.7.3 EQUIPMENT AND TOOLS REQUIRED

- Vacuum cleaner with soft brush attachment

### 2.7.4 PROCEDURE

1. Verify the primary mirror covers are closed.
2. Place the telescope in the horizontal position and lock in place using the stay pin.
3. Gently vacuum the outer surface of the mirror cover, starting on one side and cleaning to the other side.
4. Repeat step 3 for each mirror cover segment.
5. Record preventive maintenance completed in the log book.

## 2.8 CLEANING OPTICS

### 2.8.1 PURPOSE

Dust on the M1, M2 and M3 mirrors will reduce reflectivity and degrade telescope performance. The mirrors must be cleaned by qualified personnel on a regular basis.

**CAUTION: Optical cleaning should be performed with extreme care, adhering to preventive maintenance cleaning schedules. Physical contact can lead to surface degradation of the optics and their coatings.**

**REMOVE jewelry and any items in shirt/jacket pockets that may fall onto the mirror surface when leaning over.**

**Do not wear a safety hard hat or other hat that may fall onto the mirror. Restrain eyeglasses by using an eyeglass safety strap.**

**The best method for keeping the optics un-contaminated is to maintain the environmental integrity of the telescope and keep the optics free of dust, moisture and large temperature variations which cause condensation.**

### 2.8.2 EQUIPMENT AND TOOLS REQUIRED

- Powder-free Latex Gloves
- Dust Face Mask
- Safety Glasses
- $CO_2$ Snow Cleaning System

- Sterile Cotton Balls

**CAUTION: To avoid misalignment of the telescope when cleaning optics, use care not to disturb the optics or their mounts.**

### 2.8.3 CLEANING THE PRIMARY MIRROR

#### 2.8.3.1 Recommended Frequency

Snow cleaning of the primary mirror surface should be performed monthly, although severe operating conditions may require more frequent cleanings.

EOST recommends using a $CO_2$ snow cleaning system to clean all optical surfaces. If contaminants are not removed by the $CO_2$ snow cleaning system, a more thorough liquid or chemical cleaning may be performed by a qualified optician. EOST does not provide a procedure beyond the recommended $CO_2$ snow cleaning, as more direct cleaning methods can require extensive training and experience to be performed safely.

#### 2.8.3.2 Procedure

1. Either manually or via software control, move the telescope to its horizon pointing position and lock it in place using the Elevation stay pin on the Optical Support Structure.
2. Open the mirror covers.
3. Stand several feet away from the primary mirror, hold the nozzle of a $CO_2$ snow cleaning system can in a downward, angled direction (to prevent the refrigerant from fogging the coating) and spray across the surface.
4. When finished, clean the contaminants from the bottom of the mirror cell using sterile cotton balls.

### 2.8.4 CLEANING THE SECONDARY MIRROR (M2)

#### 2.8.4.1 Purpose

Dust will collect on the secondary mirror, although its orientation suggests that the amount of dust collected will be much less than on the primary mirror. Clean the secondary mirror whenever the primary mirror is cleaned. EOST recommends using a $CO_2$ snow cleaning system to clean all optical surfaces.

#### 2.8.4.2 Recommended Frequency

Snow cleaning of the secondary mirror surface should be performed monthly. Clean the secondary mirror whenever the primary mirror is cleaned.

#### 2.8.4.3 Equipment and Tools Required

- $CO_2$ snow cleaning system

#### 2.8.4.4 Procedure

1. Follow the procedure for the primary mirror in section 2.8.3.
2. Record preventive maintenance completed in the log book.

### 2.8.5 CLEANING THE TERTIARY MIRROR (M3)

#### 2.8.5.1 Purpose

Dust will collect on the tertiary mirror. Clean the tertiary mirror whenever the primary and secondary mirrors are cleaned. EOST recommends using a $CO_2$ snow cleaning system to clean all optical surfaces.

#### 2.8.5.2 Recommended Frequency

Snow cleaning of the secondary mirror surface should be performed monthly. Clean the tertiary mirror whenever the primary and secondary mirrors are cleaned.

#### 2.8.5.3 Equipment and Tools Required

- $CO_2$ snow cleaning system

#### 2.8.5.4 Procedure

1. Follow the procedure for the primary mirror in section 2.8.3.
2. Record preventive maintenance completed in the log book.

# CHAPTER 3 CORRECTIVE MAINTENANCE

The corrective maintenance tasks described in in this chapter are included in the recommended maintenance schedule shown in Table 3.

**Table 3 Telescope Corrective Maintenance Schedule**

| PROCEDURE | DURATION | FREQUENCY |
|---|---|---|
| M1 Mirror: Recoating (section 3.1) | 8 hours for removal<br>8 hours for install | Every 2 years for mirror recoating, or as required.<br>Inspect mirror annually if recoating is not required at the 2 year interval until recoating is necessary. |
| M2 Mirror Recoating (section 3.2) | 2 hours for removal<br>2 hours for install | |
| M3 Mirror: Recoating (section 3.3) | 2 hours for removal<br>2 hours for install | |
| Balancing the Telescope (section 3.4). | 20 – 30 minutes | As required. |
| Optical Alignment (section 3.5) | 12 hours | As required.<br>After mirror recoating and reinstallation of mirrors. |

## 3.1 RECOATING THE PRIMARY MIRROR

### 3.1.1 PURPOSE

Metal mirror coatings degrade over time and require recoating in order to continue to meet the reflectivity specifications.

### 3.1.2 RECOMMENDED FREQUENCY

The primary mirror (M1) generally requires recoating every two years, depending on the coating material. Recoating is typically performed whenever the reflectivity has degraded below an acceptable level. If the mirror does not require recoating at the first two year interval following site installation, evaluate the mirror surface and performance annually until recoating is necessary. Resume two year inspection/evaluation for recoating following each recoating for the life of the mirror.

### 3.1.3 PROCEDURE FOR REMOVING AND INSTALLING THE PRIMARY MIRROR (M1)

Refer to Primary Mirror Removal and Installation Procedure (ASP-13952).

## 3.2 REMOVING THE SECONDARY MIRROR (M2) FOR RECOATING

### 3.2.1 PURPOSE

Metal mirror coatings degrade over time and require recoating in order to continue to meet the reflectivity specifications.

### 3.2.2 RECOMMENDED FREQUENCY

The Secondary Mirror (M2) generally requires recoating every two years, depending on the coating material. If the mirror does not require recoating at the first two year interval following site installation, evaluate the mirror surface and performance annually until recoating is necessary. Resume two year inspection/evaluation for recoating following each recoating for the life of the mirror.

### 3.2.3 EQUIPMENT AND TOOLS REQUIRED

- Drawing ASY-5279 Upper Truss Assembly
- Drawing ASY-5201 M2 QS Focus Assembly
- M2 shipping container
- Metric Allen wrenches
- Powder-free latex gloves
- Dust face mask
- 6 foot ladder
- M2 Dummy Weight (ASY-5876)
- 10 gauge stainless steel tie wire
- Small torque wrench and Allen socket adaptors

### 3.2.4 TIME REQUIRED

2 hours, 2 people

### 3.2.5 PROCEDURE FOR REMOVING THE SECONDARY MIRROR ASSEMBLY

**CAUTION: Only qualified maintenance personnel should handle telescope optics. Read the entire procedure and review all applicable drawings before starting work.**

1. Wear a dust mask and powder-free latex gloves. Remove any jewelry and items from pockets that may fall onto the mirror surface.
2. Prepare the M2 shipping container and place it near the telescope.
3. Point the telescope to horizon and engage the elevation stay pin.
4. If desired, apply a protective coating to the optical surface of the mirror and allow it to dry according to the manufacturers recommendations. Applying multiple coats may simplify the removal process.

**CAUTION: Extreme care is required to prevent contact with the optical surface if a protective coating is not used, as even incidental contact can damage the coating and/or surface of the mirror.**

5. Identify or add marks to record the orientation of the M2 assembly on the telescope.

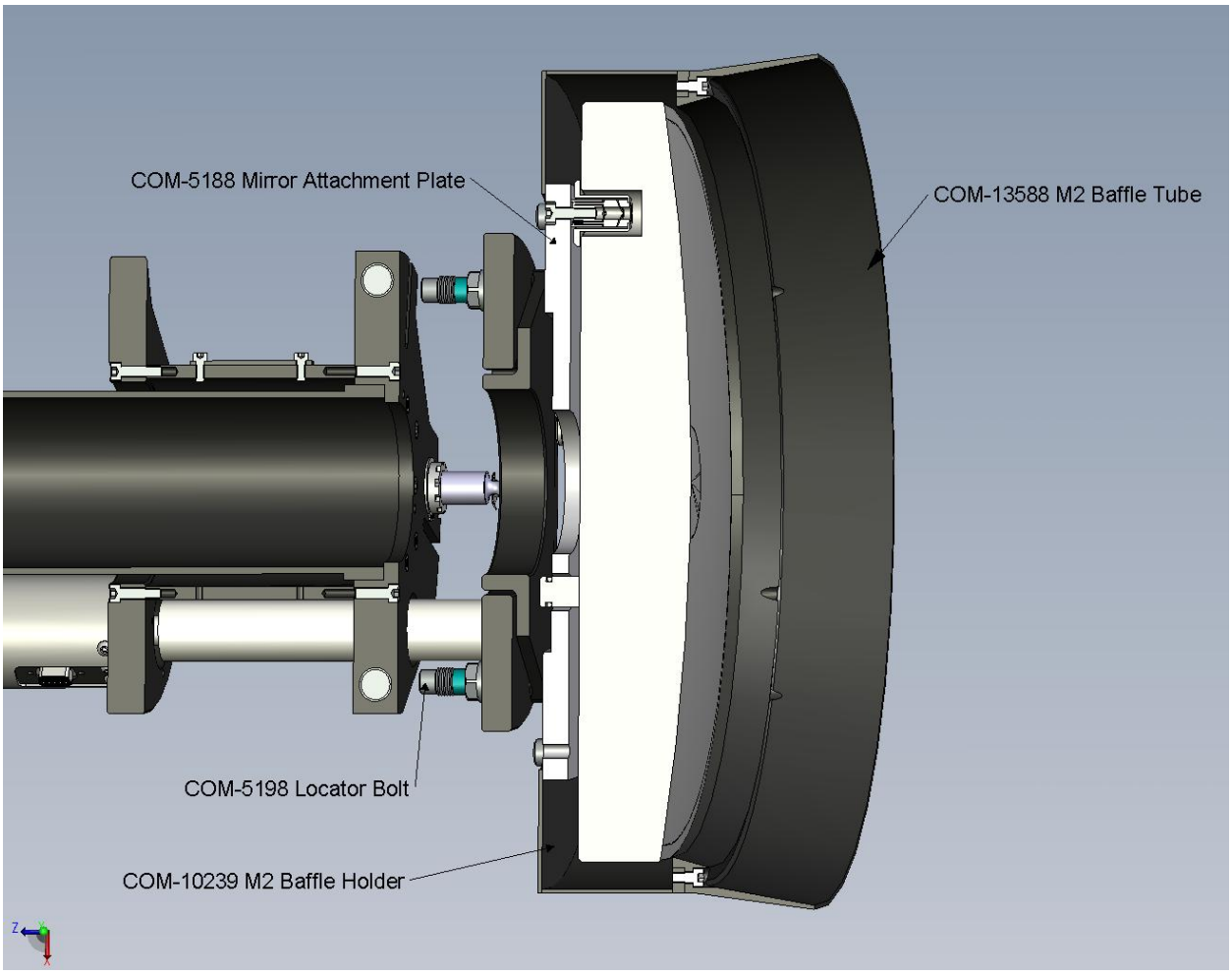


**Figure 1 M2 Assembly**

6. With one person holding the M2 Baffle Tube (COM-13588) in place, remove the six M5 SHCS that secure the M2 Baffle Tube to the M2 Baffle Holder (COM-10239).
7. Carefully remove the M2 Baffle Tube and store it in a safe location.
8. Have one person securely hold the M2 mirror assembly in place by gripping the outside edge of the M2 Baffle Holder, being careful not to contact the mirror surface.

Note: It may be beneficial to use a small ladder while removing the mirror.

9. Have the second person remove the three Locator Bolts (COM-5189) securing the M2 assembly to the focus stage.

**CAUTION: When the Locator Bolts are removed, the M2 assembly will be free to move, supported only as described in step 8.**

10. Carefully remove the M2 assembly from the Focus Stage and place it in the shipping container or in a safe work location.

**WARNING! If the M2 assembly has been removed from the telescope and the M2 counterweight assembly has not been installed, DO NOT DISENGAGE the ELEVATION STAY PIN.**

**An unbalanced telescope may cause serious injury to personnel working near the telescope and may cause severe damage to the telescope, enclosure or instrumentation.**

11. Hold the M2 Dummy Weight (ASY-5876) up to the M2 focus stage and secure it using the three Locator Bolts (COM-5189).

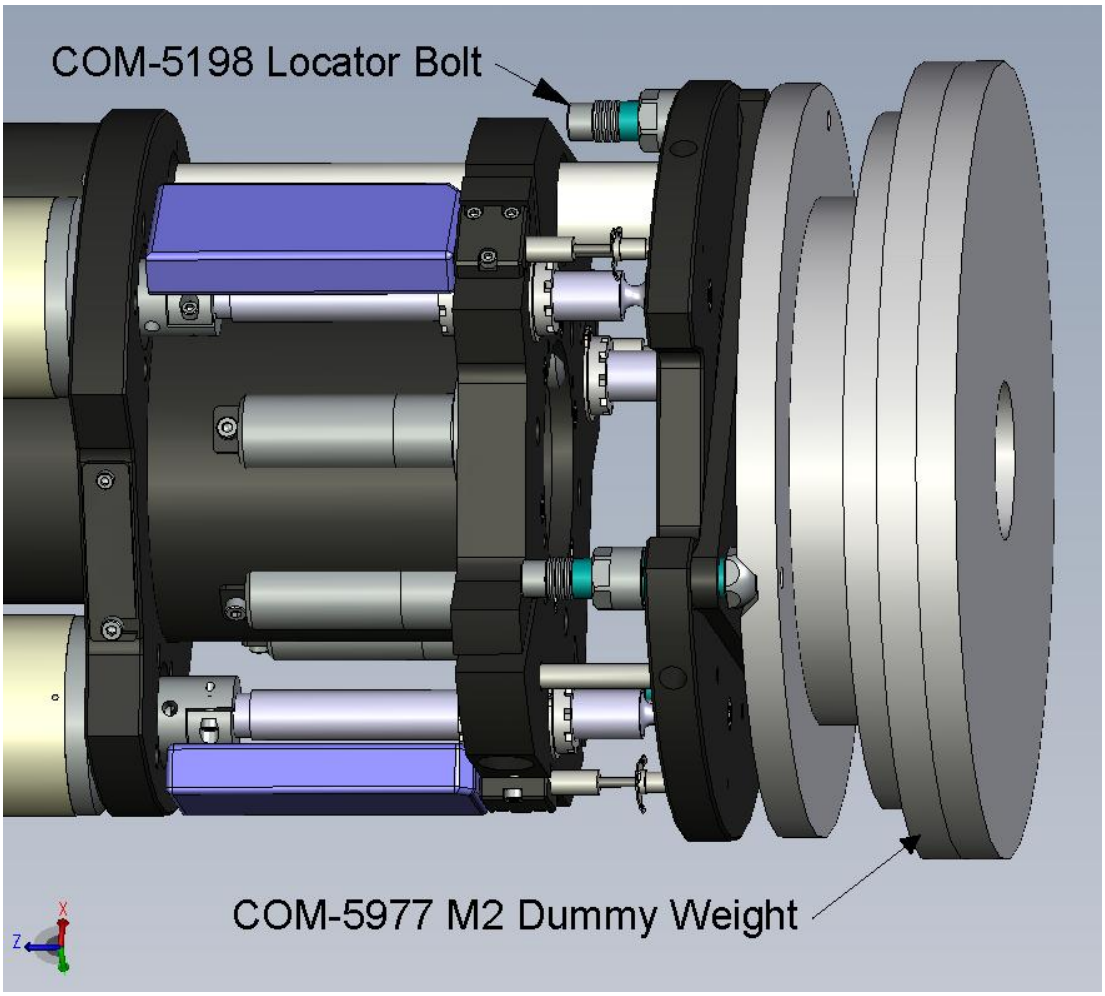


**Figure 2 M2 Dummy Weight Installed on M2 Focus Stage**

12. Check the telescope balance as described in Section 3.4.

### 3.2.6 PROCEDURE FOR REMOVING THE SECONDARY MIRROR FROM THE SUPPORT

1. Wear a dust mask and powder-free latex gloves. Remove any jewelry and items from pockets that may fall onto the mirror surface.
2. If desired, apply a protective coating to the optical surface of the mirror and allow it to dry according to the manufacturers recommendations. Applying multiple coats may simplify the removal process.
3. Place the M2 Assembly securely on blocks, leaving enough room to work under the support.
4. Remove the steel wire connected to the three safety pucks (COM-5974).
5. Move the blocks inside the diameter of the M2 Baffle Holder and verify that M2 Assembly is secure.
6. Note existing marks or mark the orientation of the M2 Mirror on the M2 Attachment Plate.
7. Remove the six M8 SHCS securing each half of the M2 Baffle Holder (COM-10239) to the M2 Attachment Plate (COM-5188) and carefully remove the baffle holder, see Figure 3.

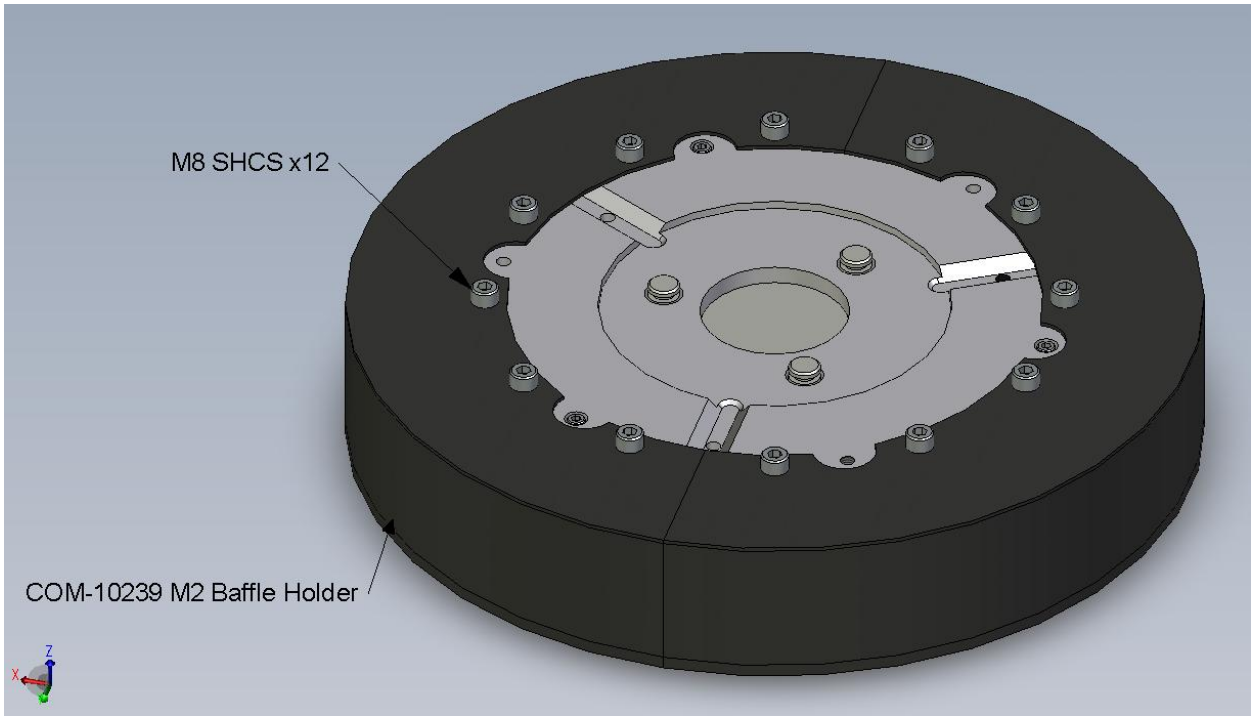


**Figure 3 M2 Assembly with Baffle Holder**

8. Remove the three M5 SHCS securing the M2 Attachment Plate to the M2 Mirror (COM-5905), see Figure 4.
9. Carefully lift the M2 Mirror off of the M2 Attachment Plate and place it in the shipping container.

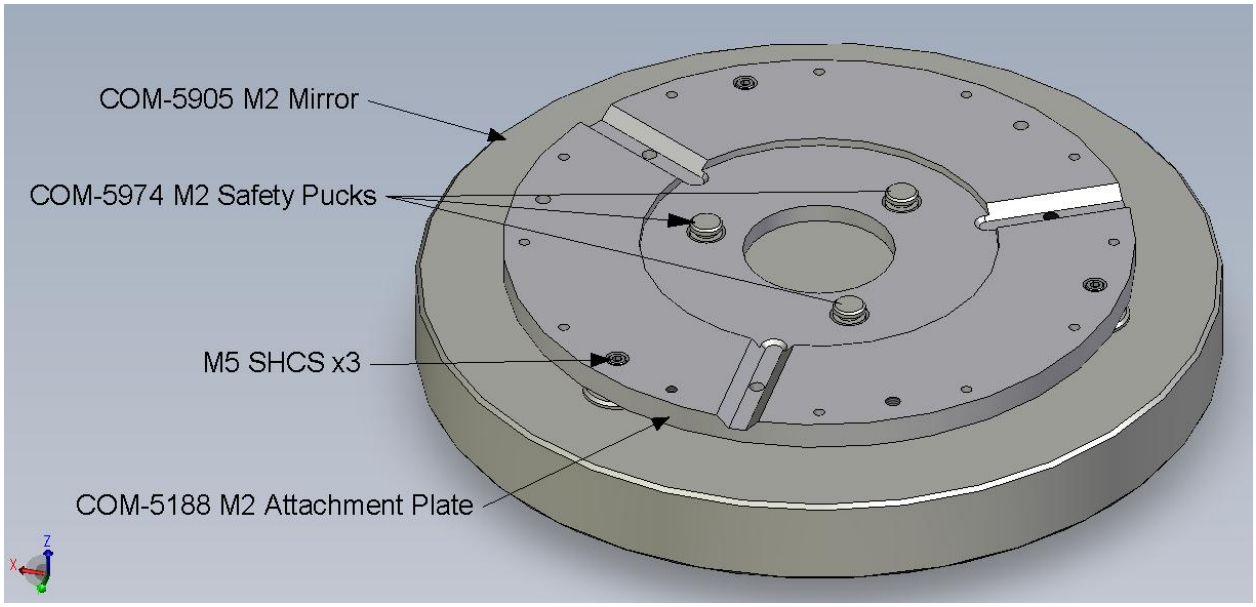


**Figure 4 M2 Assembly with Baffle Holder Removed**

### 3.2.7 PROCEDURE FOR REINSTALLING THE SECONDARY MIRROR TO THE SUPPORT

1. Wear a dust mask and powder-free latex gloves. Remove any jewelry and items from pockets that may fall onto the mirror surface.
2. Place the M2 Attachment Plate (COM-5188) securely on blocks, leaving enough room to work underneath.
3. Identify any orientation marks and carefully place the M2 Mirror (COM-5905) on the M2 Attachment Plate, see Figure 4.
4. Using the torque wrench, insert and tighten the three M5 SHCS to 22 inch lbs to secure the M2 Mirror to the M2 Attachment Plate.
5. While a second person holds half of the M2 Baffle Holder (COM-10239) in place, insert and tighten the six M8 SHCS to secure it in place. Repeat for the second half of the M2 Baffle Holder.
6. Wrap a single piece of 10 gauge stainless steel tie wire loosely around the three M2 Safety Pucks (COM-5974) and secure the ends. Verify that the wire exerts no force on the M2 Safety Pucks or the M2 Attachment Plate as this can affect the mirror figure and optical quality. If necessary, a second person can lift the M2 Assembly while the safety wire is installed.

> Note: The tie wire is only present as a safety mechanism in the unlikely event that the mirror bonds fail. Under normal conditions it should not exert any force on the M2 Safety Pucks or the M2 Attachment Plate.

### 3.2.8 PROCEDURE FOR REINSTALLING THE SECONDARY MIRROR ASSEMBLY

1. Move the telescope to horizon pointing and engage the elevation stay pin.
2. If the M2 Dummy Weight has been installed, remove it by loosening the three Locator Bolts (COM-5189) and set it aside.
3. Wear a dust mask and powder-free latex gloves. Remove any jewelry and items from pockets that may fall onto the mirror surface.
4. Grip the M2 Mirror Assembly by the outside of the M2 Baffle Holder and remove it from the shipping container.
5. Note the orientation markings on the M2 Assembly and hold it in position in front of the M2 Focus Stage while a second person inserts and tightens the three Locator Bolts (COM-5198), see Figure 1.
6. With one person holding the M2 Baffle Tube (COM-13588) in place, insert and tighten the six M5 SHCS that secure the M2 Baffle Tube to the M2 Baffle Holder (COM-10239).
7. Check the telescope balance as described in Section 3.4.

## 3.3 REMOVING THE TERTIARY MIRROR (M3) FOR RECOATING

### 3.3.1 PURPOSE

Metal mirror coatings degrade over time and require recoating in order to continue to meet the reflectivity specifications.

### 3.3.2 RECOMMENDED FREQUENCY

The Tertiary Mirror (M3) may or may not require recoating every two years, depending on the coating material. If the mirror does not require recoating at the first two year interval following site installation, evaluate the mirror surface and performance annually until recoating is necessary. Resume two year inspection /evaluation for recoating following each recoating for the life of the mirror.

### 3.3.3 EQUIPMENT AND TOOLS REQUIRED

Only qualified individuals should remove and re-install the M1, M2, and M3 mirrors.

- Tertiary mirror shipping crate
- Dust masks
- Latex gloves (powder-free)
- Metric Allen wrenches
- Metric Hex Wrenches
- “Short” M6 Hex Wrench

### 3.3.4 TIME REQUIRED

2 hours, 2 people

### 3.3.5 PROCEDURE FOR REMOVING THE TERTIARY MIRROR ASSEMBLY

1. Wear a dust mask and powder-free latex gloves. Remove any jewelry and items from pockets that may fall onto the mirror surface.
2. Prepare the mirror shipping crate and place it near the telescope.
3. Point the telescope to horizon and engage the elevation stay pin.
4. Install the protective M1 cover or apply a protective coating product to the M1.
5. While one person holds the M3 Baffle (COM-10194) in place, remove the six M4 SHCS that attach the M3 Baffle to the M3 Baffle Adaptor Plate (COM-13827), see Figure 5.
6. Carefully remove the M3 Baffle from the M3 Rotator Assembly. Use extreme caution to prevent the baffle tube from contacting the M3 Mirror Mount Assembly (ASY-5818).

**CAUTION: Be careful not to contact the M3 Mirror or Mount Assembly when removing the Baffle as this can result in misalignment or damage to the glass.**

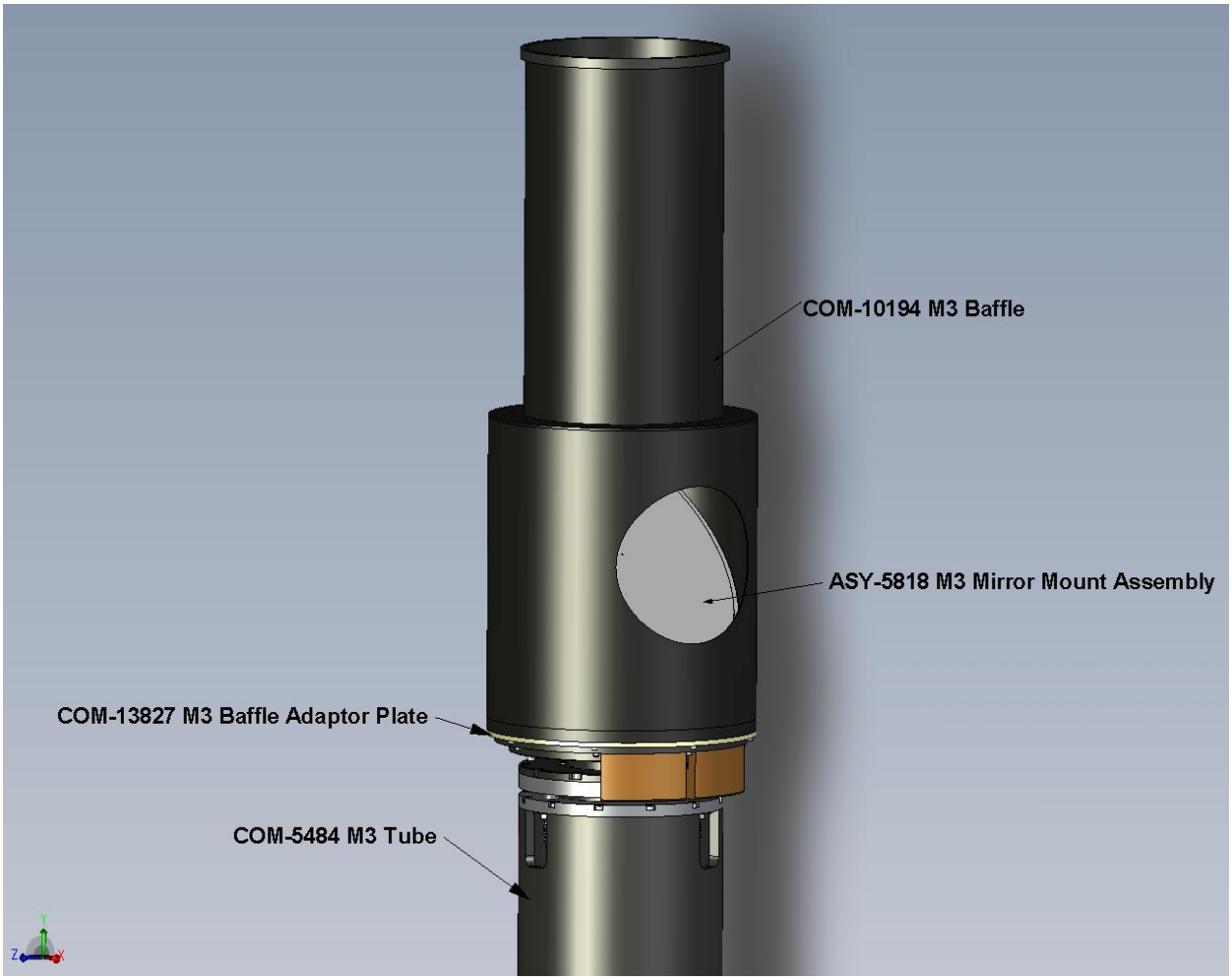


**Figure 5 M3 Assembly with Baffle Installed**

7. If desired, apply a protective coating product to the optical surface of the mirror and allow it to dry according to the manufacturer recommendations. Applying multiple coats may simplify the removal process.

**CAUTION: Extreme care is required to prevent contact with the optical surface if a protective coating is not used, as even incidental contact can damage the coating and/or surface of the mirror.**

8. While a second person firmly holds the M3 Mirror Mount Gusset (COM-5823), remove the three M3 Mirror Mount Locator Bolts (COM-5827), see Figure 6. The M3 Rotator can be easily turned by hand to place it in the most convenient position.

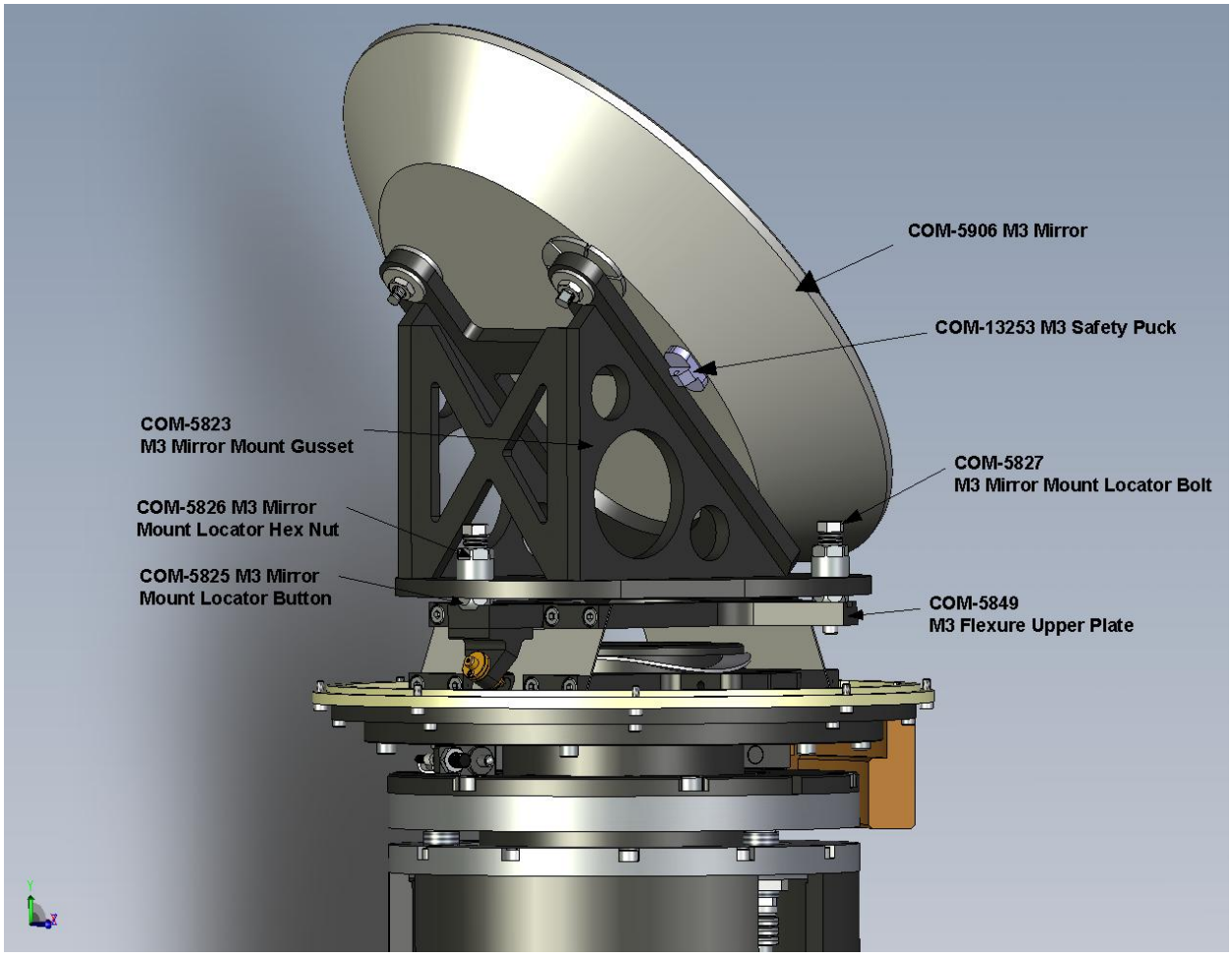


**Figure 6 M3 Assembly with Baffle Removed**

9. Carefully remove the M3 Mirror Mount Assembly (ASY-5818) from the M3 Flexure Upper Plate (COM-5849) and place it in a secure location.

> NOTE: Take care not to disturb the M3 Mirror Mount Locator Hex Nuts (COM-5826) or M3 Mirror Mount Locator Buttons (COM-5825) as this could affect alignment.

### 3.3.6 PROCEDURE FOR REMOVING THE TERTIARY MIRROR FROM THE SUPPORT

1. Wear a dust mask and powder-free latex gloves. Remove any jewelry and items from pockets that may fall onto the mirror surface.
2. Place the M3 Mirror Mount Assembly (ASY-5818) in a secure workspace.

> NOTE: During this procedure, take care not to disturb the M3 Mirror Mount Locator Hex Nuts (COM-5826) or M3 Mirror Mount Locator Buttons (COM-5825) as this could affect alignment.

3. Prepare the mirror shipping crate and place it near the workspace.
4. Carefully cut and remove the Stainless Steel tie wire connecting the M3 Safety Pucks (COM-13253) to the M3 Mirror Mount Gussets (COM-5823).
5. While holding each corresponding M3 Mirror Mount Flexure (COM-5695) with an M6 Hex Wrench, loosen the three M8 Hex Nuts that secure the Flexures to the M3 Mirror Mount, see Figure 7. It may be necessary to use a shortened M6 Hex Wrench (provided with the telescope tooling) to hold the lower of the three flexures.

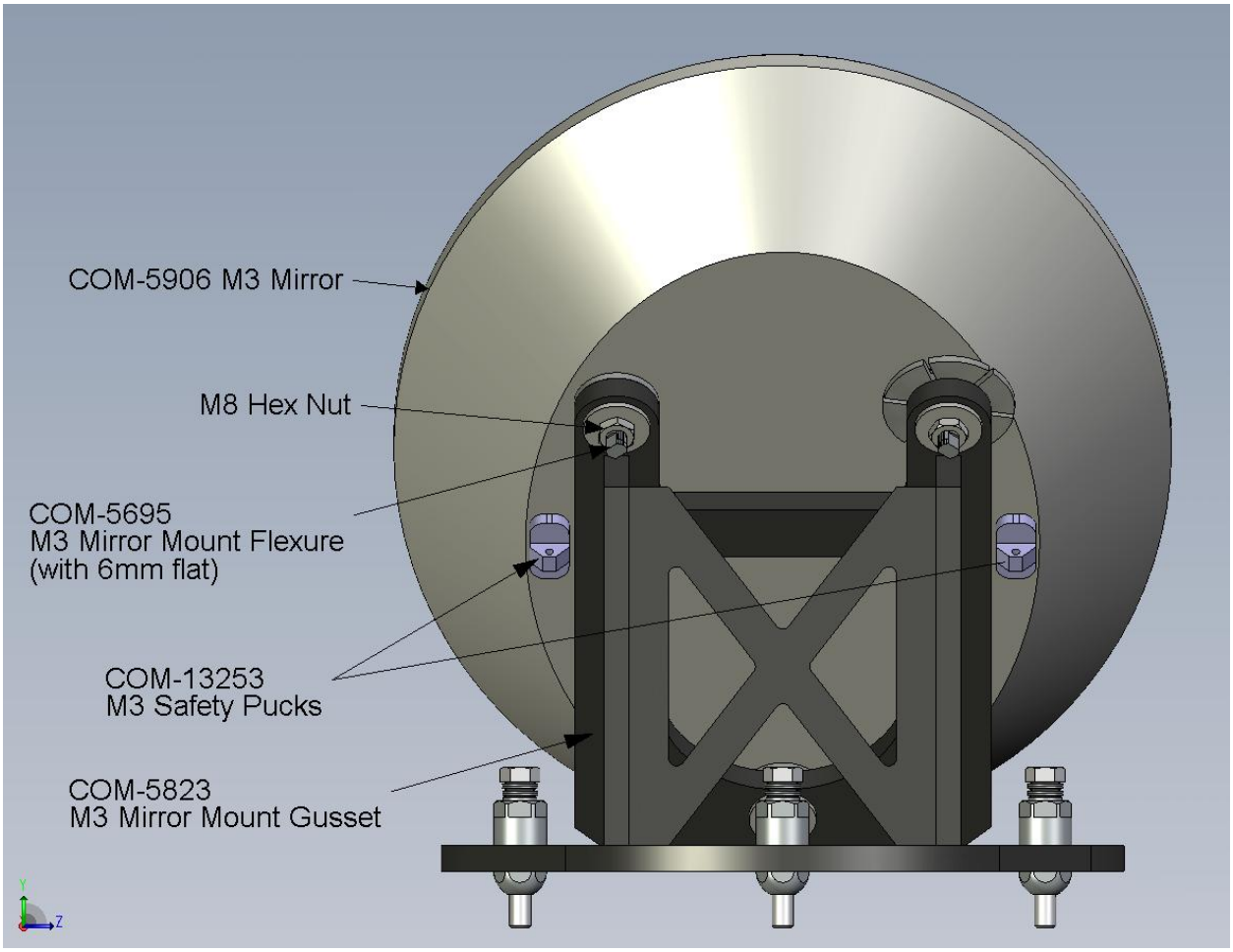


**Figure 7 M3 Mirror Mount Assembly Removed from Telescope**

**CAUTION: It is critical that the M3 Mirror Mount Flexures be held stationary while loosening the M8 Hex Nuts. Failure to do so may result in damage to the flexures or M3 Mirror.**

6. While one person holds the M3 Mirror (COM-5906) by the edge, remove the three M8 Hex Nuts.

7. Carefully lift the M3 Mirror off of the support, being careful not to place unnecessary stress on the flexures. It may be helpful to have a second person steady the M3 Mirror Mount Assembly during this process.
8. Remove the three 8mm Stainless Steel Shim Washers from between the M3 Mirror Mount Flexures and the M3 Mirror Mount and set them aside.
9. Place the mirror in the M3 shipping container and pack it for transport to the coating facility.

### 3.3.7 PROCEDURE FOR REINSTALLING THE TERTIARY MIRROR TO THE SUPPORT

1. Wear a dust mask and powder-free latex gloves. Remove any jewelry and items from pockets that may fall onto the mirror surface.
2. Place the M3 Mirror (COM-5906) and M3 Mirror Mount Assembly (ASY-5818) on a secure, level workspace.

> NOTE: During this procedure, take care not to disturb the M3 Mirror Mount Locator Hex Nuts (COM-5826) or M3 Mirror Mount Locator Buttons (COM-5825) as this could affect alignment.

3. Place the three 8mm Stainless Steel Shim Washers (set aside during the disassembly process) over the threaded ends of the M3 Mirror Mount Flexures. Make sure these washers stay in position during the remainder of the assembly process.
4. Carefully set the M3 Mirror on the support, being careful not to place unnecessary stress on the flexures. It may be helpful to have a second person steady the M3 Mirror Mount Assembly during this process.
5. While one person holds the M3 Mirror (COM-5906) by the edge, thread the three M8 Hex Nuts onto the M3 Mirror Mount Flexures (COM-5695), see Figure 7.
6. While holding each corresponding M3 Mirror Mount Flexure with an M6 Hex Wrench, tighten the three M8 Hex Nuts that secure the Flexures to the M3 Mirror Mount. It may be necessary to use a shortened M6 Hex Wrench (provided with the telescope tooling) to hold the lower of the three flexures.

**CAUTION: It is critical that the M3 Mirror Mount Flexures be held stationary while tightening the M8 Hex Nuts. Failure to do so may result in damage to the Flexures or M3 Mirror.**

7. Use 10 gauge Stainless Steel tie wire to connect the M3 Safety Pucks (COM-13253) to the M3 Mirror Mount Gussets (COM-5823). Verify that the wire exerts no force on the M3 Safety Pucks or the M3 Mirror Mount Assembly as this can affect the mirror figure and optical quality.

> Note: The tie wire is only present as a safety mechanism in the unlikely event that the mirror bonds fail. Under normal conditions it should not exert any force on the M3 Safety Pucks or the M3 Mirror Mount Assembly.

### 3.3.8 PROCEDURE FOR REINSTALLING THE TERTIARY MIRROR ASSEMBLY

1. Wear a dust mask and powder-free latex gloves. Remove any jewelry and items from pockets that may fall onto the mirror surface.
2. Point the telescope to horizon and engage the elevation stay pin.
3. Install the protective M1 cover or apply a protective coating product to the M1.
4. Place the M3 Mirror Mount Assembly (ASY-5818) near the telescope on a stable work platform.

> NOTE: Take care not to disturb the M3 Mirror Mount Locator Hex Nuts (COM-5826) or M3 Mirror Mount Locator Buttons (COM-5825) as this could affect alignment.

5. If desired, apply a protective coating product to the optical surface of the mirror and allow it to dry according to the manufacturer recommendations. Applying multiple coats may simplify the removal process.

**CAUTION: Extreme care is required to prevent contact with the optical surface if a protective coating is not used, as even incidental contact can damage the coating and/or surface of the mirror.**

6. Note the current position of the M3 Rotator and lift the M3 Mirror Mount Assembly into position by holding the M3 Mirror Mount Gusset (COM-5823). The M3 Rotator can be easily turned by hand to place it in the most convenient position.
7. Have a second person insert and tighten the three M3 Mirror Mount Locator Bolts (COM-5827), see Figure 6.
8. Carefully place the M3 Baffle into position on the M3 Rotator Assembly, see Figure 5. It is advisable to have one person guide the baffle over the M3 Mirror and Mount while another person supports the weight of the tube. Use extreme caution to prevent the baffle tube from contacting the M3 Mirror (COM-5906) or M3 Mirror Mount Assembly (ASY-5818).

**CAUTION: Be careful not to contact the M3 Mirror or Mount Assembly when installing the Baffle as this can result in misalignment or damage to the glass.**

9. While one person holds the M3 Baffle (COM-10194) in place, insert and tighten the six M4 SHCS that attach the M3 Baffle to the M3 Baffle Adaptor Plate (COM-13827), see Figure 5.

**WARNING! Verify the installation is completed before removing the Elevation stay pin locks on the OSS.**

## 3.4 BALANCING THE TELESCOPE

### 3.4.1 PURPOSE

With the telescope fully assembled and populated with all accessories such as guide telescope, cameras, cables, M2 mirror and instrumentation, the telescope should be balanced about its elevation axis.

### 3.4.2 RECOMMENDED FREQUENCY

As needed only basis. Any time equipment or instrumentation is added to or removed from the OSS.

### 3.4.3 TIME REQUIRED

1 hour

### 3.4.4 PROCEDURE

**CAUTION: On initial release from the elevation stay pin, connect the telescope to a crane at the middle of one of the head ring members. This precaution allows the magnitude of any imbalance to be safely determined. If the imbalance is small and can easily be controlled by hand, the crane connection can be released.**

1. Do not operate the motor. Open the mirror covers and move the telescope optical support structure OSS (The OSS includes everything that rotates as the elevation motor rotates the telescope) to the horizon position by hand.
2. Bring the telescope OSS to a complete stop.
3. Let go of the telescope OSS and allow it to move by itself, but prevent it from running away by keeping your hands close to the head ring.
4. If the telescope moves towards the floor, because it is top heavy, weights must be removed from the head ring to balance the telescope.
5. If the OSS moves in an upward direction, then it is bottom heavy and weights must be added to the head ring to balance the telescope.
6. Repeat steps 1 through 5 until the telescope OSS stops in any position when it is placed near horizon.
7. Repeat this procedure (steps 1 through 6) near zenith.
8. To obtain a more accurate gauge of the imbalance, proceed as follows:
   a. From the a position near horizon pointing, move the telescope OSS in an upward direction and let go, allowing the OSS to move freely a short distance.
   b. From the same position, move the telescope OSS towards the ground.

> **NOTE:** If the same input force is applied in each direction, the OSS should come to a stop at the same distance.
>
> This procedure helps to overcome the inherent bearing static friction and allows a more accurate balance.

c. Note any difference in distance and add weight to compensate as before.

9. Repeat step 8 for a position near zenith pointing.
10. The telescope OSS should now remain still when placed in any elevation position.
11. More accurate balance can be obtained by looking at bi-directional motor torque. In general, the balancing techniques described above are sufficient.

> **CAUTION: Any device added to or removed from the telescope OSS will require a re-balance to compensate.**

## 3.5 OPTICAL ALIGNMENT

### 3.5.1 INDICATION OF FAILURE

Anything that significantly diminishes image quality/waveffront error. This could be caused by optics being bumped or shocked and so forth.

### 3.5.2 FREQUENCY

An optical alignment is required whenever the Primary, Secondary or Tertiary mirrors have been removed and reinstalled.

### 3.5.3 PROCEDURE

Refer to ASP-13964 Lick APF Optical Alignment Procedure

## 3.6 STAR MAPPING

### 3.6.1 INDICATION OF FAILURE

Anything that significantly diminishes open-loop pointing and tracking performance could require a new Pointing Model to be performed. This could be caused by optics being bumped, shocked or realigned, changes in instrument alignment or mass and so forth.

### 3.6.2 FREQUENCY

As needed basis.

### 3.6.3 PROCEDURE

Refer to SUM-13948 Lick APF Software User Manual for the Pointing Model Procedure.